

PROGRESS REPORT

INCORPORATION OF PHELLINUS ROOT ROT IMPACTS IN THE TREE AND STAND SIMULATOR (TASS)

MINOR SERVICE CONTRACT (CONTROL NO. 49782)

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TABLE OF CONTENTS

CONTRACT SPECIFICATIONS.....	3
SUMMARY	4
RECOMMENDATIONS	4
INTRODUCTION.....	5
THE TOOLS.....	5
DEVELOPMENT OF THE TOOLS	5
APPLICATION OF DISEASE STANDARDS.....	6
RELIABILITY OF THE METHOD.....	6
DEVELOPMENT OF DISEASE CLASSIFICATION STANDARDS FOR PHELLINUS ROOT ROT	6
PRODUCTION OF DISEASE DISTRIBUTION MAPS (PATHOGRAMS)	7
DERIVING ROOT ROT INPUTS FOR SIMULATING EACH DISEASE CLASS BY TASS	7
SIMULATION OF ROOT ROT IMPACTS	8
COMPARISONS OF SIMULATION RESULTS BY TASS, RREST, AND FIELD DATA.....	9
CONCLUSIONS.....	9
PATHOGRAMS (DISEASE CENTER DISTRIBUTION MAPS) OF PHELLINUS ROOT ROT BY DISEASE CLASSIFICATION	13
PRELIMINARY YIELD TABLES FOR COASTAL DOUGLAS-FIR INFECTED WITH PHELLINUS ROOT ROT.....	39
INTRODUCTION	39
OBJECTIVE.....	39
METHODS.....	40
RESULTS	41
CONCLUSION.....	42
PATHOGRAMS (DISEASE CENTER DISTRIBUTION MAPS) OF PHELLINUS ROOT ROT BY DISEASE CLASSIFICATION	56

CONTRACT SPECIFICATIONS

- I. a) Develop criteria for field classification of Phellinus root rot in coastal Douglas-fir stands to provide inputs for TASS-ROTSIM model estimates of disease impact. The criteria will evaluate severity, frequency, homogeneity, and uniformity.
- b) Use this system to classify approximately 200 survey reports in the Vancouver Region collected by the Ministry and other agencies.
- c) Record the data in a spreadsheet.
- II. a) Use the data in item I.c to determine breakpoints for 3 classes of each criterion and assign each stand to the appropriate class.
- b) Calculate the mean of each class having sufficient representatives.
- III. Produce tables and draft maps of each root rot class selected in item II.
- IV. a) Prepare selected root rot class parameters as inputs to the root rot spread model (RREST).
- b) Derive initial infected stump numbers, diameters and coordinates from model outputs.
- c) Tabulate as inputs to TASS-ROTSIM.
- V. a) Assist the Ministry in the preparation and execution of test runs with TASS-ROTSIM and evaluate the simulated results as follows:
 - i) Compare with field survey results.
 - ii) Compare with the RREST results at rotation age.
 - iii) Compare projections with survey results of stands judged to have been similar at earlier ages.
 - iv) Evaluate disease progress variables according to known behavior of the disease.
 - v) Consult with Protection Branch and the Vancouver Region.

SUMMARY

1. Two hundred Douglas-fir stands, age class III, medium-good site, surveyed for Phellinus root rot, were stratified into three severity classes (% area infected), three center frequency (no. centers/ha) classes, and four center uniformity (distribution in stand) classes.
2. Infection centers were grouped into 6 size classes; percentages of centers within each size class were calculated for each disease (severity-frequency) class.
3. The number of centers in each size class was determined for a 10 ha stand in each disease class. These were used as inputs to the root rot model RREST to generate disease distribution maps (pathograms) for each disease class.
4. The number, diameter and spatial distribution of infected stumps necessary to simulate infection centers of each size class by TASS were determined at stand density 2500 sph, site index 30.
5. Yields (cu. m/ha, stems/ha) were calculated in 0.64 (80m x 80m) plots, the maximum plot size allowed by computer memory, containing centers of each size class.
6. Yields in 10.2 ha stands were calculated by averaging the yields of 16 0.64 plots containing the appropriate number and size of centers for each disease class. Comparisons were made among disease classes and with a healthy stand.
7. Comparisons were made between simulation results of TASS, RREST and with field observations.

RECOMMENDATIONS

1. Carry out field-testing of the disease classification system for Phellinus root rot.
2. Simulate silvicultural and disease management interactions with Phellinus root rot, i.e., planting density, juvenile spacing, site index, tree resistance, stump removal, and bridge-tree removal.
3. Draft disease management guidelines for disease classes.
4. Evaluate cost-benefits.

INTRODUCTION

As soon as managers become aware of the presence of root rot in stands, two questions assume priority: What will be the probable impacts of the disease? and what can be done to lessen them, with what benefits and costs?

The objectives, some of which are addressed by this contract are to provide the tools by which managers can answer these questions.

THE TOOLS

The basis for all pest impact assessment is a system for classifying the observed effects of a pest. The most useful classifications are relatively easy to apply, are based on a wide range of field measurements and offer practical guides to pest management. For root rot these requirements can be best met by:

1. A standard classification for root rot based on broad classes for disease severity (percent area infected), and infection center frequency and spatial distribution in stands. The classification should comprise clear graphical aids (pathograms or disease distribution maps) and easily applied look-up tables.
2. Estimates of volume at rotation as for a healthy stand and as for an infected stand of a specific disease class, with or without silvicultural intervention (spacing, precommercial and commercial thinning).
3. Estimates of volume at rotation with control (stumping, varying planting density, bridge tree removal).

DEVELOPMENT OF THE TOOLS

The following approach was used to develop the management tools:

1. From a database of approximately 200 Phellinus root rot survey results in the coastal Douglas-fir zone, derive broad disease classes with respect to major disease parameters, i.e., severity, center frequency, size, and distribution at stand age 50 (mid-rotation).
2. Assign stands to disease classes and calculate averages and ranges for each class.
3. Through independent reverse simulation, derive initial disease parameters (at stand age 1) which produce the average disease conditions.

Incorporation of Phellinus Root Rot Impacts in TASS

4. Use the initial disease parameters to derive inputs to TASS-ROTSIM growth and yield model. Simulate disease impacts at different stand ages to rotation.
5. Compile descriptive statistics and visual aids for assigning stands to their standard disease classification.

APPLICATION OF DISEASE STANDARDS

The disease standards are designed to be applied in the following way:

1. Choose the visual aid (pathogram) most similar to the disease conditions and stand age for a given stand.
2. Select the appropriate disease parameters from the tables showing the standard severity, center frequency and spatial-distribution classes. The choice can be based on (in increasing order of accuracy) guestimates, stand walk-throughs, disease maps, or disease surveys. The reliability of the choice will affect that of the result.
3. Refer to the yield table corresponding to the disease class of the stand. Read off a) the volume/ha of the stand if it had not been infected. b) the volume to be expected if no control actions are taken. c) the volume corresponding to different types of silvicultural and disease control interventions.

RELIABILITY OF THE METHOD

The stand growth and disease estimates are produced by combining Ken Mitchell's stand growth model for coastal Douglas-fir with Bill Bloomberg/Robert MacDonald's model of Phellinus root rot. Both models have been extensively tested individually. The combined model is tested to ensure that it produces realistic results for the growth and disease impact (spread, tree growth reduction, and tree mortality).

DEVELOPMENT OF DISEASE CLASSIFICATION STANDARDS FOR PHELLINUS ROOT ROT

Data from approximately 200 root disease surveys using the CFS ground survey method were incorporated into a spreadsheet showing location, date, stand size, age, area and percent infection, distribution of center sizes, and number of centers/ha. For all stands in medium-good sites, age class III (40 – 60) – 90% of the stands—means, minima, maxima, ranges and counts were used to determine breakpoints in stratifying the stands according to severity, frequency, center size class and uniformity of center distribution. Stratum criteria (disease classes) are shown in Table 1. Each stand was allocated to its stratum (disease class) and the means calculated for each class (Table 2).

The following classes were recognized:

S(everity)1 F(requency)1, S1F2, S2F2, S3F2, S3F3

Insufficient samples (minimum 15) for S1F3, S2F1, S2F3, and S3F1 classes very likely due to mutual exclusion of the severity and frequency levels, i.e., high frequency with low severity and vice versa.

PRODUCTION OF DISEASE DISTRIBUTION MAPS (PATHOGRAMS)

The numbers and sizes of infection centers in each disease class were derived from their distributions (Table 3) as for a 10 ha stand, the minimum area necessary to include all centers at age 50 (Table 3). These were used as inputs to the stand root rot simulator RREST (Bloomberg et al 1919). Disease distribution maps (pathograms) were produced for each disease class at different stand ages.

DERIVING ROOT ROT INPUTS FOR SIMULATING EACH DISEASE CLASS BY TASS

By trial and error, the number, size and distribution of infected stumps necessary to simulate infection centers of each size class at stand age 50 were derived as inputs to TASS. This necessitated many runs but was guided by the principle that the larger, more numerous and more widely separated were the stumps, the larger were the centers. This was based on field observations, especially that large centers result from the coalescence of smaller centers, not from individual infected stumps, or stump clusters, however large the stump diameters. Stump configurations for each center size class are shown in Table 4. Maps of centers are shown on pp. 25-35.

Stocking density was standardized at 2500 sph, corresponding to the average planting density generally used at the time the stands were created, i.e., 6 - 8 ft spacing. Site index was standardized at 30.0 as representative of the medium- good site quality of the stands.

SIMULATION OF ROOT ROT IMPACTS

Owing to computer memory limitations, an entire 10 ha stand could not be simulated for root rot. Therefore, the stands were built up from plots 80 x 80m, the maximum allowed by memory limits. Each stand therefore consisted of 16 0.64 ha plots, totalling 10.2 ha. Yields of plots were averaged to produce stand yield. If the number of centers per stand did not exceed the number of plots, each plot was simulated as containing one center.

$$Y_s = (Y_{p1} + Y_{p2} + \dots + Y_{pn})/16$$

where Y_s = stand yield (cu. m/ha, stems/ha), Y_{p1} = yield of plot 1

If, as in the higher disease classes, the number of centers exceed the number of plots, more than one center was included in a plot, the total center areas always being less than that of the plot. In this case, the healthy plot yield had to be decremented by the yield loss attributable to each center.

$$Y_p = Y_{ph} - N_{p1}(Y_h - Y_{p1}) - N_{p2}(Y_h - Y_{p2}) - \dots - N_{pn}(Y_h - Y_{pn})$$

where Y_{ph} = healthy yield of plot p, N_{p1} = no. of centers of size class 1 in plot p, Y_{p1} = the yield of plot p with center size c. Yields of plots devoid of centers were those of healthy plots.

$$Y_s = (Y_{p1} + Y_{p2} + \dots + Y_{pn})/16$$

Up to stand age 50, centers were by definition discrete, therefore no provision was made for coalescence. After age 50, coalescence necessarily occurred because the combined center areas were greater than the plot area. As stated, memory limitations did not allow centers in a stand to expand and coalesce as happens in the forest. The problem was treated mathematically as follows:

1. The area of a single center of each size class was simulated by RREST at ages 50 to 90 without restriction on spread.
2. The aggregate area of unrestricted centers in each disease class was calculated. This could obviously exceed 10 ha.
3. In each disease class, the calculated unrestricted aggregate area was compared with the coalesced infected area produced by RREST.
4. The ratio of the unrestricted area to the coalesced area was used as a reduction factor for the yield at ages greater than 50 years (Table 6).

Stems/ha and total stand volumes simulated by TASS for each root disease class are shown in Tables 5 and figures 1, 2.

COMPARISONS OF SIMULATION RESULTS BY TASS, RREST, AND FIELD DATA

Comparisons of simulation results for individual centers by TASS and RREST are shown in Table 5. Comparisons of results for whole stands were made between percent reduction in stand stocking are shown in Figs. 3, 4. Six stands 90 years old had root rot ranging from 52.4 - 100%, mean 78.1%. Estimates by TASS for the severest disease class, S3F3 was 69%.

CONCLUSIONS

The database of 200 Douglas-fir stands surveyed for root rot was representative of conditions in the south coastal and Vancouver Island conditions. The average disease conditions derived from them should therefore be realistic standards by which to compare other stands within the same geographic area.

Simulations by TASS of individual centers were very accurate up to stand age 50. Beyond that age, they matched the simulated sizes by RREST closely in most cases.

Simulations by TASS of whole stands over a 90 year rotation matched those of RREST quite well with respect to total area infected and impact and were within the range of root rot of 90 year-old stands surveyed in the field.

Disease progress curves and disease spread simulated by TASS were realistic with respect to behavior of Phellinus root rot.

T A B L E 1**DISEASE CLASSES FOR PHELLINUS ROOT ROT IN COASTAL DOUGLAS FIR,
AGE CLASS III, MEDIUM-GOOD SITE**

1. DISEASE SEVERITY		
Class 1 (light).	<=6.0% of stand with visible infection.	
Class 2 (moderate)	>6.0<12.0% of stand with visible infection.	
Class 3 (heavy).	>12.0% of stand with visible infection.	
2. CENTER FREQUENCY		
Class 1 (light).	<=1.0 centers/ha (>100 in av. distance between centers)	
Class 2 (moderate).	>1.0<4.0 centers/ha (>50<100 in av. distance between centers)	
Class 3 (heavy).	<=4.0 centers/ha (<50 in av. distance between centers)	
3. CENTER SIZE CLASSES		
1. V. small	(<.05 ha)	(10 - 25 m diam)
2. Small	(>.05-0.1 ha)	(>25 - 35 m diam)
3. Medium	(>0.1 - 0.5 ha)	(>35 - 80 m diam)
4. Large	(>0.5 - 1.0 ha)	(>80 - 110 m diam)
5. V. large	(>1.0 ha)	(>110 m diam)
4. CENTER DISTRIBUTION		
V. uniform	All quadrants with infection	
Nearly uniform	Three quadrants with infection	
Non-uniform	Two quadrants with infection	
V. non-uniform	One quadrant with infection	

T A B L E 2**Phellinus Root Rot Classification – Coastal Douglas Fir Disease Parameter Averages**SEVERITY CLASS 1 ($\leq 6.0\%$), FREQUENCY CLASS 1 (≤ 1.0 CPH)

CENTER SIZE CLASS										
SEV- ERITY	FREQ.	1	2	3	4	5	SEV. MIN	FREQ MIN	SEV. MAX	FREQ. MAX
%	CPH	%	%	%	%	%	%	CPH	%	CPH
2.15	.54	49.2	34.6	15.3	0.0	0.9	0.2	0.1	4.4	0.9

SEVERITY CLASS 1 ($\leq 6.0\%$), FREQUENCY CLASS 2 ($>1.0 < 4.0$ CPH)

CENTER SIZE CLASS										
SEV- ERITY	FREQ.	1	2	3	4	5	SEV. MIN	FREQ MIN	SEV. MAX	FREQ. MAX
%	CPH	%	%	%	%	%	%	CPH	%	CPH
3.88	1.81	64.6	17.5	11.9	4.0	1.5	1.6	1.0	5.7	4.4

SEVERITY CLASS 2 ($>6.0\% \leq 12.0\%$), FREQUENCY CLASS 2 ($>1.0 < 4.0$ CPH)

UNIFORMITY CLASS 2-3

CENTER SIZE CLASS										
SEV- ERITY	FREQ.	1	2	3	4	5	SEV. MIN	FREQ MIN	SEV. MAX	FREQ. MAX
%	CPH	%	%	%	%	%	%	CPH	%	CPH
8.71	2.08	34.7	21.7	32.4	0.2	8.3	6.1	0.5	11.5	4.5

SEVERITY CLASS 2 ($>6.0\% \leq 12.0\%$), FREQUENCY CLASS 2 ($>1.0 < 4.0$ CPH)

UNIFORMITY CLASS 4

CENTER SIZE CLASS										
SEV- ERITY	FREQ.	1	2	3	4	5	SEV. MIN	FREQ MIN	SEV. MAX	FREQ. MAX
%	CPH	%	%	%	%	%	%	CPH	%	CPH
9.88	2.78	46.3	24.9	21.3	6.9	2.6	6.5	1.7	11.9	4.3

T A B L E 2 (C o n t i n u e d)

Phellinus Root Rot Classification – Coastal Douglas Fir Disease Parameter Averages

SEVERITY CLASS 3 (>12.0%), FREQUENCY CLASS 3 (>4.0 CPH) (<=70% sev.)

SEV- ERITY	FREQ. CPH	CENTER SIZE CLASS					SEV. MIN	FREQ MIN	SEV. MAX	FREQ. MAX
		1	2	3	4	5				
		%	%	%	%	%				
19.83	1.94	16.8	15.9	29.4	10.4	26.7	12.1	0.1	44.4	4.0

SEVERITY CLASS 3 (>12.0%), FREQUENCY CLASS 3 (>4.0 CPH)

SEV- ERITY	FREQ. CPH	CENTER SIZE CLASS					SEV. MIN	FREQ MIN	SEV. MAX	FREQ. MAX
		1	2	3	4	5				
		%	%	%	%	%				
25.41	6.12	42.5	19.9	21.0	3.6	14.2	14.6	4.1	41.7	8.8

**PATHOGRAMS (DISEASE CENTER DISTRIBUTION MAPS) OF PHELLINUS ROOT ROT
BY DISEASE CLASSIFICATION**

(derived from simulations with RREST)

Each letter represents a separate infection center.

Asterisks represent the mortality area within centers.

As center become larger they coalesce to form even larger centers.

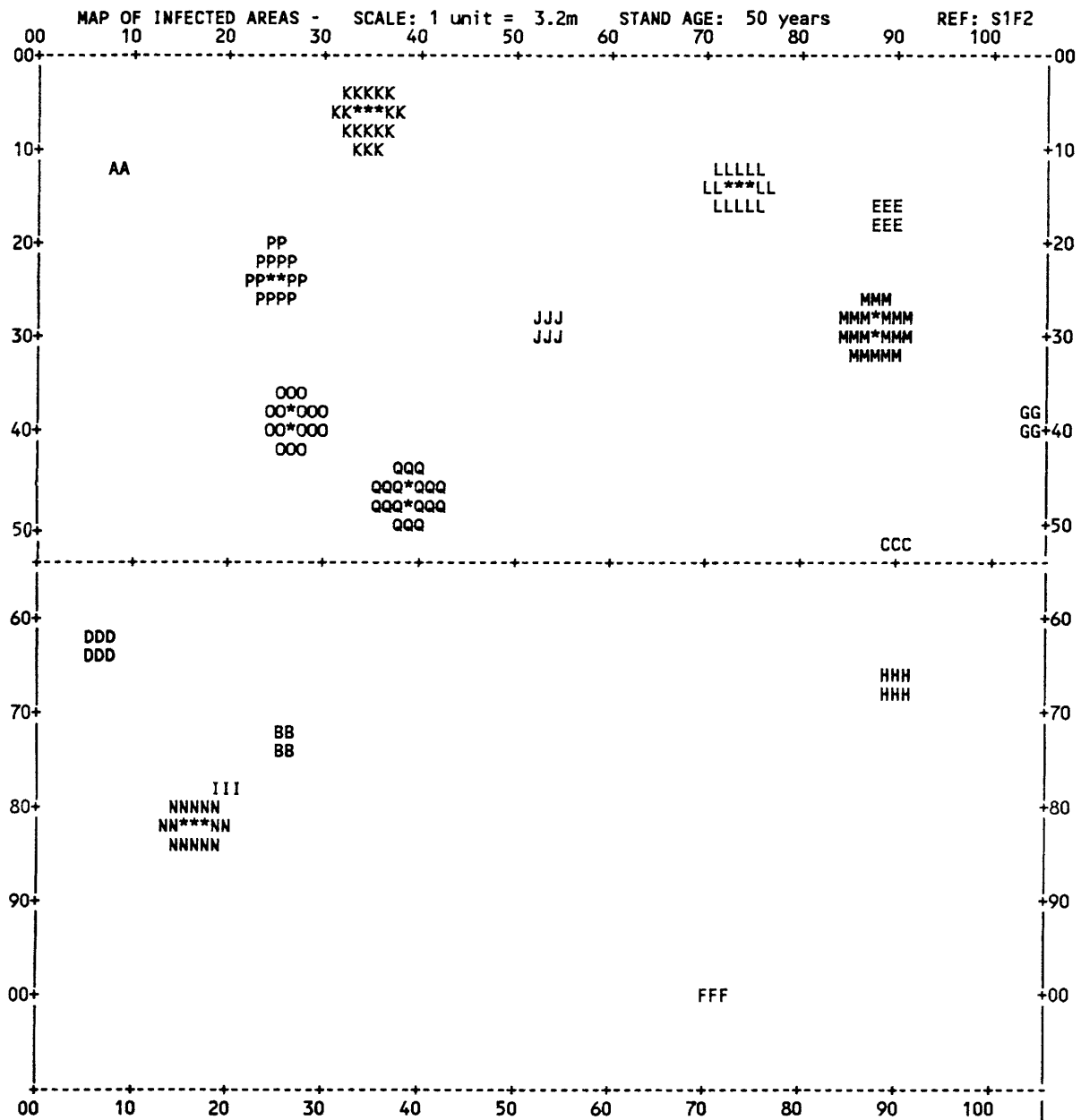
PATHOGRAM OF PHELLINUS ROOT ROT

Severity Class 1 (<6.0% at 50 yr)

Frequency Class 2 ($\geq 1.0 > 4.0$ centers/ha)

Stand Area = 10 ha

Stand Age = 50 yr



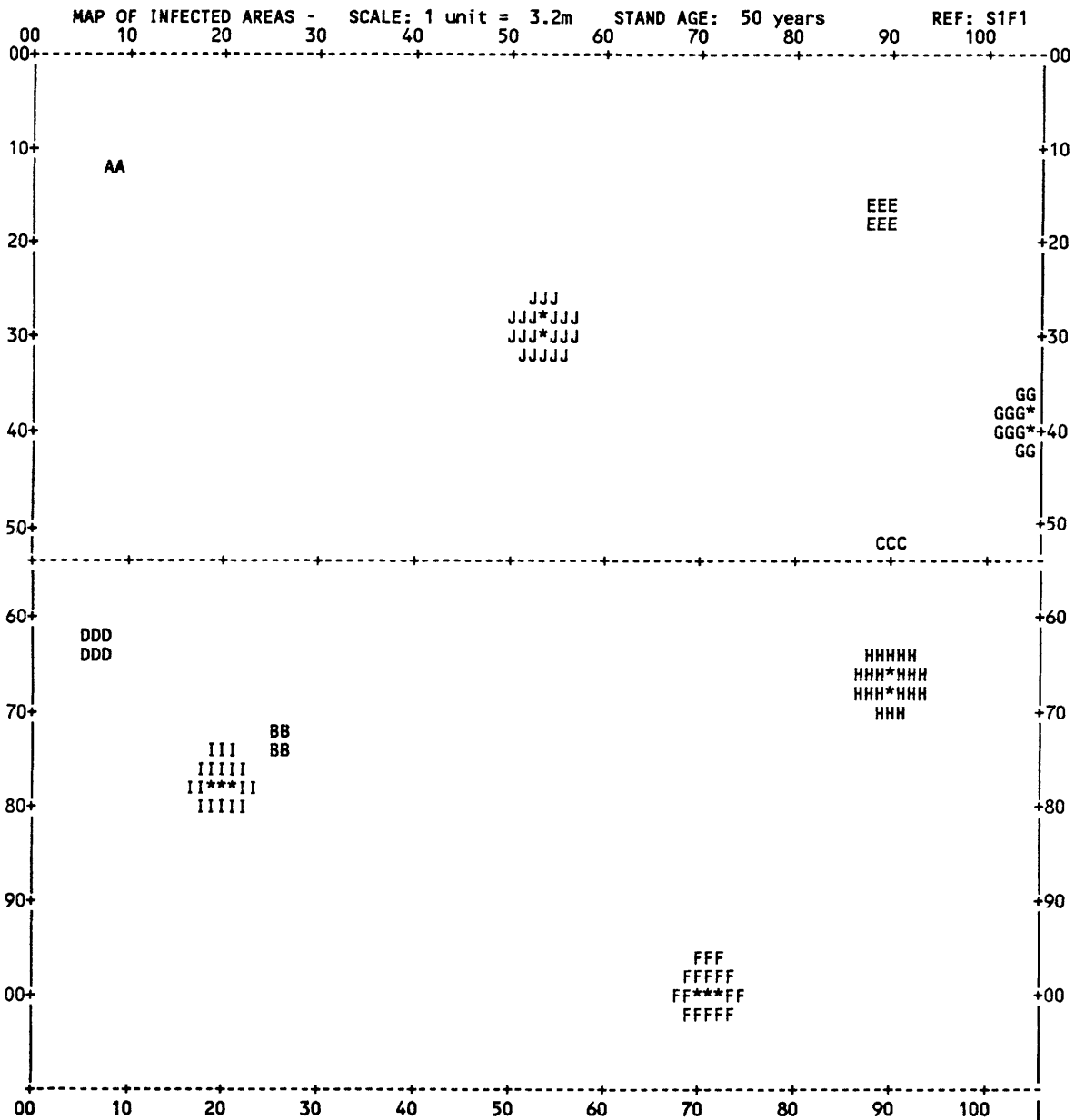
PATHOGRAM OF PHELLINUS ROOT ROT

Severity Class 1 (<6.0% at 50 yr)

Frequency Class 1 <=1.0 centers/ha)

Stand Area = 10 ha

Stand Age = 50 yr



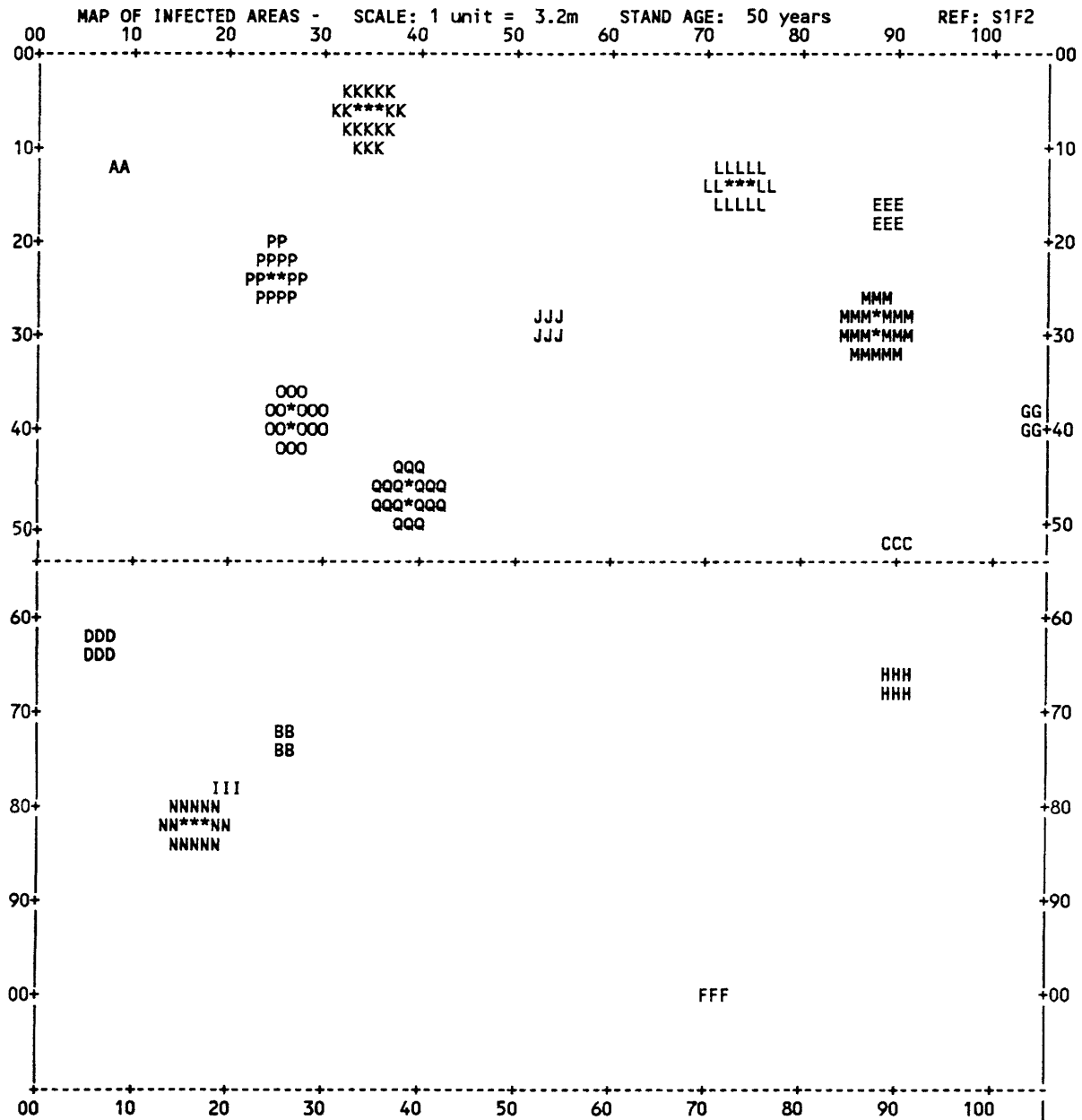
PATHOGRAM OF PHELLINUS ROOT ROT

Severity Class 2 ($\geq 6.0\% < 12.0\%$ at 50 yr)

Frequency Class 2 ($\geq 1.0 > 4.0$ centers/ha)

Stand Area = 10 ha

Stand Age = 50 yr



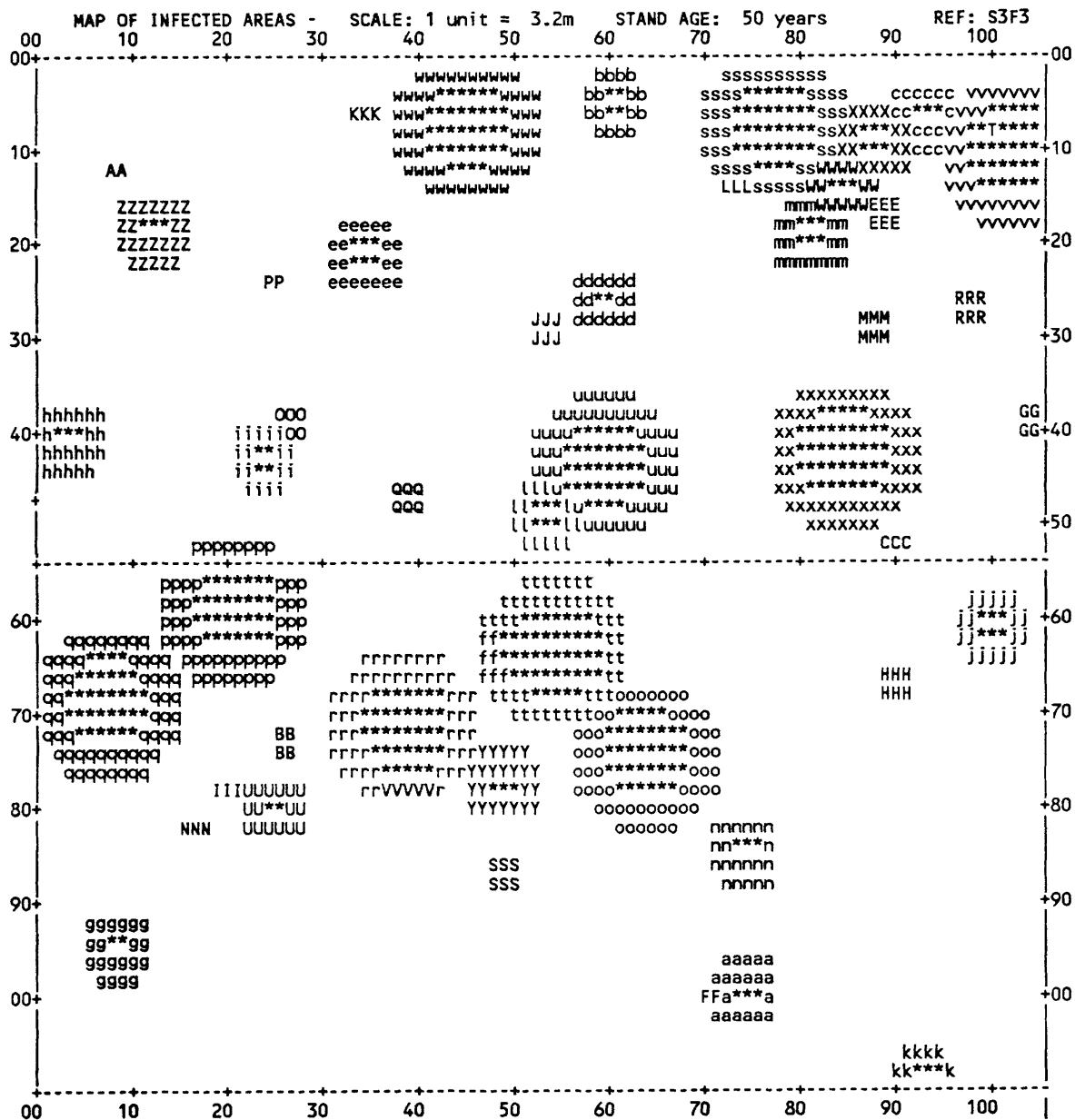
PATHOGRAM OF PHELLINUS ROOT ROT

Severity Class 3 (>12.0% at 50 yr)

Frequency Class 3 (>4.0 centers/ha)

Stand Area = 10 ha

Stand Age = 50 yr



T A B L E 3**NUMBERS AND SIZES OF ROOT ROT CENTERS IN EACH ROOT ROT CLASS
PER 10 HA STAND**

ROOT ROT CLASS	SIZE CLASS HA	AV. SIZE SQ. M	NO./ 10/HA STAND	NO./ HA	TOTAL AREA SQ. M	PERCENT OF STAND
S1F1	<=.02	90	5		450	
	.02-.05	370	5		1850	
	TOTAL		10	1.0	2300	2.3
S1F2		90	10		900	
		370	7		2590	
	TOTAL		17	1.7	3490	3.5
S2F2		90	11		990	
		370	6		2220	
	>.05-0.1	700	8		5600	
	TOTAL		25	2.5	8880	8.8
S3F2		90	6		450	
	>.02-.07	450	6		2700	
	>.07-.30	1800	7		12600	
	>.30	3200	1		3200	
	TOTAL		20	2.0	18950	19.0
S3F3		90	20		1800	
		450	20		9000	
		1800	10		18000	
	TOTAL		50	5.0	28880	28.9

T A B L E 4**SIZE OF ROOT ROT CENTERS AND STUMP CONFIGURATIONS
REQUIRED TO SIMULATE THEM BY TASS**

SIZE CLASS HA	AV. SIZE SQ. M	NO.	<u>STUMP CONFIGURATION</u>	
			DIAM. CM	DISTANCE BETWEEN M
<=.02	90	1	20	-
.02-.05	370	3	75	8
>.02-.07	450	4	75	8
>.05-0.1	700	5	100	16
>.07-.30	1800	9	100	22
>.30	3200	(7 x 450)		

T A B L E 5**COMPARISON OF CENTER SIZES SIMULATED AT STAND AGE 30, 60, 90
BY TASS AND BY RREST**

CENTER SIZE AT 50 YR SQ.M	STAND AGE	RREST SQ. M	TASS SQ. M	TASS:ROTSIM % DIFFERENCE
90	30	10	10	0
	60	274	280	+10.2
	90	1186	1200	+10.1
370	30	50	160	+32.0
	60	698	608	-12.9
	90	1994	2300	+15.3
700	30	210	320	+52.3
	60	1119	1250	+11.7
	90	2703	2924	+8.2
1800	30	690	600	-13.1
	60	2370	2100	-11.4
	90	4418	4448	+0.7

T A B L E 6**REDUCTION FACTORS FOR EACH DISEASE CLASS
CAUSED BY COALESCENCE OF CENTERS**

STAND AGE	S1F1	S1F2	S2F2	S3F2	S3F3
10	1.000	1.000	1.000	1.000	1.000
20	1.000	1.000	1.000	1.000	1.000
30	1.000	1.000	1.000	1.000	1.000
40	1.000	1.000	1.000	1.000	1.000
50	0.935	0.991	0.955	0.975	0.968
60	0.831	0.865	0.821	0.874	0.838
70	0.869	0.901	0.805	0.825	0.781
80	0.886	0.915	0.774	0.775	0.694
90	0.870	0.883	0.717	0.767	0.630

T A B L E 7**TOTAL STAND VOLUMES OF ROOT DISEASE CLASSES SIMULATED BY TASS**

STAND AGE	HEALTHY	S1F1	S1F2	S2F2	S3F2	S3F3
CU. M. / HA						
10	1.0	0.9	0.9	0.9	0.9	0.9
20	70.0	60.6	60.5	59.7	58.2	57.1
30	230.0	198.9	198.5	194.8	190.9	187.0
40	414.0	355.4	352.6	344.1	336.7	323.0
50	567.0	518.1	483.4	483.1	452.9	426.6
60	671.0	690.1	655.5	652.9	583.7	559.9
70	757.0	738.7	701.6	722.0	659.3	614.3
80	833.0	776.8	728.0	763.7	680.8	594.6
90	889.0	809.7	749.2	761.1	600.3	423.7

T A B L E 8**STAND STOCKING OF ROOT DISEASE CLASSES SIMULATED BY TASS STAND**

AGE	HEALTHY	S1F1	S1F2	S2F2	S3F2	S3F3
STEMS/HA						
10	2412.0	2407.0	2404.8	2377.7	2339.9	2308.3
20	2242.0	2231.7	2227.0	2195.7	2153.4	2113.3
30	2203.0	2188.6	2181.9	2132.7	2083.9	2029.3
40	2114.0	2103.7	2100.5	2050.7	1997.8	1951.5
50	1712.0	1678.3	1658.8	1580.5	1518.9	1413.3
60	1188.0	1156.8	1137.1	1054.6	1011.4	908.6
70	934.0	895.9	872.6	780.3	728.4	609.6
80	806.0	751.0	717.6	605.4	543.4	387.3
90	CR9.0	622.4	580.3	459.2	398.4	214.6

FIGURE 1

STEMS/HA FOR ROOT DISEASE CLASSES SIMULATED BY TASS

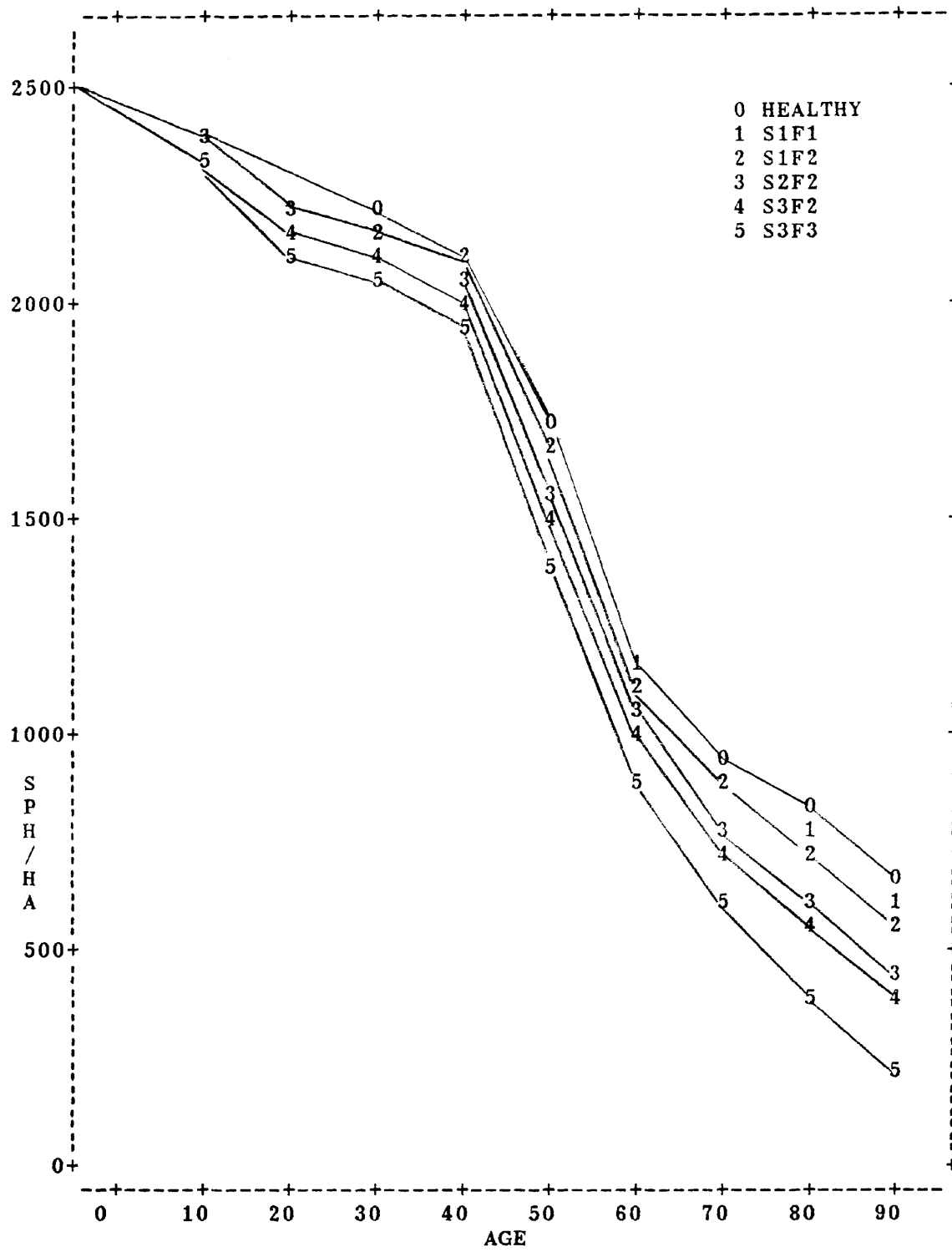
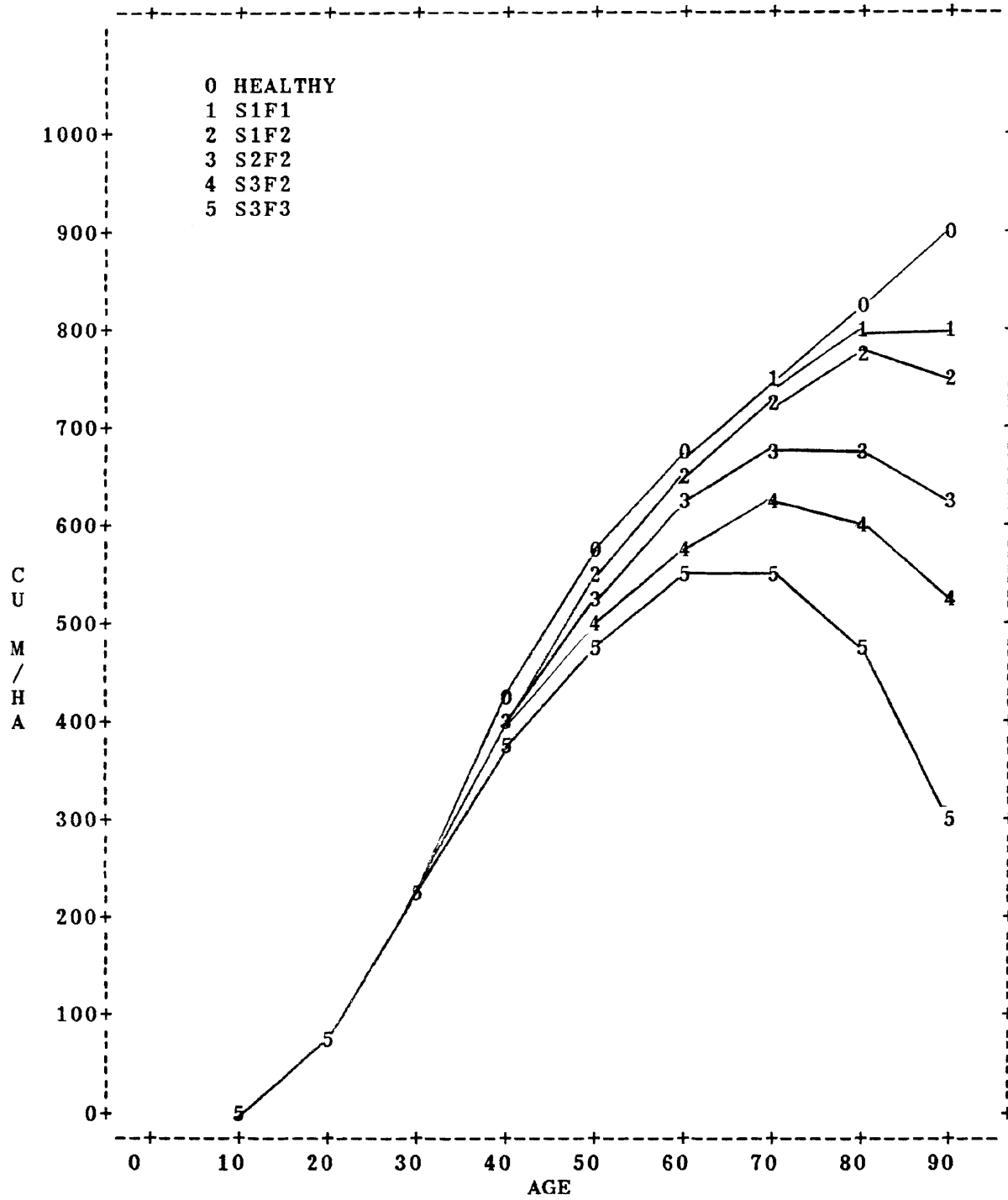


FIGURE 2

TOTAL STAND VOLUME OF ROOT DISEASE CLASSES SIMULATED BY TASS

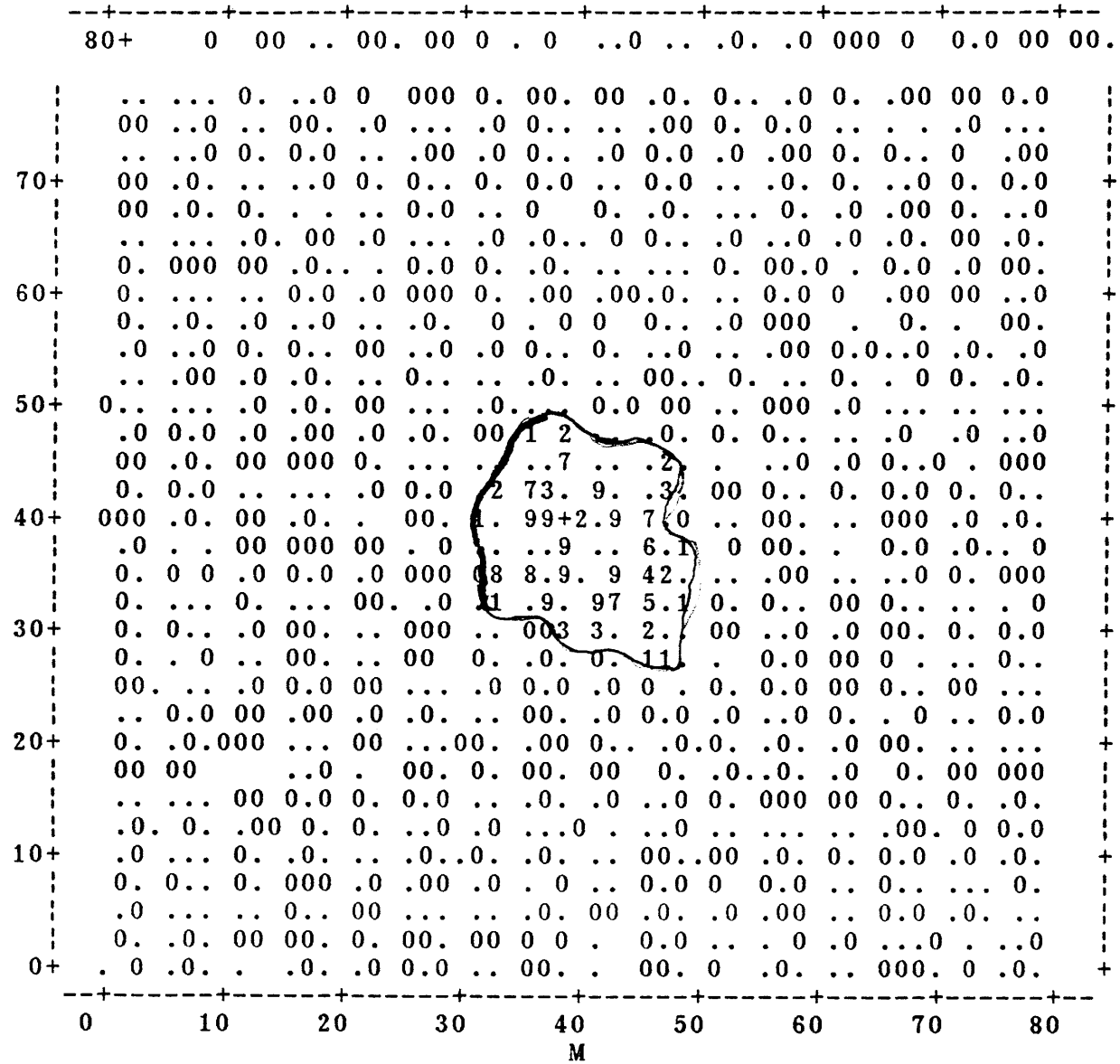


**MAP OF ROOT ROT AT STAND AGE 60 FOR CENTER SIZE CLASS 1
(90 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

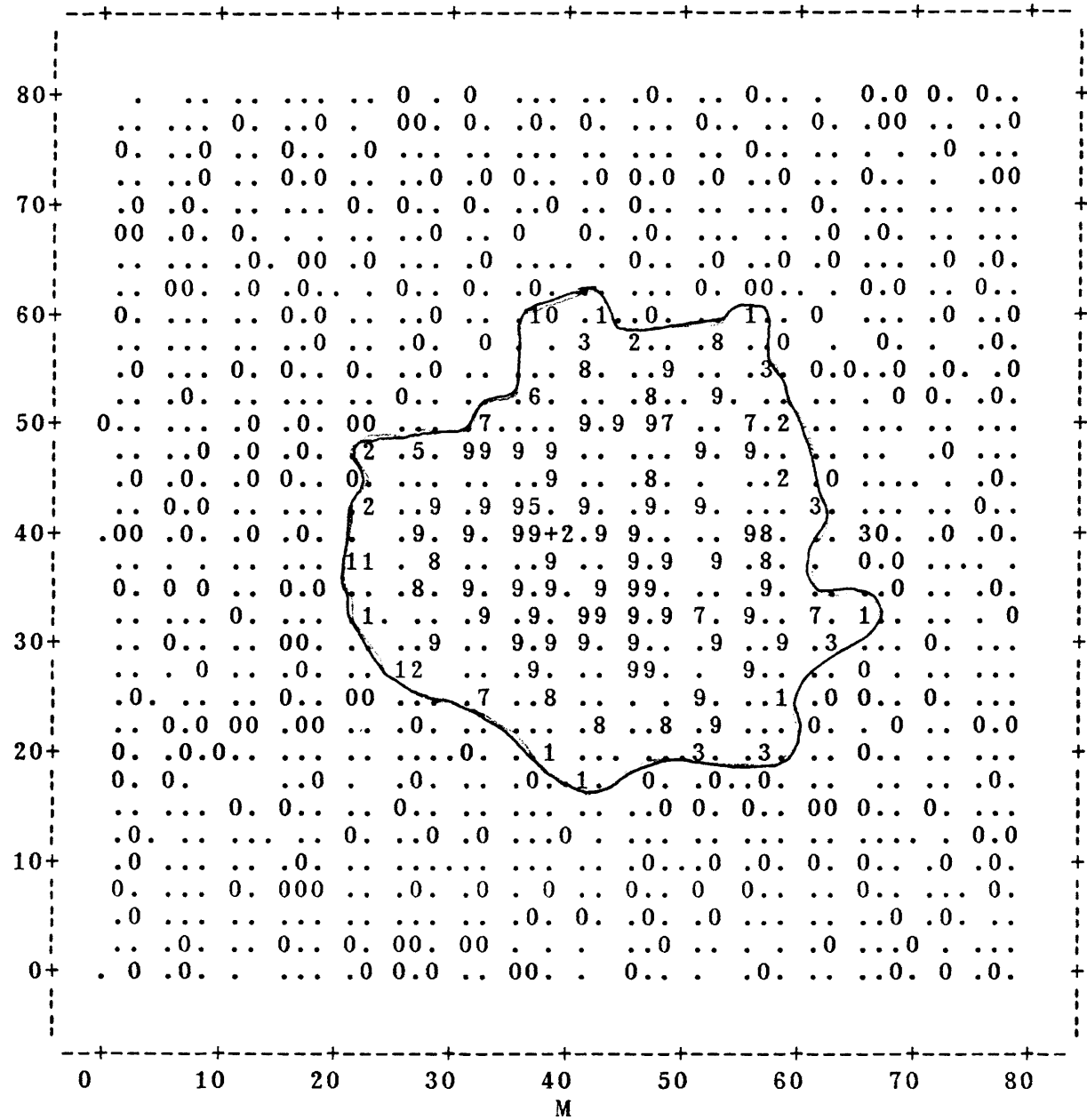


**MAP OF ROOT ROT AT STAND AGE 90 FOR CENTER SIZE CLASS 1
(90 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

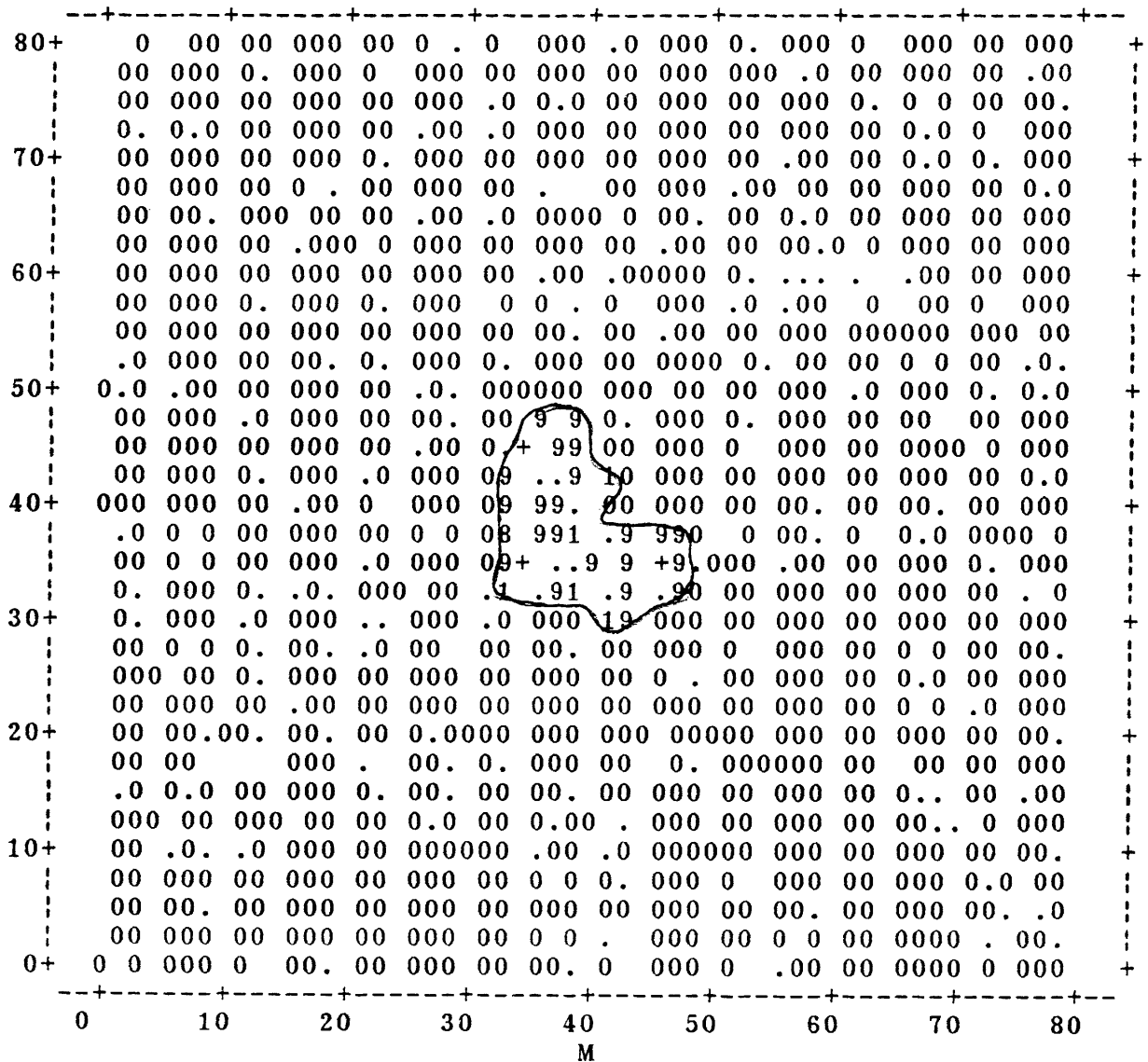


**MAP OF ROOT ROT AT STAND AGE 30 FOR CENTER SIZE CLASS 2
(370 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

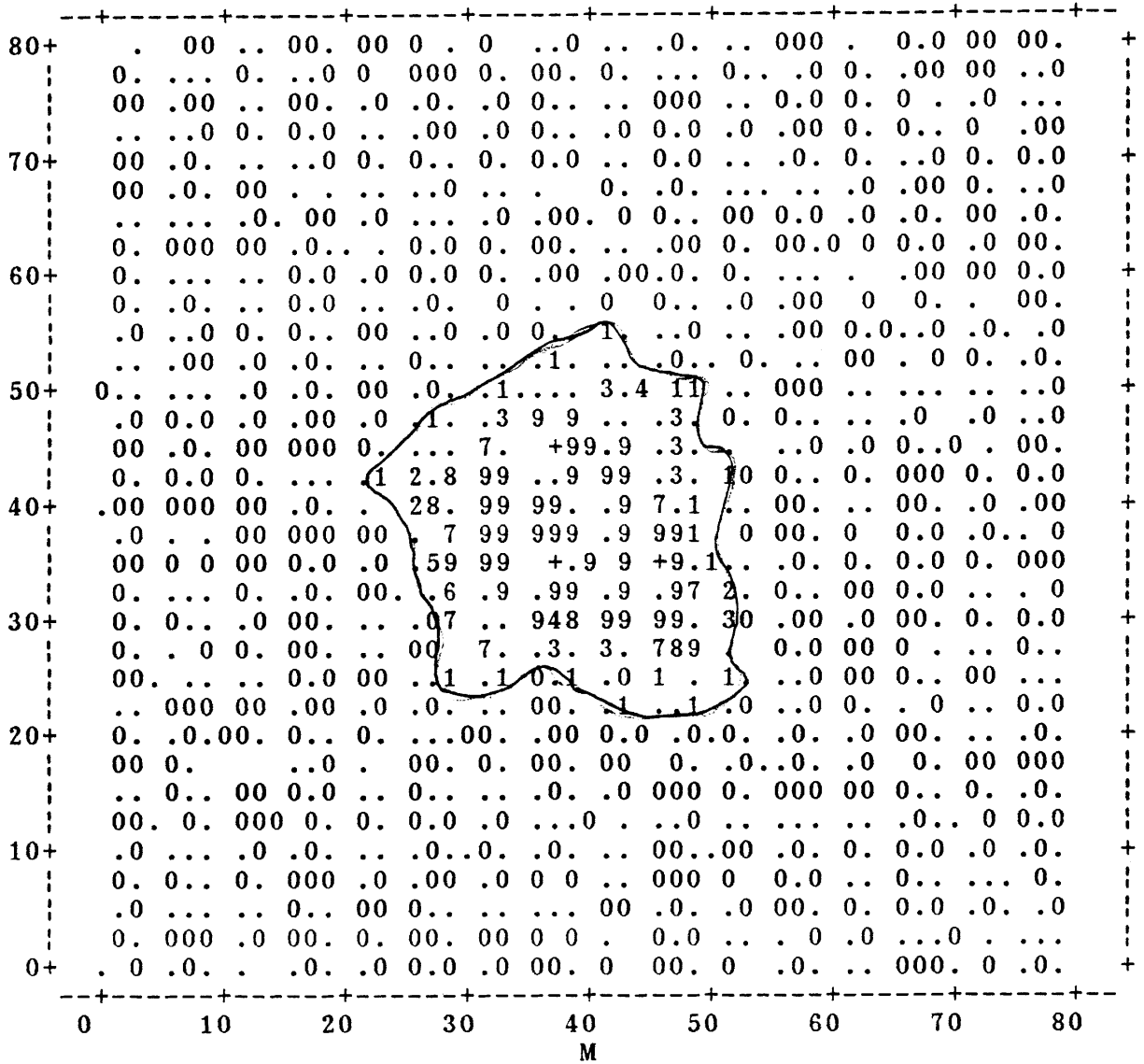


**MAP OF ROOT ROT AT STAND AGE 60 FOR CENTER SIZE CLASS 2
(370 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

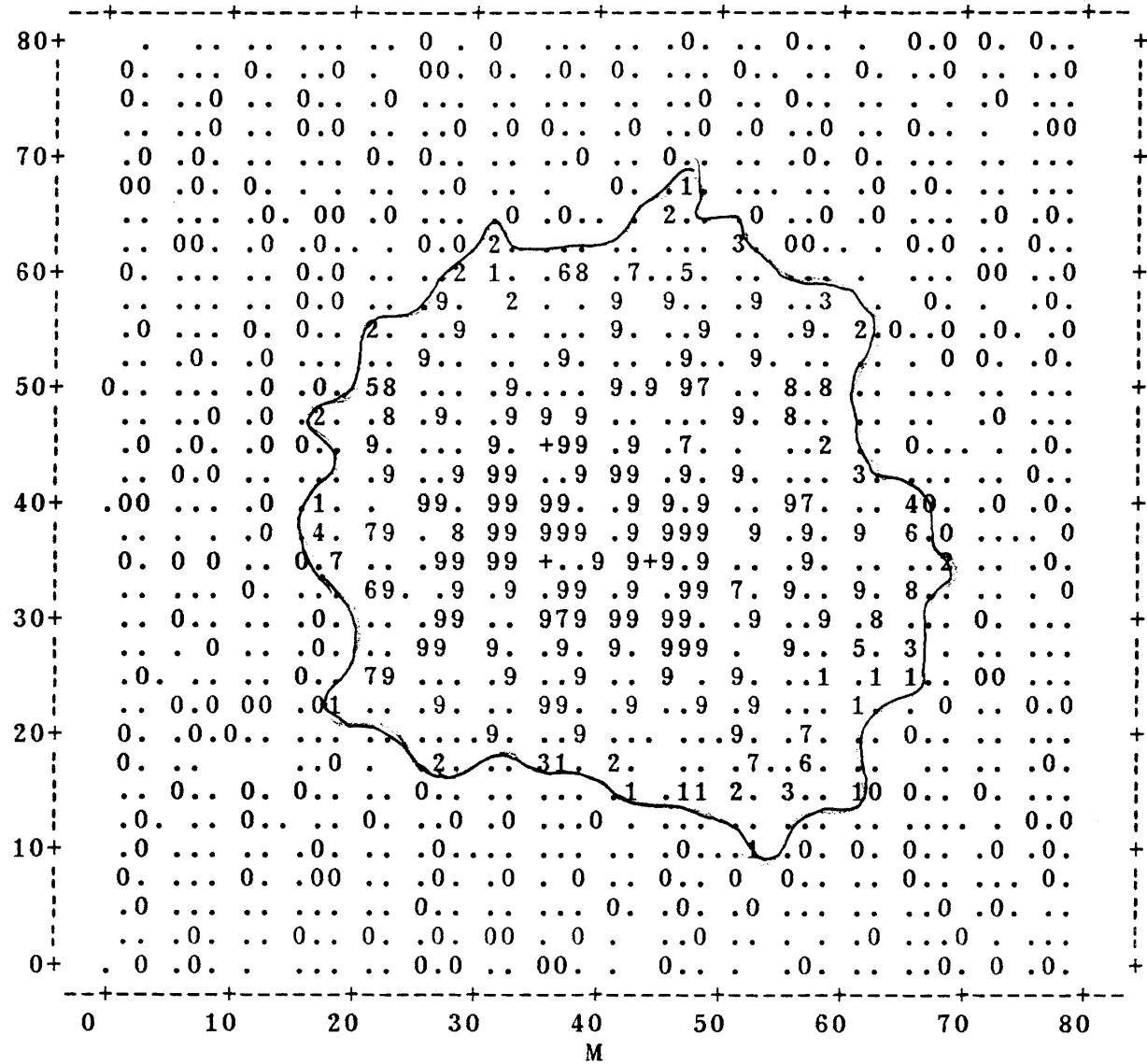


**MAP OF ROOT ROT AT STAND AGE 90 FOR CENTER SIZE CLASS 2
(370 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

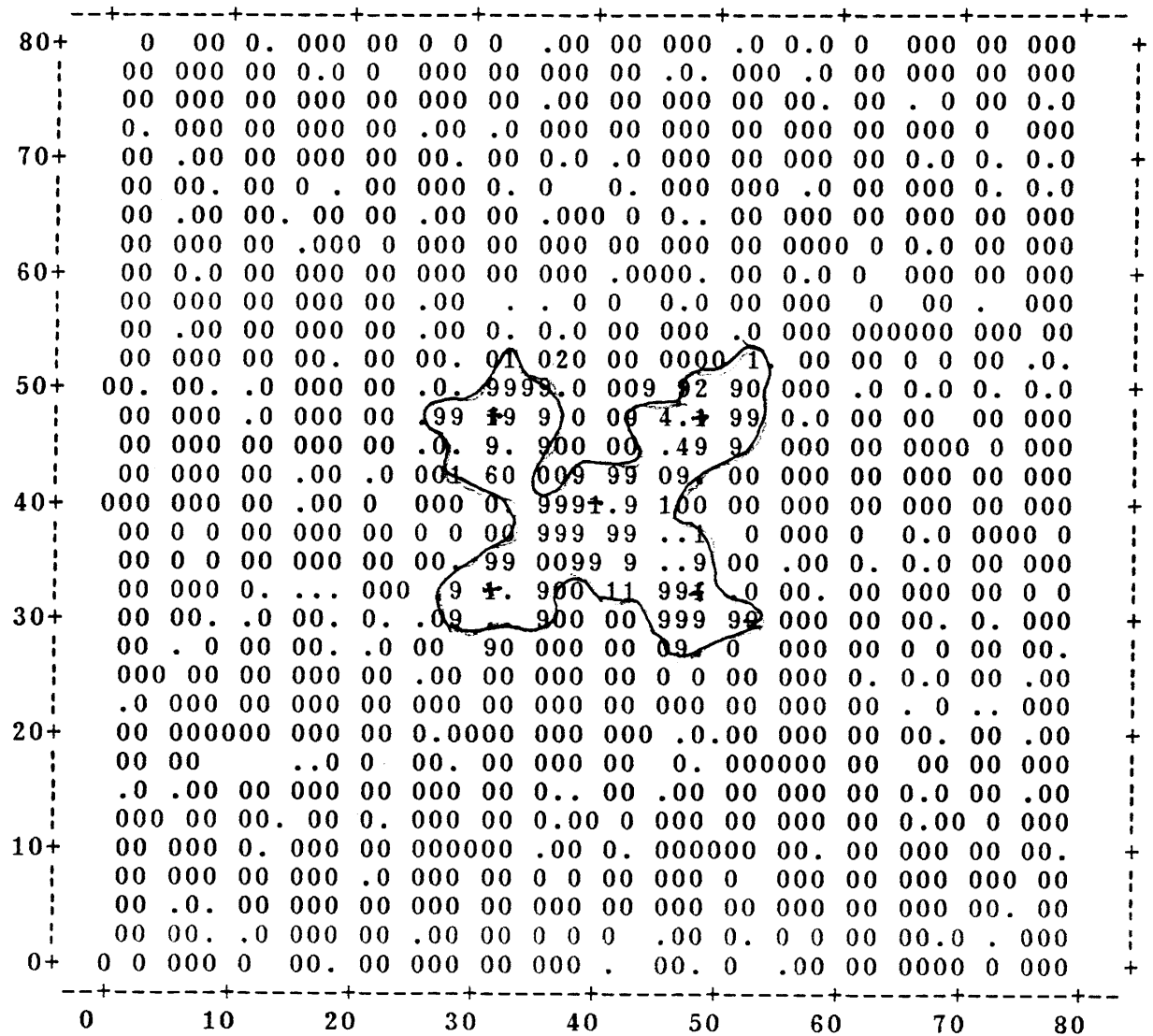


**MAP OF ROOT ROT AT STAND AGE 30 FOR CENTER SIZE CLASS 3
(700 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

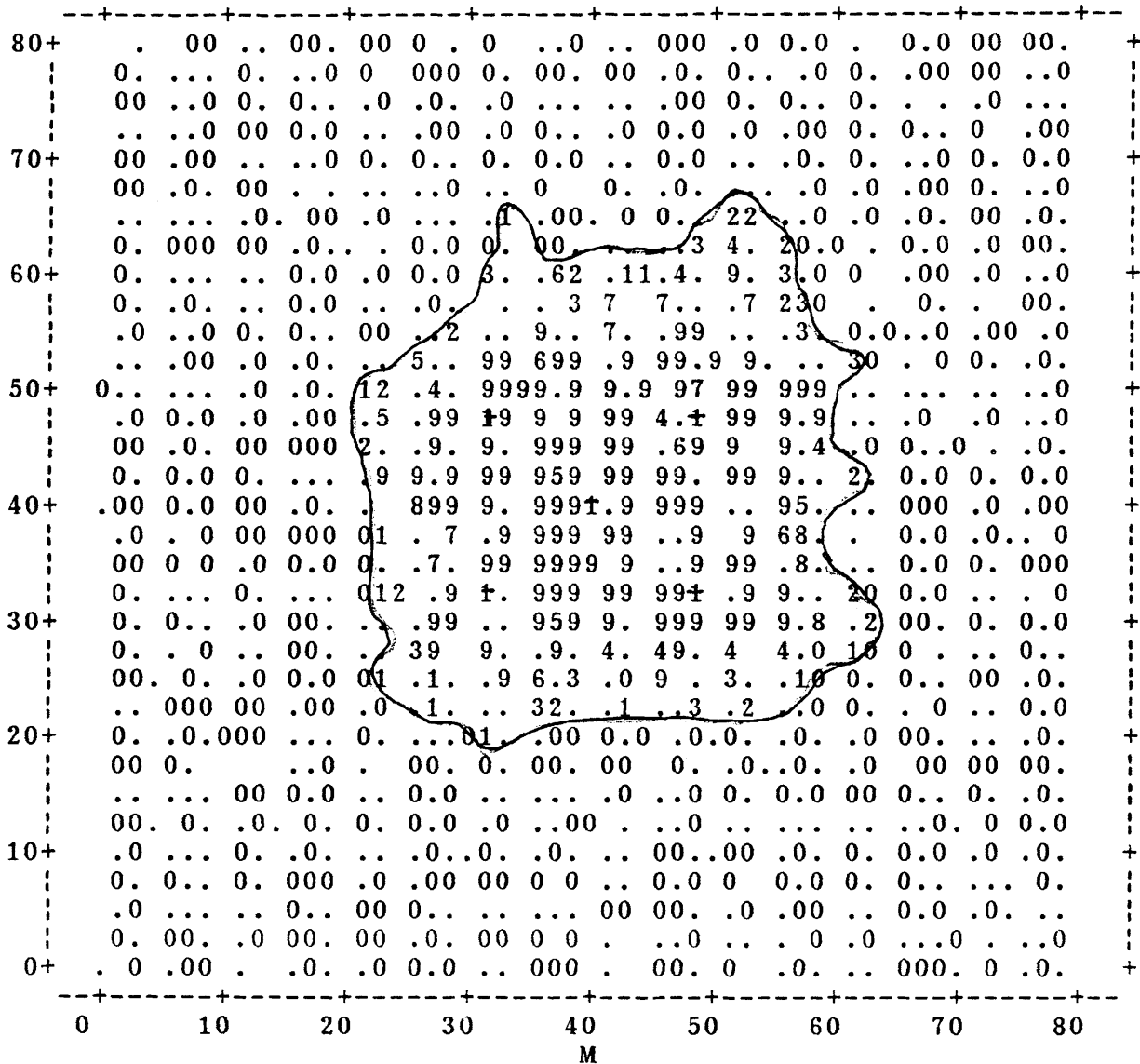


**MAP OF ROOT ROT AT STAND AGE 60 FOR CENTER SIZE CLASS 3
(700 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

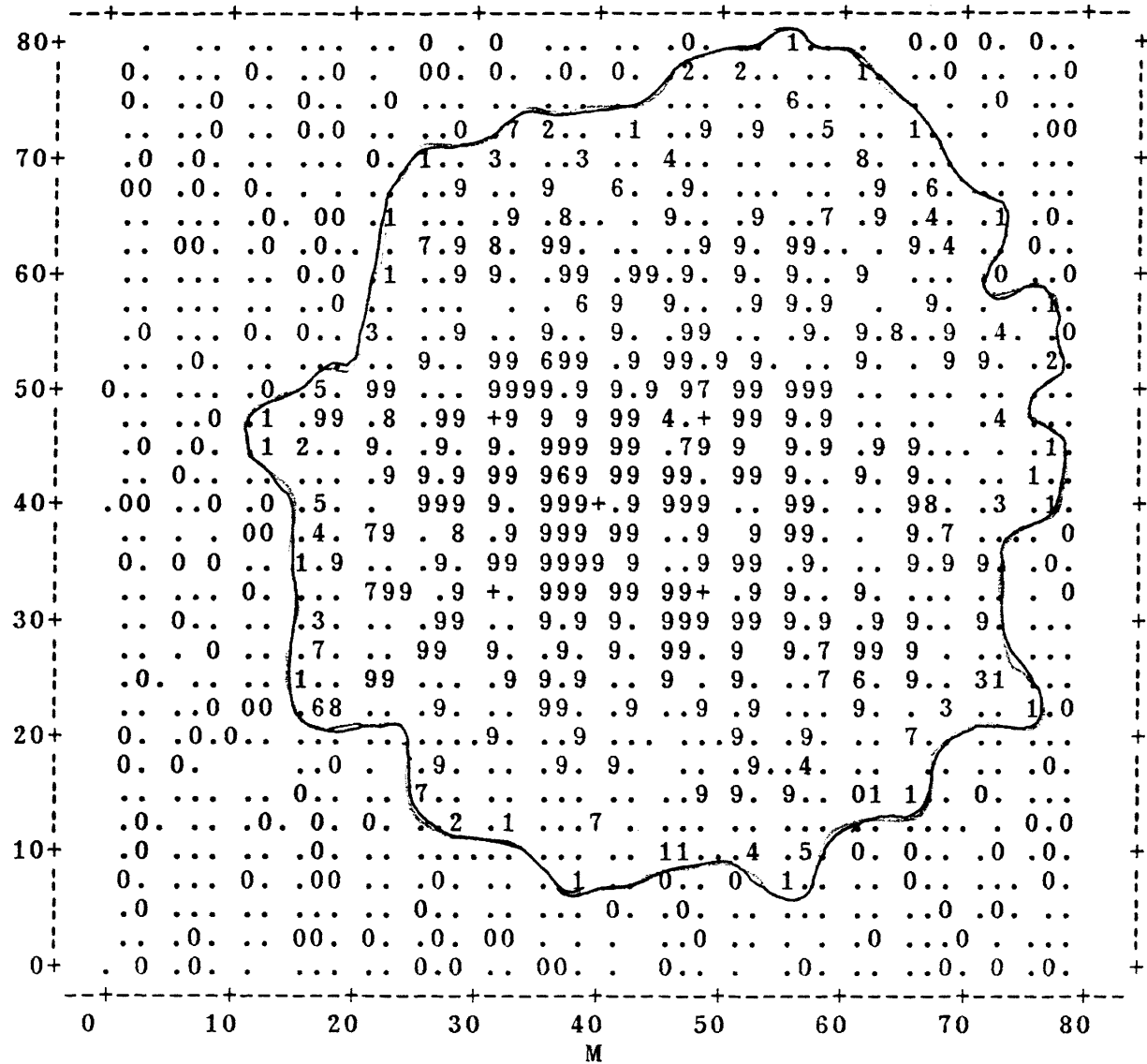


**MAP OF ROOT ROT AT STAND AGE 90 FOR CENTER SIZE CLASS 3
(700 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

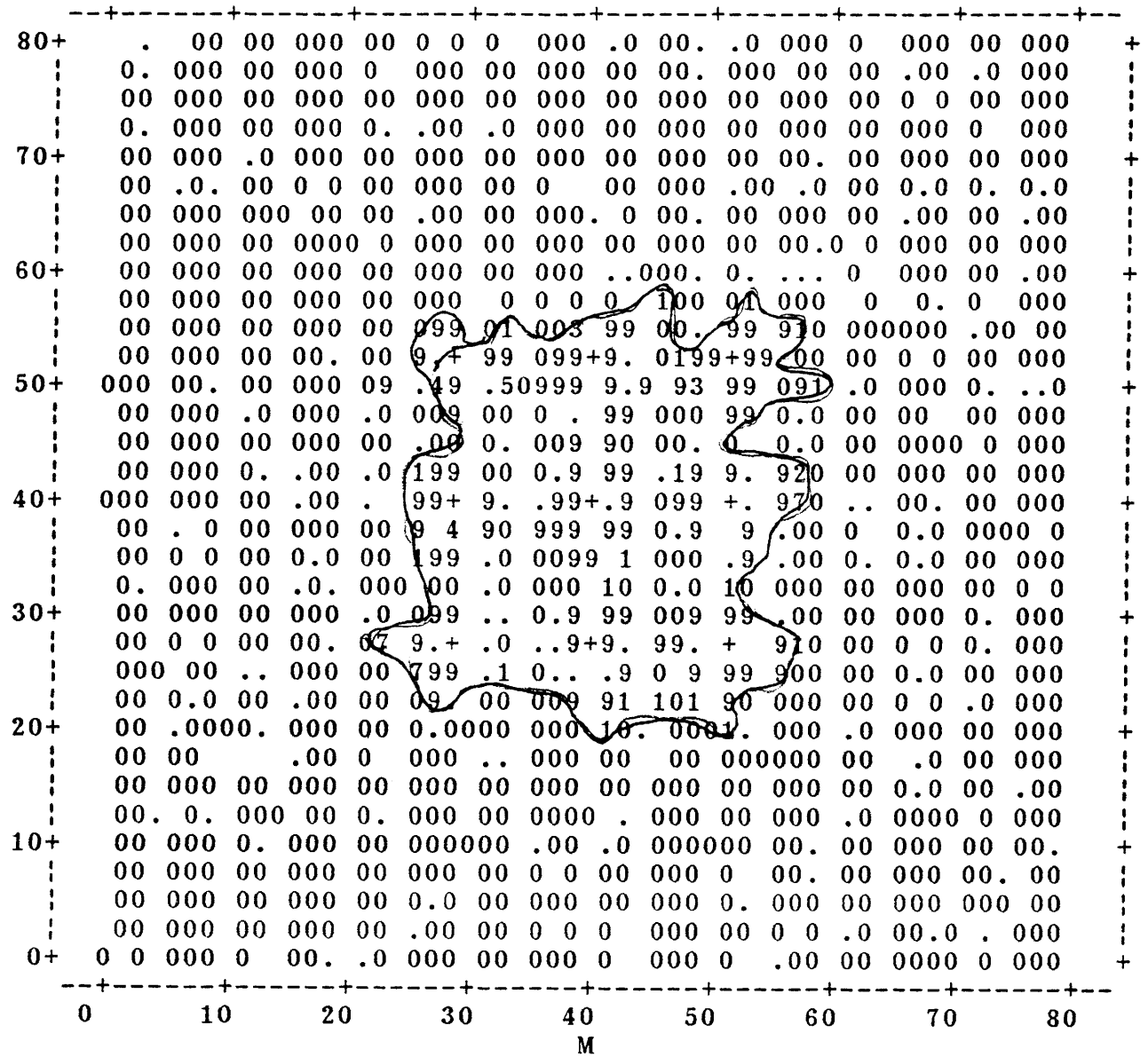


MAP OF ROOT ROT AT STAND AGE 30 FOR CENTER SIZE CLASS 4
(1800 SQ. M AT 50 YR.)

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

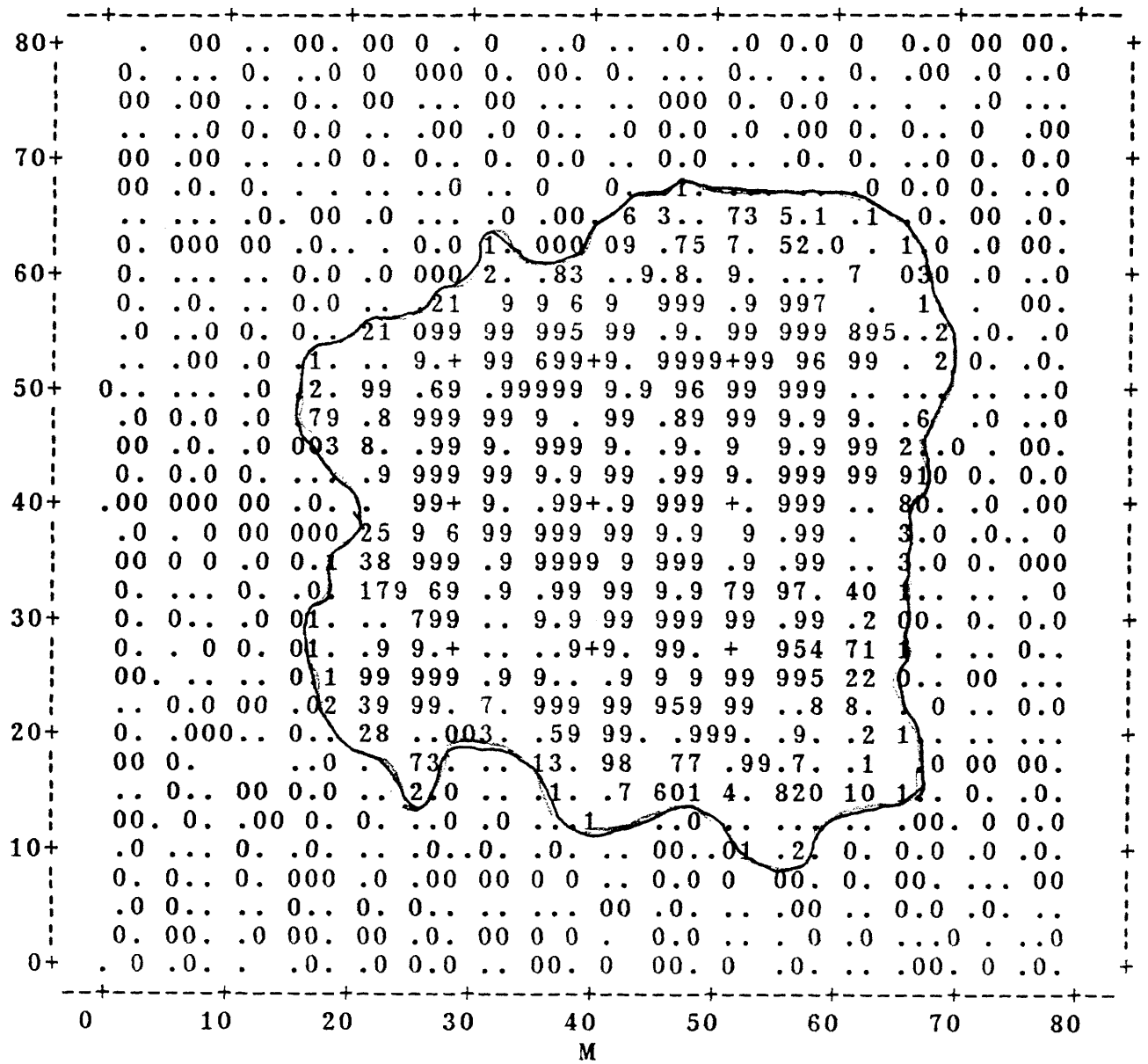


**MAP OF ROOT ROT AT STAND AGE 60 FOR CENTER SIZE CLASS 4
(1800 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP



**MAP OF ROOT ROT AT STAND AGE 90 FOR CENTER SIZE CLASS 4
(1800 SQ. M AT 50 YR.)**

ROOT ROT RATINGS 0 (HEALTHY) – 9 (KILLED)

. = SUPPRESSION MORTALITY

+ = STUMP

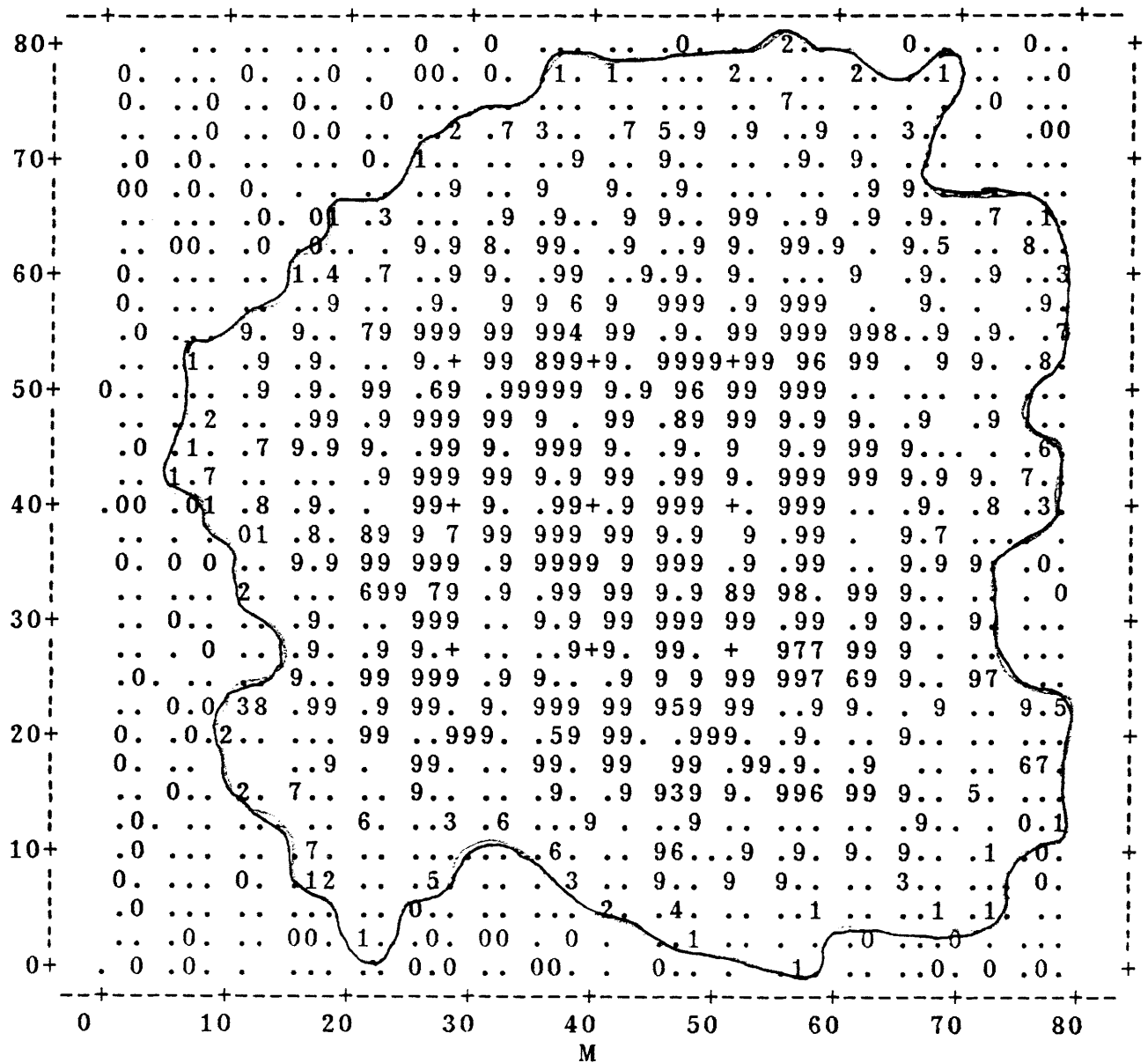


FIGURE 3

PERCENT ROOT ROT REDUCTION STAND STOCKING SIMULATED BY TASS

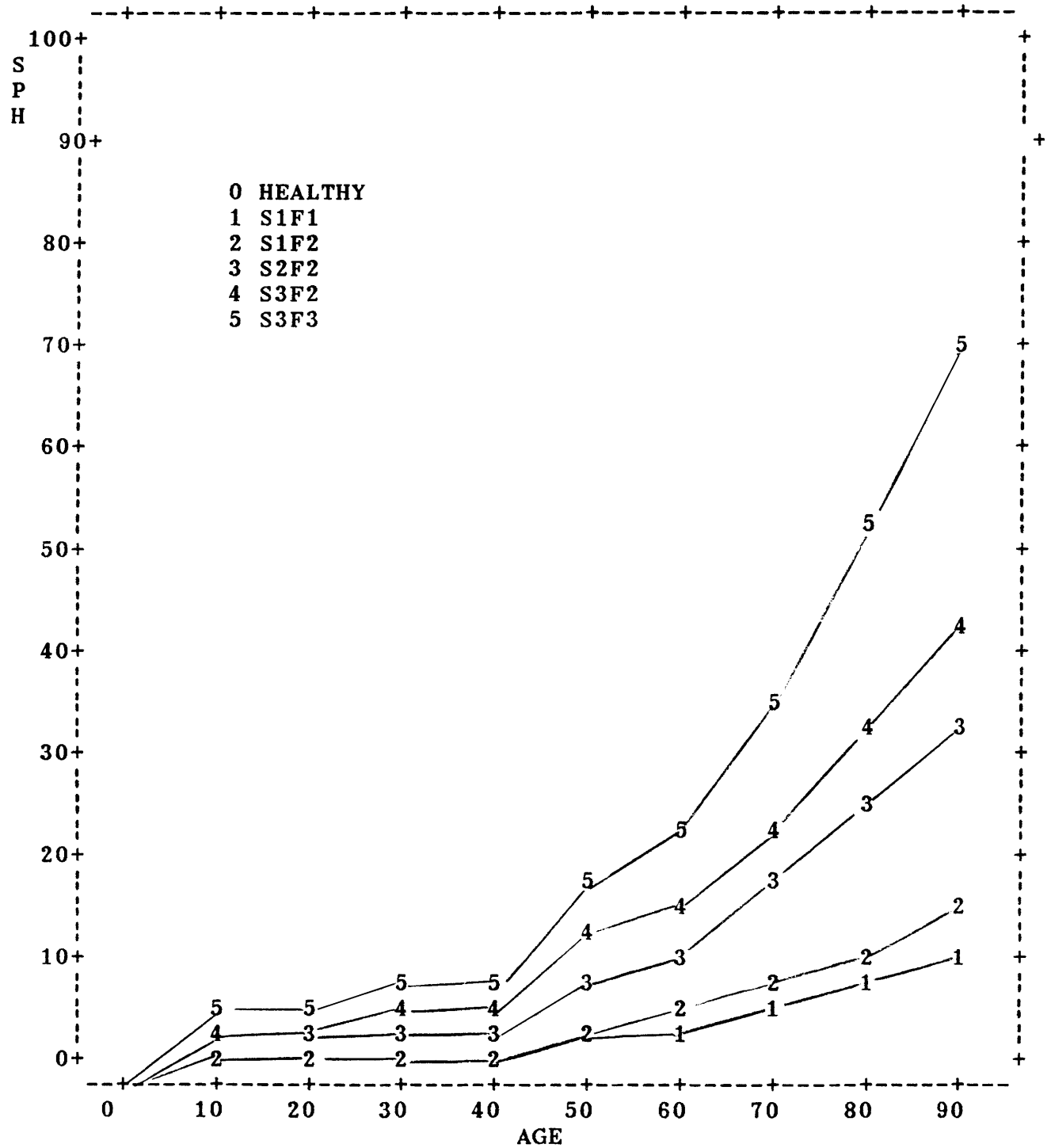
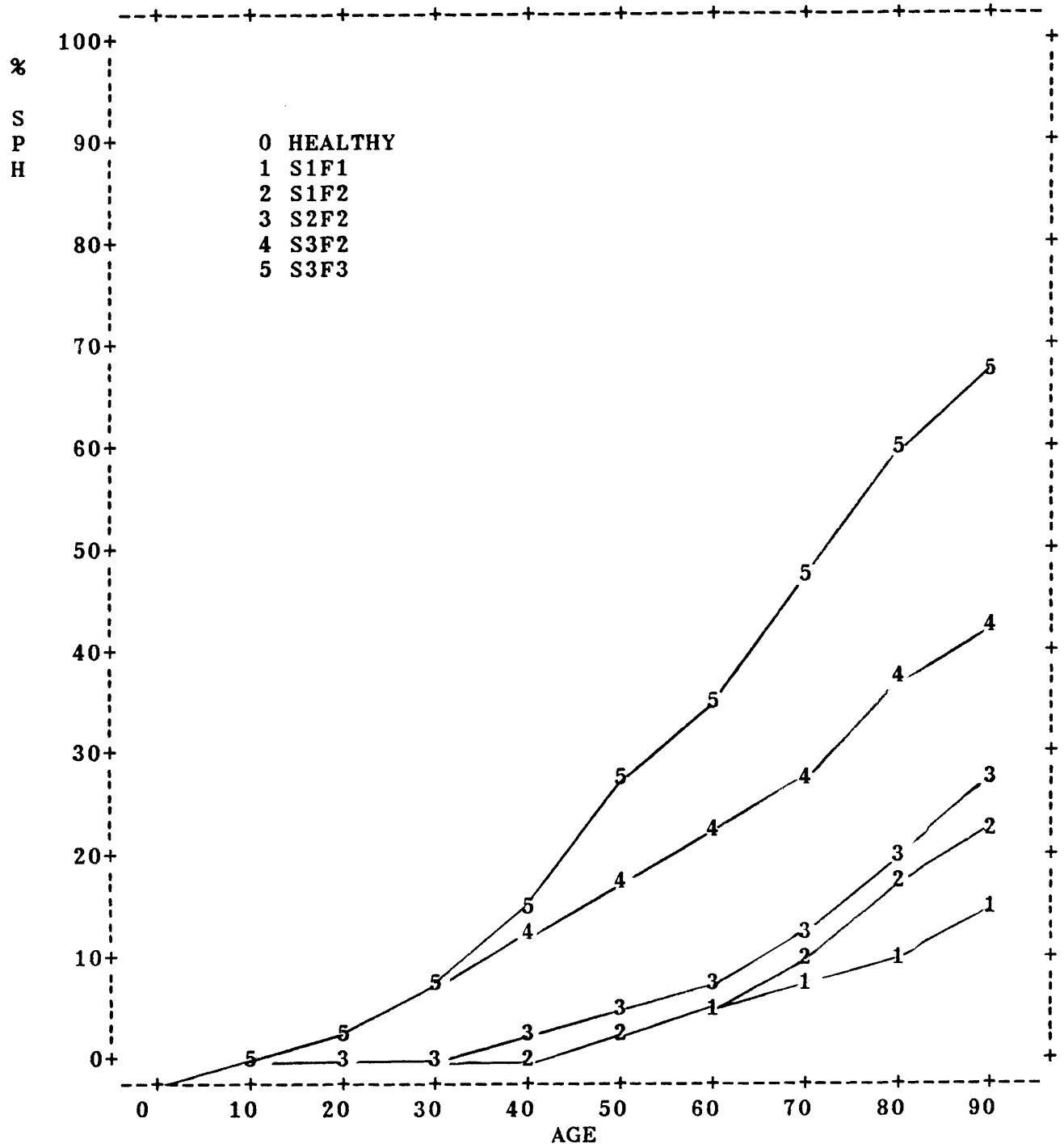


FIGURE 4

PERCENT ROOT ROT REDUCTION STAND STOCKING SIMULATED BY RREST



PRELIMINARY YIELD TABLES

FOR COASTAL DOUGLAS-FIR INFECTED WITH
PHELLINUS ROOT ROT

CONTRACT #69168
W.J. BLOOMBERG
JUNE 10, 1991

**PRELIMINARY YIELD TABLES FOR COASTAL DOUGLAS-FIR INFECTED WITH PHELLINUS
ROOT ROT**

INTRODUCTION

Phellinus root rot is distributed widely in coastal Douglas—fir stands. In a survey of the Vancouver Region, J. Beale found that more than 80% of stands were infected to varying degrees ranging from less than 1% to over 40% of stand area. Infection tended to increase as site improved. B. Bloomberg has found evidence that stand stocking also influences spread of the disease, primarily through its effect on root contacts by which the fungus passes from tree to tree. Thirdly, the initial inoculum level at stand creation, i.e., number and size of infected stumps, has a major effect on subsequent impact by the disease.

Because the major impact of Phellinus root rot is in the form of patchy mortality increasing with age, in effect creating unstocked areas in stands, yields in infected stands cannot be estimated using yield tables for healthy stands. There is a need therefore for yield tables based on the major factors, which determine the impact of the disease, i.e., site, stocking, and initial inoculum.

OBJECTIVE

In the absence of permanent plot data for growth and yield in stands infected by root rot, a modelling approach has been used combining K. Mitchell's stand growth simulator for Douglas-fir (TASS) and B. Bloomberg's root rot model (ROTSIM). The accuracy of the results depends, of course, on the accuracy of both models individually and in combination. Each has been extensively validated against field data. In combination (TASS-ROTSIM), results corresponded well with data from root rot surveys, as well as with results from an independent whole-stand model (RREST).

The immediate objective is to produce preliminary yield tables for evaluation and comment by provincial forest pathologists, leading to refinement, and with increase in computing capacity, greater flexibility.

METHODS

Stand areas of 10 ha are the minimum for realistically simulating spread of multiple root rot infection centers during a 90—yr rotation. Owing to present computer memory limitations, an entire 10 ha stand cannot not be simulated for root rot. Therefore, stands were built up from plots 80 x 80m, the maximum allowed by memory limits. Each stand therefore consisted of 16 0.64 ha plots, totalling 10.2 ha. Yields of plots were averaged to produce stand yield. If the number of centers per stand did not exceed the number of plots, each plot was simulated as containing one center.

$$Y_s = (Y_{p1} + Y_{p2} + \dots Y_{pn})/16$$

Where Y_s = stand yield (cu. M/ha, stems/ha), Y_{p1} = yield of plot 1

If, as in the higher disease classes, the number of centers exceed the number of plots, more than one center was included in a plot, the total center areas always being less than that of the plot. In this case, the healthy plot yield had to be decremented by the yield loss attributable to each center.

$$Y_p = Y_{ph} - N_{pc1}(Y_h - Y_{pc1}) - N_{pc2}(Y_h - Y_{pc2}) - \dots N_{pcn}(Y_h - Y_{pcn})$$

where Y_{ph} healthy yield of plot p, N_{pc1} no. of centers of size class 1 in plot p, Y_{pc1} the yield of plot p with center size c. Yields of plots devoid of centers were those of healthy plots.

$$Y_s = (Y_{p1} + Y_{p2} + \dots Y_{pn})/16$$

Theoretically, it is possible for each infection center to occupy a separate block of the stand, but is an unlikely, artificial situation. In nature, centers are randomly distributed resulting in some merging as they expand. Estimates of merging of randomly distributed centers were obtained from RREST using the same center sizes, nos./ha, and proportions as for TASS-ROTSIM. The aggregate area of centers simulated by TASS-ROTSIM was compared with that produced by RREST. Their ratio was used in calculating a merging factor to modify TASS-ROTSIM outputs. The method is more fully described in B. Bloomberg, Progress Report Minor Service Contract (Control No. 49782) "Incorporation of Phellinus root rot impacts in the tree and stand simulator (TASSY'.

The wide range of root rot levels occurring in stands was condensed into five classes: very light, light,

moderate, heavy, and very heavy. The classes were derived by analysis of 200 root rot surveys by selecting midpoints of the most frequent strata (see the above report for details). Typical disease distribution maps (pathograms) for each class are shown .

The requisite initial inoculum, i.e., number, size and spatial distribution of infected stumps, to reproduce these disease classes in TASS—ROTSIM was derived by methods also described in the above report. They ranged from a single stump 20 cm diam to nine stumps 100cm diam spaced 12m apart.

Initial stocking, i.e., at stand creation, was varied from 500 –2500 stems/ha, representing the range of planting distances from 2x2m to 4.5X4.5m.

Site indices 25, 30, and 35 were used to represent poor, medium and good sites.

RESULTS

Results are presented as tables of volumes/ha and stems/ha by decade to rotation age 90. Plots are presented the trend over age of volume, stocking, and impact (volume stocking as a percent of that of healthy stands). Plots for all site indeces and stocking levels are shown in the appendix. For convenience of comparison, plots are arranged by variable (stems/ha impact, volume impact, and volume/ha) and in the order of site index and initial stocking.

In general, impact increased as initial stocking due to increased number of root contacts and hence more rapid disease spread. Impact was least at SI 25 and can be attributed to small tree growth and hence fewer root contacts than at the higher site indeces. The lower impact at SI 35 compared to SI 30 resulted from greater tree growth without a corresponding increase in disease spread. Apparently, the number of root contacts at SI 30 was sufficient to spread the fungus as rapidly as in SI 35 but the more robust root systems at the higher site delayed mortality. Comparison of impacts at 500 and 2500 stems/ha is shown in Table 1. Impacts at other stocking densities is shown in Appendix S%25-35 and V%25—35. Plots of stems/ha and volume/ha over age for initial stocking of 2500 stems/ha are shown in Figs. 1 — 6. Plots for other stockings are shown in Appendix 525—35 and V25—35.

An interaction occurred between site index and stocking at SI 35 and at 1000 stems/ha initial stocking which had lower volumes than at 1500 stems/ha (537.0 vs 749.1 at age 90 in the very heavy disease class). Apparently, a lower rate of suppression mortality combined with sufficient root contacts allowed the disease to spread more rapidly than at the higher stocking level. B. Bloomberg found evidence that dead trees provide a barrier to spread of *Phellinus* because they are not infected. This is the principle of bridge—tree removal for interrupting spread of the disease.

Table 1. Effect of site index and initial stocking on impact of very heavy *Phellinus* root rot in coastal Douglas-fir (living trees at age 90 as percent of healthy stand)

Initial stocking stem/ha				
Site index	500		2500	
	% trees	% volume	% trees	% volume
25	88.5	91.0	65.2	77.9
30	80.3	86.2	29.4	34.5
35	82.9	96.9	44.9	46.0

At higher stocking levels, spread of root rot was increased by more frequent root contacts; on the other hand it was partly limited by the increased number of suppression-killed trees.

CONCLUSION

The results of simulation agree generally with field observations and survey results with respect to the effects of site, stocking and initial inoculum level. The yield tables produced from the simulations provide a basis for evaluation and refinement. Classification of disease levels for application to yield tables should be further developed so that consistent standards are used.

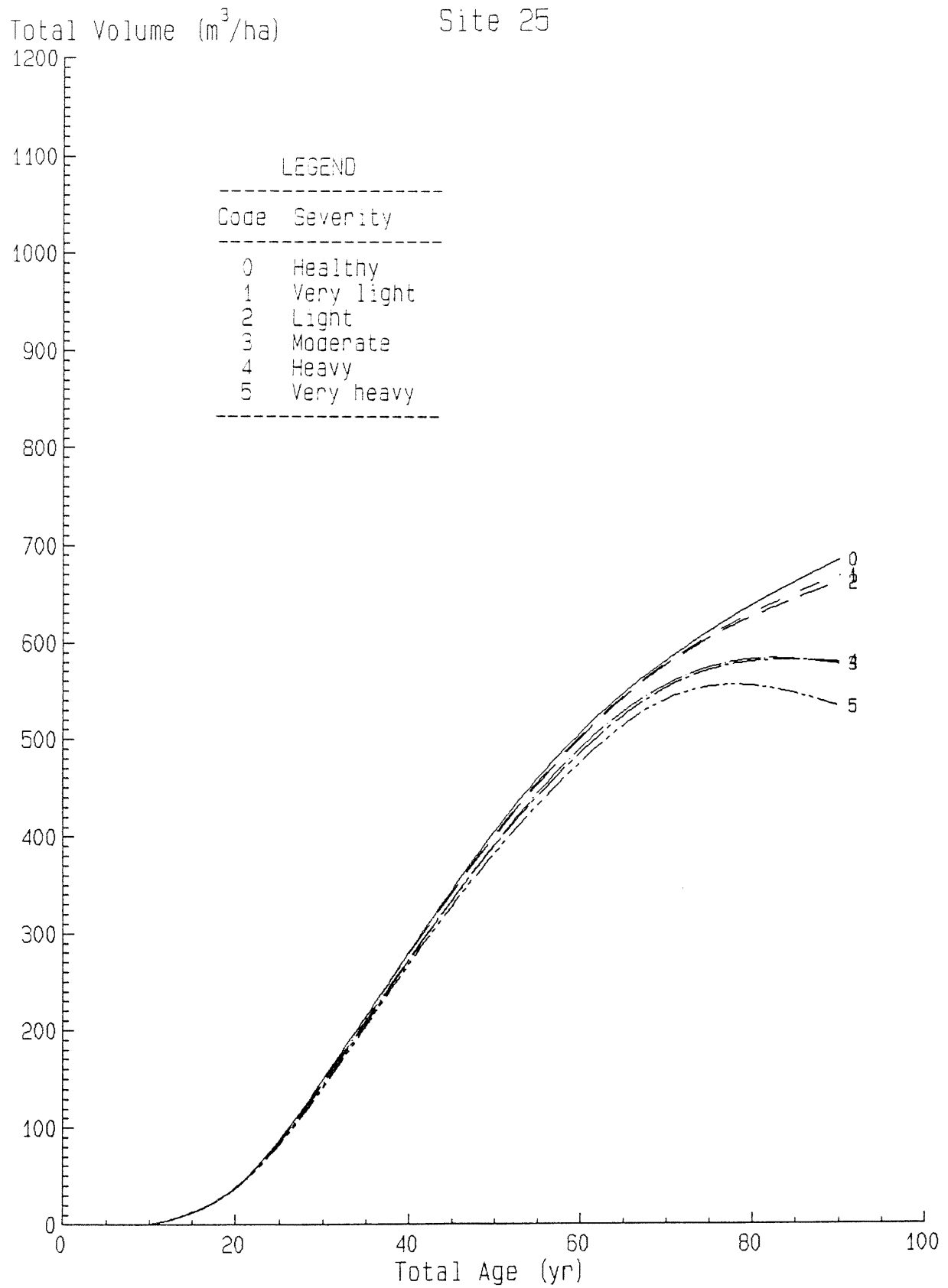


Figure 1.

Preliminary Yield Tables

Site 30

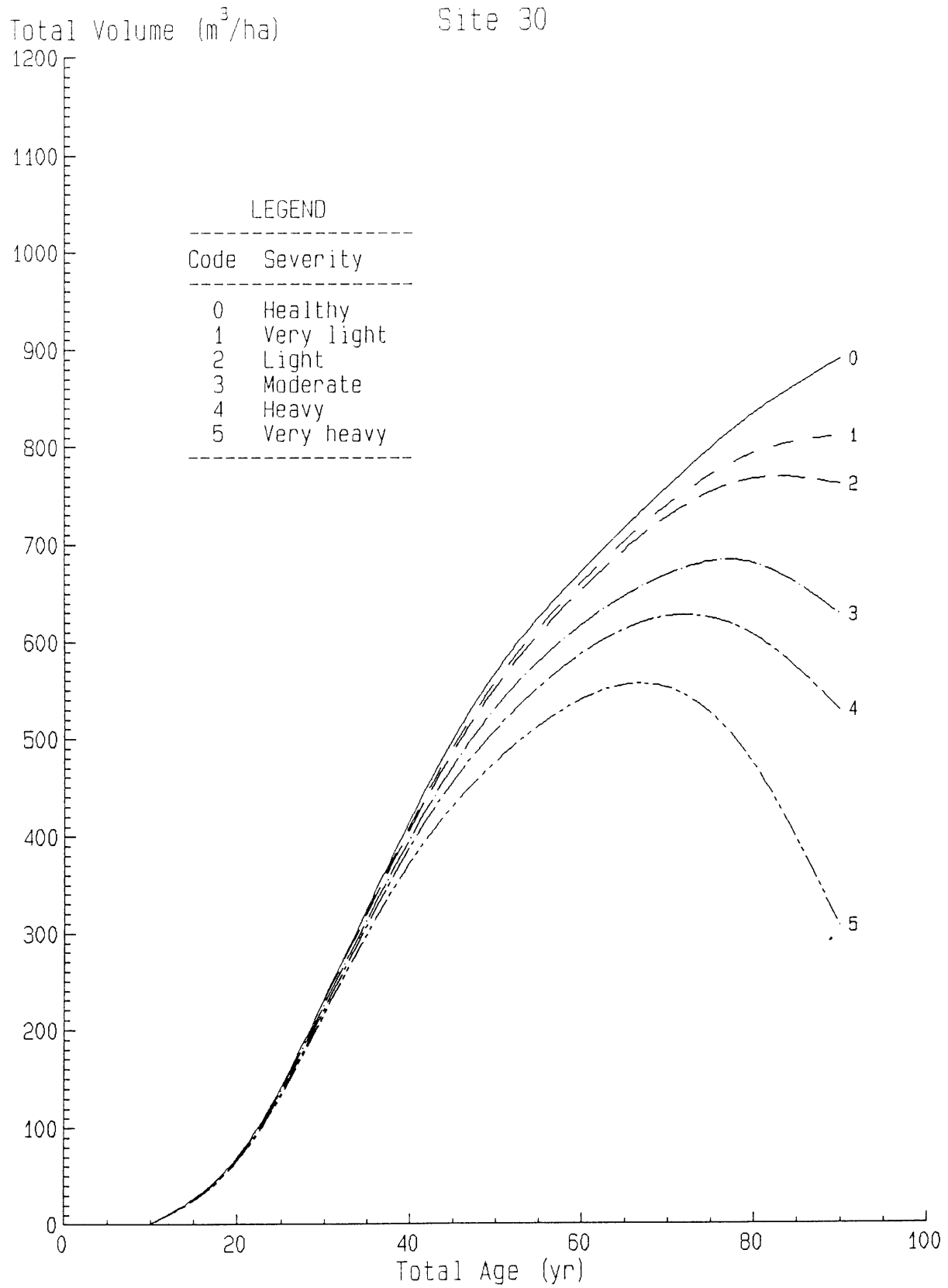
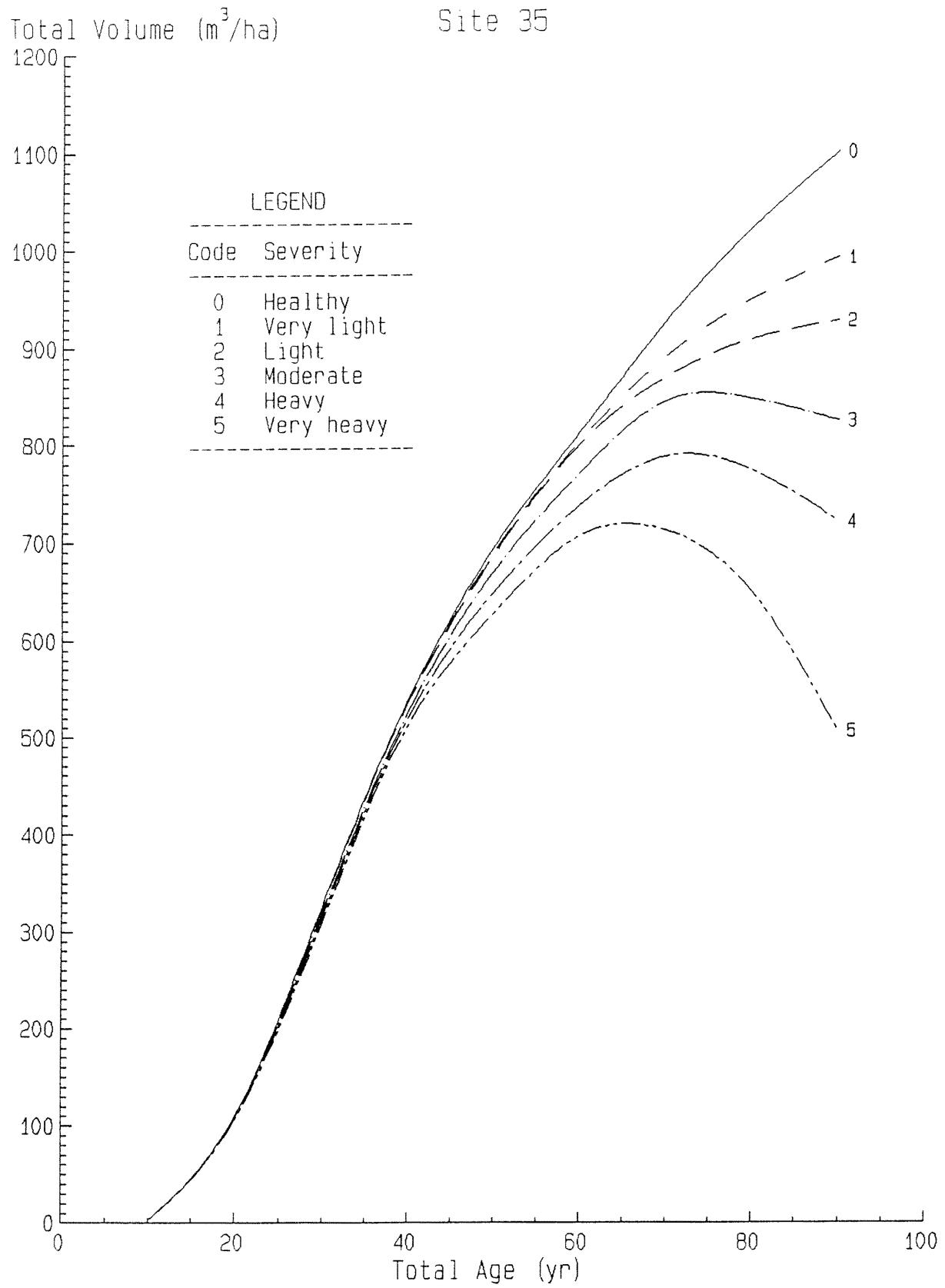


Figure 2.

**Figure 3.**

Preliminary Yield Tables

Site 25

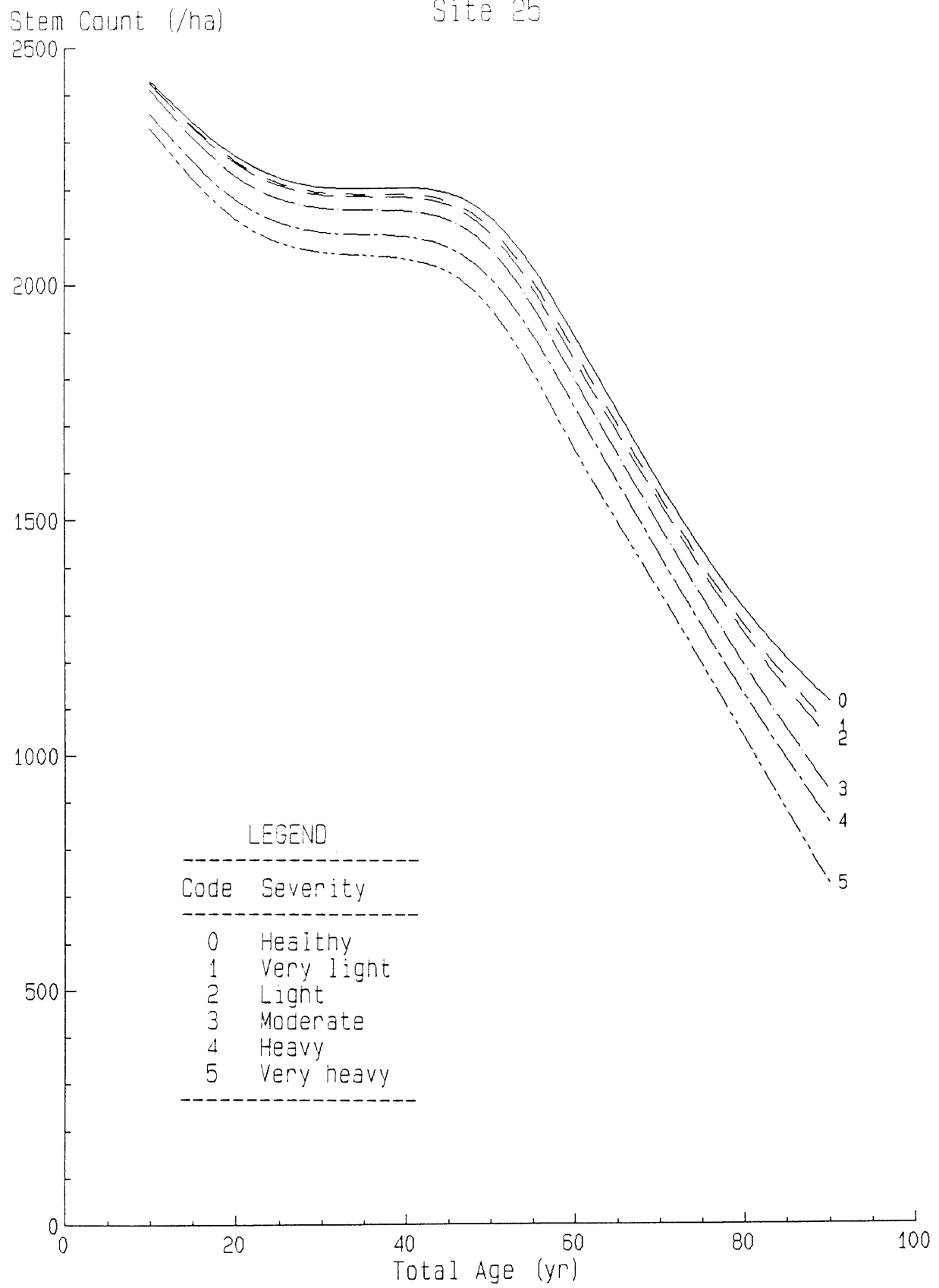


Figure 4.

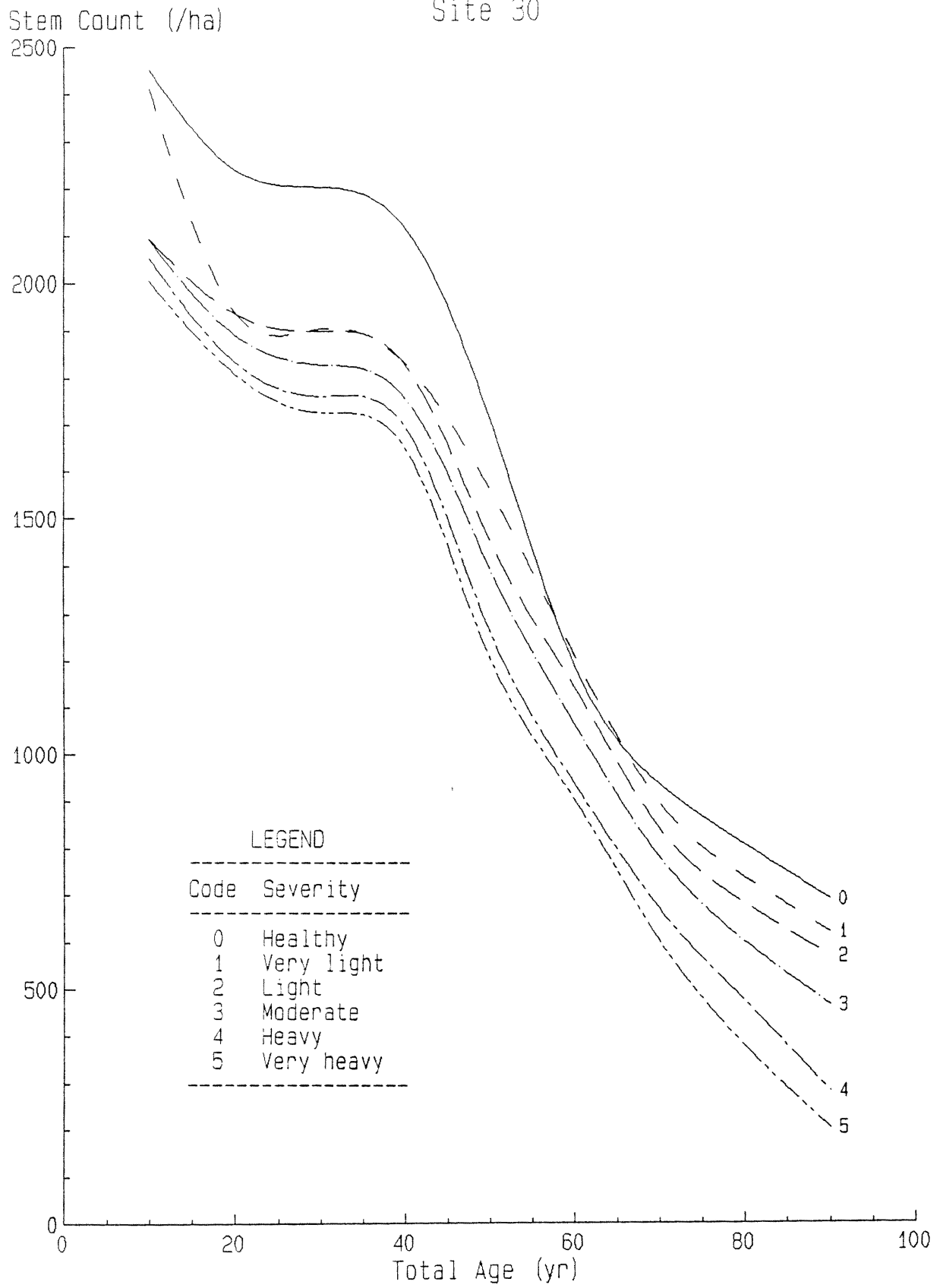


Figure 5.

Preliminary Yield Tables

Site 35

Stem Count (/ha)

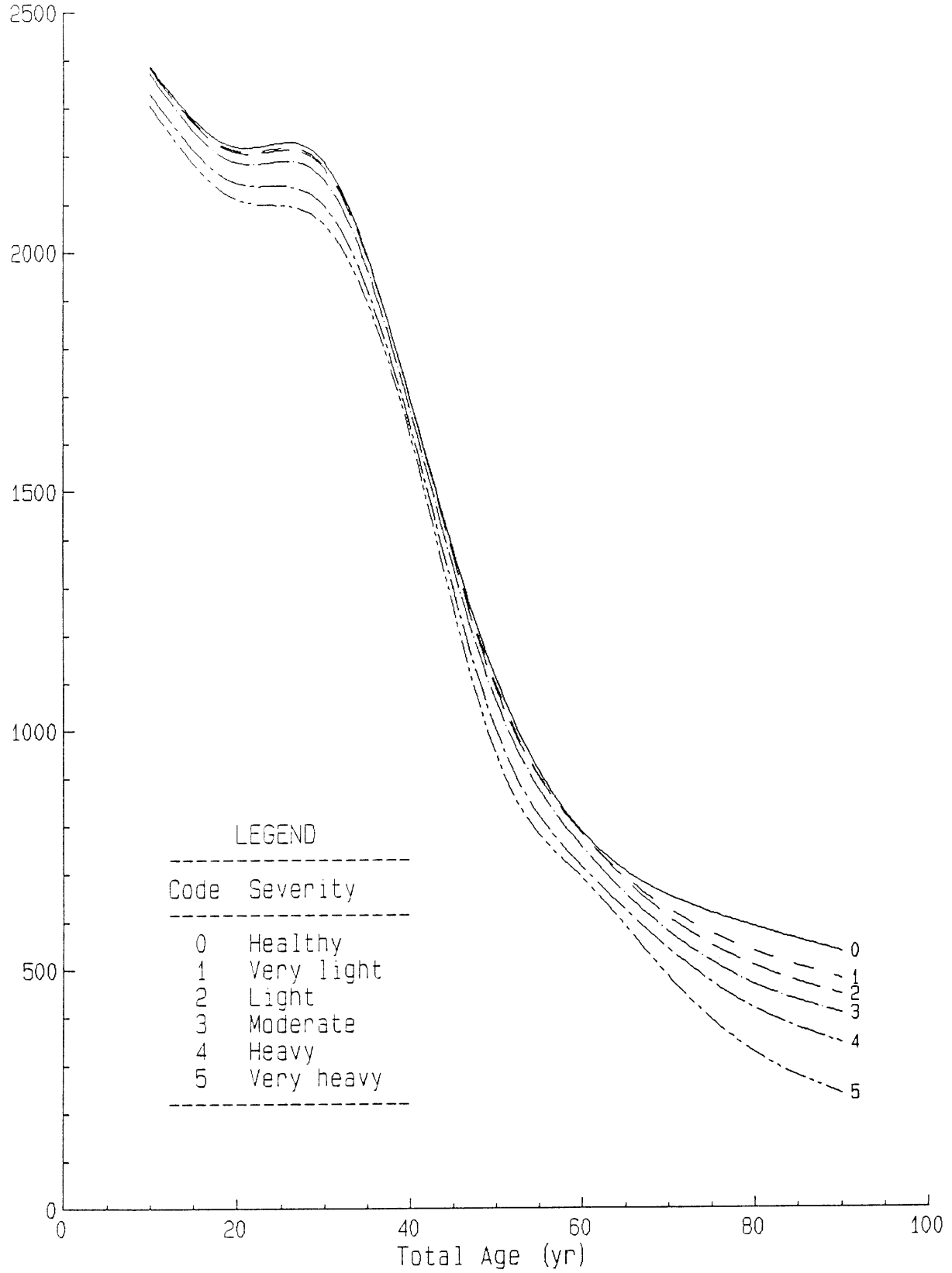


Figure 6.

PRELIMINARY YIELD TABLES FOR COASTAL DOUGLAS—FIR INFECTED WITH RC

Root rot classes: V.L. = very light, L. = light, M. = moderate, H. = heavy, V.H. = very heavy
See explanation of classification method.

SITE INDEX 25 INITIAL STOCKING 500 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	0.0	0.0	0.0	0.0	0.0	492.0	489.2	488.1	485.6	475.4	468.3
20	12.0	12.0	12.0	12.0	11.6	11.4	459.0	455.6	454.2	447.9	438.0	429.0
30	72.0	72.0	72.0	70.3	70.7	70.1	447.0	443.6	442.2	435.9	425.1	415.8
40	172.0	171.1	170.7	166.8	165.9	163.3	447.0	442.9	441.3	434.1	423.4	413.3
50	281.0	279.8	279.3	274.0	272.3	268.5	447.0	442.9	441.3	434.1	423.4	413.3
60	388.0	386.1	385.4	379.3	374.9	369.3	447.0	442.9	441.3	434.1	422.1	411.4
70	486.0	483.5	482.5	475.5	466.3	457.9	447.0	442.9	441.3	434.1	419.0	407.0
80	573.0	569.9	568.6	560.8	546.8	535.5	447.0	442.9	441.3	434.1	417.3	404.5
90	650.0	646.6	645.2	636.0	609.3	591.9	447.0	442.9	441.3	434.1	411.1	395.8

SITE INDEX 25 INITIAL STOCKING 750 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	0.0	0.0	0.0	0.0	0.0	736.0	733.5	732.5	733.5	714.6	705.4
20	17.0	16.7	16.6	15.7	15.7	15.1	688.0	683.3	681.1	683.3	650.9	633.6
30	92.0	91.4	91.1	87.6	87.6	85.8	667.0	662.3	660.3	662.3	629.0	612.0
40	206.0	204.4	203.6	196.0	196.0	191.0	667.0	661.4	658.6	661.4	626.9	607.6
50	329.0	325.6	323.8	311.2	311.2	302.1	667.0	660.1	656.4	660.1	623.6	601.4
60	444.0	438.4	435.0	419.4	419.4	404.6	667.0	657.6	651.8	657.6	619.1	590.8
70	545.0	534.1	526.1	508.1	518.3	488.3	667.0	652.0	641.3	652.0	614.3	576.4
80	634.0	612.4	596.5	569.5	598.0	539.7	664.0	640.3	622.9	640.3	598.3	549.5
90	711.0	670.7	640.9	611.8	666.3	559.4	662.0	621.7	591.3	627.9	606.4	494.5

SITE INDEX 25 INITIAL STOCKING 1000 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	0.0	0.0	0.0	0.0	0.0	950.0	948.4	947.8	938.1	925.9	915.6
20	20.0	20.0	20.0	20.0	19.6	19.4	888.0	881.8	878.5	861.3	843.6	821.8
30	104.0	103.4	103.1	102.3	99.6	97.8	862.0	854.5	850.9	833.6	814.1	791.4
40	223.0	221.8	221.3	220.4	215.6	212.4	861.0	852.3	848.2	831.6	809.1	784.8
50	349.0	346.8	345.9	346.4	338.1	333.4	861.0	851.3	846.9	830.4	806.5	781.0
60	463.0	458.9	457.3	461.3	445.9	438.6	861.0	849.1	843.8	827.8	799.1	770.4
70	563.0	555.2	551.9	556.2	543.1	529.0	855.0	840.6	834.3	818.8	783.4	765.6
80	650.0	635.9	630.1	637.1	618.7	590.6	847.0	827.0	818.4	801.6	761.0	735.8
90	724.0	698.7	688.4	698.8	710.4	657.2	830.0	794.4	778.3	749.6	742.4	691.4

PRELIMINARY YIELD TABLES FOR COASTAL DOUGLAS—FIR INFECTED WITH ROOT

Root rot classes: V.L. = very light, L. = light, M. = moderate, H. = heavy, V.H. = very heavy

See explanation of classification method.

SITE INDEX 25 INITIAL STOCKING 1500 STEMS/HA

AGE	CUBIC METERS PER HECTARE						NO. STEMS PER HECTARE					
	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	0.0	0.0	0.0	0.0	0.0	1461.0	1457.6	1455.8	#####	1422.2	1404.1
20	29.0	28.4	27.9	27.4	26.9	25.3	1364.0	1358.1	1355.3	#####	1309.9	1285.3
30	126.0	125.7	125.6	123.4	122.1	120.4	1325.0	1319.1	1316.3	#####	1267.8	1241.9
40	255.0	255.0	255.2	250.4	248.8	246.9	1323.0	1317.4	1314.9	#####	1266.2	1241.1
50	378.0	378.3	378.8	372.4	369.6	367.4	1323.0	1316.8	1313.7	#####	1260.6	1231.8
60	486.0	485.7	485.6	472.9	472.0	466.0	1305.0	1295.6	1290.9	#####	1226.6	1189.4
70	572.0	572.0	572.0	552.8	553.2	545.1	1241.0	1228.2	1220.1	#####	1150.6	1100.4
80	643.0	641.4	640.6	598.6	604.1	586.8	1169.0	1148.4	1137.1	#####	1031.8	961.5
90	695.0	686.3	682.8	615.4	616.3	582.5	1069.0	1033.7	1019.0	945.7	863.6	773.4

SITE INDEX 25 INITIAL STOCKING 2000 STEMS/HA

AGE	CUBIC METERS PER HECTARE						NO. STEMS PER HECTARE					
	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	0.0	0.0	0.0	0.0	0.0	1970.0	1966.6	1965.2	#####	1919.3	1897.5
20	34.0	34.3	34.6	34.7	33.5	34.0	1841.0	1833.5	1830.1	#####	1767.6	1734.8
30	140.0	139.7	139.6	137.4	135.2	133.1	1788.0	1779.3	1775.4	#####	1708.1	1672.4
40	270.0	269.7	269.6	266.5	263.0	260.0	1784.0	1775.6	1772.0	#####	1704.4	1669.6
50	392.0	392.0	392.2	389.2	382.8	379.5	1756.0	1751.0	1750.1	#####	1678.2	1649.1
60	497.0	497.3	497.6	492.4	483.8	478.9	1675.0	1665.3	1662.0	#####	1578.1	1538.8
70	574.0	575.3	576.1	568.4	548.5	539.0	1464.0	1451.8	1444.9	#####	1345.7	1287.1
80	634.0	630.3	629.5	613.1	574.3	551.5	1252.0	1225.1	1215.7	#####	1065.2	990.1
90	683.0	667.7	661.9	634.5	556.0	503.0	1105.0	1058.4	1038.3	975.1	838.2	718.1

SITE INDEX 25 INITIAL STOCKING 2500 STEMS/HA

AGE	CUBIC METERS PER HECTARE						NO. STEMS PER HECTARE					
	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	0.0	0.0	0.0	0.0	0.0	2431.0	2426.0	2423.8	#####	2361.1	2330.4
20	39.0	39.0	39.0	38.1	38.1	37.8	2272.0	2261.7	2257.0	#####	2181.6	2140.8
30	150.0	149.1	148.7	146.5	143.9	141.3	2206.0	2194.4	2189.3	#####	2110.8	2067.9
40	280.0	278.8	278.3	273.0	271.7	268.1	2203.0	2189.3	2182.8	#####	2100.1	2052.4
50	405.0	401.6	399.8	391.4	390.3	382.5	2141.0	2118.2	2107.2	#####	2011.7	1949.1
60	506.0	502.3	500.6	490.4	485.5	476.0	1888.0	1856.4	1837.3	#####	1737.5	1648.0
70	581.0	577.9	576.6	555.6	552.6	540.4	1576.0	1550.1	1536.3	#####	1424.9	1347.3
80	638.0	629.6	626.0	582.2	579.9	554.3	1308.0	1273.3	1255.9	#####	1126.8	1035.5
90	684.0	667.8	660.9	576.8	579.1	532.8	1111.0	1056.6	1029.8	921.8	854.1	724.8

Preliminary Yield Tables

PRELIMINARY YIELD TABLES FOR COASTAL DOUGLAS—FIR INFECTED WITH ROC

Root rot classes: V.L. = very light, L. = light, M. = moderate, H. = heavy, V.H. = very heavy

See explanation of classification method.

SITE INDEX 30 INITIAL STOCKING 500 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	0.0	0.0	0.0	0.0	0.0	489.0	486.2	485.1	480.1	474.1	467.8
20	24.0	23.7	23.6	24.0	22.3	21.5	455.0	450.9	449.3	443.6	430.9	420.6
30	127.0	126.7	126.9	127.5	122.9	122.6	447.0	442.9	441.3	435.1	423.4	413.3
40	278.0	277.7	278.1	278.3	269.9	268.6	447.0	442.9	441.3	435.1	422.5	412.0
50	438.0	438.0	438.9	438.8	426.8	425.5	447.0	442.9	441.3	435.1	422.1	411.4
60	588.0	582.5	582.9	577.5	564.1	558.6	447.0	438.6	436.2	428.5	414.1	400.1
70	721.0	714.5	714.7	694.0	687.0	677.0	447.0	438.3	435.6	423.9	409.9	393.3
80	838.0	832.6	828.2	786.8	781.4	748.6	447.0	439.1	434.0	417.6	401.3	373.8
90	939.0	936.7	927.9	842.8	836.4	810.2	447.0	440.7	433.5	407.2	395.1	359.1

SITE INDEX 30 INITIAL STOCKING 750 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	2.8	3.9	3.4	7.9	11.3	730.0	728.4	727.8	717.1	711.2	703.1
20	33.0	33.0	33.0	32.5	32.1	31.8	678.0	673.9	671.9	660.0	645.8	630.5
30	158.0	157.4	157.1	153.3	151.4	148.6	667.0	662.3	660.3	648.1	630.3	613.9
40	328.0	326.1	325.4	318.3	314.4	308.6	667.0	662.0	659.8	646.7	629.4	612.6
50	502.0	498.9	497.4	487.4	478.0	467.0	667.0	661.4	658.9	645.9	623.3	603.9
60	657.0	655.7	652.6	641.3	628.9	611.5	667.0	658.6	655.0	640.7	611.4	586.6
70	793.0	785.4	774.7	749.4	729.6	682.8	664.0	648.0	645.0	624.4	585.9	562.0
80	909.0	883.9	856.5	813.3	780.9	673.2	650.0	619.6	613.0	587.6	529.5	486.4
90	####	956.3	907.3	808.4	764.3	563.6	628.0	584.3	582.1	558.1	471.8	429.8

SITE INDEX 30 INITIAL STOCKING 1000 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	0.0	0.0	0.0	0.0	0.0	0.0	942.0	941.1	940.7	929.4	920.1	910.8
20	40.0	39.7	39.6	39.1	38.3	37.5	876.0	871.3	868.9	853.4	839.4	821.6
30	175.0	174.1	173.7	171.9	167.6	164.4	861.0	854.8	851.7	835.1	815.7	794.1
40	355.0	351.9	350.4	347.4	337.1	328.8	861.0	853.8	850.4	833.9	810.9	787.3
50	528.0	523.3	521.3	518.1	498.3	484.9	859.0	849.9	845.6	828.4	796.7	767.1
60	680.0	677.4	672.5	670.4	647.3	624.4	845.0	839.6	832.8	815.0	785.9	749.6
70	798.0	798.7	788.8	784.2	752.9	707.9	816.0	809.1	795.0	766.2	734.7	669.3
80	888.0	883.2	860.7	833.9	792.2	690.2	770.0	755.5	731.1	677.2	639.8	526.6
90	954.0	933.2	894.5	830.5	749.3	563.7	708.0	681.5	647.2	571.2	507.1	341.0

PRELIMINARY YIELD TABLES FOR COASTAL DOUGLAS—FIR INFECTED WITH ROOT ROT

Root rot classes: V.L. = very light, L. = light, M. = moderate, H. = heavy, V.H. = very heavy

See explanation of classification method.

SITE INDEX 30 INITIAL STOCKING 1500 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	1.0	1.0	1.0	1.0	1.0	1.0	1450.0	#####	1444.2	#####	1408.2	1388.1
20	53.0	53.0	53.0	52.5	51.7	51.1	1347.0	#####	1336.8	#####	1290.3	1263.9
30	204.0	203.7	203.6	201.1	197.9	195.3	1323.0	#####	1313.7	#####	1264.1	1236.8
40	382.0	381.7	381.8	377.4	371.9	368.3	1323.0	#####	1313.7	#####	1260.2	1231.1
50	544.0	544.3	544.6	536.2	529.1	523.4	1276.0	#####	1269.1	#####	1209.3	1177.9
60	674.0	647.8	648.2	629.7	618.8	606.7	1175.0	#####	1106.6	#####	1011.9	956.8
70	762.0	746.9	747.5	707.1	700.0	680.5	988.0	949.0	940.7	877.3	840.6	781.8
80	826.0	812.8	810.4	740.5	722.6	680.9	825.0	794.5	782.9	703.1	666.9	593.2
90	878.0	875.8	867.0	748.0	698.1	613.5	719.0	706.3	694.1	597.9	532.4	443.7

SITE INDEX 30 INITIAL STOCKING 2000 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	1.0	1.0	1.0	1.0	1.0	1.0	1955.0	#####	1948.8	#####	1906.2	1883.1
20	62.0	62.0	62.0	61.1	60.3	59.5	1816.0	#####	1804.6	#####	1744.1	1709.8
30	220.0	219.1	218.7	214.8	211.7	208.1	1784.0	#####	1771.4	#####	1705.9	1669.6
40	397.0	396.4	396.5	392.3	386.4	383.3	1761.0	#####	1749.1	#####	1680.7	1644.1
50	549.0	549.0	549.8	542.1	537.4	535.3	1526.0	#####	1513.8	#####	1446.9	1416.6
60	663.0	662.2	661.1	642.8	638.8	631.0	1194.0	#####	1162.9	#####	1077.5	1029.3
70	749.0	759.0	751.0	724.8	717.8	708.7	966.0	958.7	937.4	905.8	851.3	792.2
80	818.0	813.7	810.5	755.8	737.5	705.6	805.0	787.4	777.4	735.6	669.6	601.9
90	878.0	868.6	850.4	800.0	757.6	704.4	702.0	681.6	675.1	602.2	545.5	444.9

SITE INDEX 30 INITIAL STOCKING 2500 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	1.0	1.0	1.0	1.0	1.0	1.0	2450.0	#####	2092.9	#####	2052.8	2005.0
20	70.0	69.7	69.6	68.6	66.9	65.6	2242.0	#####	1936.2	#####	1834.9	1810.0
30	230.0	228.8	228.3	224.0	219.5	215.0	2203.0	#####	1896.9	#####	1760.9	1725.0
40	414.0	408.7	405.4	395.8	387.3	371.5	2114.0	#####	1826.2	#####	1693.6	1648.0
50	567.0	557.0	551.0	530.4	507.7	475.1	1712.0	#####	1453.8	#####	1262.6	1206.0
60	671.0	659.8	652.4	616.3	586.6	539.8	1188.0	#####	1141.3	#####	935.7	902.0
70	757.0	738.6	726.7	668.4	625.5	552.0	934.0	895.1	841.0	780.0	669.8	602.0
80	833.0	791.8	766.1	679.7	606.4	474.3	806.0	735.5	679.9	600.1	472.9	377.0
90	889.0	809.9	760.5	627.4	529.2	307.1	689.0	620.7	569.0	463.7	280.4	203.0

PRELIMINARY YIELD TABLES FOR COASTAL DOUGLAS—FIR INFECTED WITH ROO

Root rot classes: V.L. = very light, L. = light, M. = moderate, H. = heavy, V.H. = very heavy

See explanation of classification method.

SITE INDEX 35 INITIAL STOCKING 500 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	1.00	1.00	1.00	1.00	1.00	1.00	484.0	482.1	481.4	478.8	470.0	464.0
20	43.0	42.7	42.6	41.3	40.8	39.9	450.0	446.6	445.2	437.9	428.6	419.4
30	203.0	201.4	200.8	197.8	194.3	190.5	445.0	442.2	441.1	434.6	424.9	416.3
40	417.0	414.8	413.9	410.0	402.1	395.8	445.0	442.2	441.1	434.6	423.6	414.4
50	634.0	630.9	629.6	623.5	611.3	601.5	445.0	441.6	440.2	433.4	420.5	410.0
60	831.0	827.6	826.2	801.3	796.0	781.0	445.0	441.6	440.2	428.4	416.6	404.4
70	984.0	986.5	987.5	947.3	950.3	935.9	445.0	441.6	440.2	422.4	410.4	395.6
80	1106.0	1115.4	1119.1	1055.3	1078.9	1067.3	444.0	439.6	437.9	412.8	399.4	380.3
90	1205.0	1222.2	1229.1	1093.9	1178.8	1167.5	439.0	434.6	432.9	393.3	386.5	364.0

SITE INDEX 35 INITIAL STOCKING 750 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	1.0	1.0	1.0	1.0	1.0	1.0	723.0	722.7	722.6	719.6	708.1	701.8
20	58.0	57.7	57.6	56.3	54.9	53.6	672.0	668.9	667.3	660.6	642.8	628.9
30	241.0	240.1	239.7	234.9	231.4	227.3	667.0	663.3	661.6	653.7	634.7	620.1
40	475.0	471.9	470.4	460.3	454.1	444.4	667.0	662.9	661.1	651.8	633.8	618.9
50	692.0	687.6	685.9	664.0	660.1	646.4	666.0	656.9	652.0	636.4	616.1	589.8
60	864.0	862.1	863.1	821.2	834.6	828.4	652.0	635.8	626.6	596.1	582.0	542.0
70	995.0	981.3	975.2	919.1	929.3	923.3	614.0	585.3	567.0	540.5	521.6	478.1
80	1102.0	1055.1	1025.9	946.8	951.5	915.6	583.0	528.9	493.4	456.9	428.7	350.6
90	1178.0	1081.8	1016.3	878.3	903.5	721.5	542.0	468.6	418.8	370.9	342.1	179.7

SITE INDEX 35 INITIAL STOCKING 1000 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	1.0	1.0	1.0	1.0	1.0	1.0	933.0	932.1	931.7	926.9	915.1	907.4
20	67.0	67.0	67.0	65.3	65.7	65.1	867.0	864.5	862.9	853.6	837.0	822.0
30	262.0	260.8	260.3	256.8	252.8	248.9	861.0	856.6	854.3	843.8	821.4	802.3
40	495.0	491.6	490.2	485.4	476.2	468.1	861.0	854.8	851.7	839.1	814.4	792.3
50	714.0	704.6	699.4	677.0	668.1	642.8	841.0	827.6	819.2	793.9	768.1	725.4
60	880.0	863.1	851.9	800.5	798.4	746.3	770.0	750.6	738.2	693.9	670.5	610.0
70	991.0	956.3	931.9	874.1	875.9	793.8	666.0	635.1	615.9	586.0	556.0	489.9
80	1078.0	1010.5	965.5	879.6	854.8	727.3	592.0	547.6	519.0	482.4	442.9	366.3
90	1149.0	1031.5	955.3	811.3	774.1	537.0	530.0	472.8	435.9	390.3	347.2	231.6

Preliminary Yield Tables

PRELIMINARY YIELD TABLES FOR COASTAL DOUGLAS—FIR INFECTED WITH ROOT

Root rot classes: V.L. = very light, L. = light, M. = moderate, H. = heavy, V.H. = very heavy
See explanation of classification method.

SITE INDEX 35 INITIAL STOCKING 1500 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	2.0	2.0	2.0	2.0	2.0	2.0	1434.0	1431.2	1429.9	1422.8	#####	#####
20	86.0	86.3	86.6	85.8	84.6	84.8	1333.0	1327.4	1324.8	1308.1	#####	#####
30	296.0	294.4	293.8	289.9	284.6	279.8	1323.0	1318.0	1315.8	1295.7	#####	#####
40	520.0	518.4	518.0	509.3	502.4	495.6	1288.0	1283.0	1282.1	1262.4	#####	#####
50	699.0	701.2	702.3	686.6	675.8	666.5	1066.0	1075.1	1082.4	1067.1	#####	#####
60	824.0	828.1	829.3	792.9	783.4	764.6	826.0	818.5	816.4	790.1	732.9	696.6
70	922.0	923.6	921.2	839.4	868.7	834.2	676.0	660.4	651.9	632.4	589.4	540.6
80	1006.0	999.8	989.8	840.2	899.8	839.7	581.0	555.7	539.2	508.8	468.2	401.6
90	1075.0	1044.1	1018.2	798.2	861.1	749.1	514.0	480.3	459.1	423.1	376.9	300.7

SITE INDEX 35 INITIAL STOCKING 2000 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	3.0	2.7	2.6	2.1	1.7	1.1	1936.0	1931.9	1929.9	1919.5	#####	#####
20	100.0	99.7	99.6	98.3	96.1	94.4	1797.0	1790.1	1786.4	1769.2	#####	#####
30	312.0	310.8	310.3	306.8	301.5	297.0	1781.0	1772.3	1768.2	1747.1	#####	#####
40	530.0	528.8	528.4	522.8	517.3	512.5	1581.0	1578.8	1580.4	1551.9	#####	#####
50	692.0	688.6	686.3	671.9	666.9	652.6	1111.0	1090.1	1079.6	1044.9	#####	961.6
60	809.0	806.5	804.4	780.4	767.4	745.3	769.0	756.2	753.1	732.6	674.3	641.5
70	916.0	902.3	892.3	804.1	819.5	791.4	630.0	602.5	587.4	541.6	495.3	455.6
80	1002.0	957.9	929.8	795.5	795.9	717.7	533.0	499.6	479.1	422.5	387.1	342.0
90	1084.0	1005.9	955.5	775.9	769.3	628.9	486.0	446.0	420.6	358.9	325.1	273.3

SITE INDEX 35 INITIAL STOCKING 2500 STEMS/HA

CUBIC METERS PER HECTARE							NO. STEMS PER HECTARE					
AGE	NIL	V.L.	L.	M.	H.	V.H.	NIL	V.L.	L.	M.	H.	V.H.
10	3.0	3.0	3.0	3.0	3.0	3.0	2389.0	2385.3	2383.6	2373.2	#####	#####
20	109.0	109.0	109.2	107.9	106.3	105.9	2219.0	2211.2	2207.5	2186.7	#####	#####
30	324.0	322.4	321.8	317.0	312.6	307.8	2189.0	2179.3	2175.3	2151.6	#####	#####
40	537.0	534.8	534.1	524.6	518.6	511.4	1695.0	1694.7	1695.5	1672.2	#####	#####
50	695.0	690.0	687.4	671.1	650.1	628.8	1111.0	1095.7	1088.1	1064.1	#####	952.3
60	814.0	804.9	801.7	771.6	738.6	707.8	789.0	784.6	784.9	757.7	716.6	693.4
70	928.0	892.4	871.8	846.9	789.5	713.4	656.0	626.9	610.6	579.6	543.5	485.5
80	1024.0	951.8	910.8	849.7	775.3	651.7	589.0	536.5	506.5	468.1	417.8	326.0
90	1103.0	994.6	929.8	827.1	722.6	507.7	536.0	479.8	446.9	407.2	345.6	240.6

The Preliminary Yield Tables reproduced above are also available as Microsoft Excel Worksheets:

- [TASS-01-00046.xls](#)
- [TASS-01-00047.xls](#)
- [TASS-01-00048.xls](#)
- [TASS-01-00049.xls](#)
- [TASS-01-00050.xls](#)
- [TASS-01-00051.xls](#)

**PATHOGRAMS (DISEASE CENTER DISTRIBUTION MAPS) OF PHELLINUS ROOT ROT BY
DISEASE CLASSIFICATION (DERIVED FROM SIMULATIONS WITH RREST)**

Each letter represents a separate infection center.

Asterisks represent the mortality area within centers.

As center become larger they coalesce to form even larger centers .

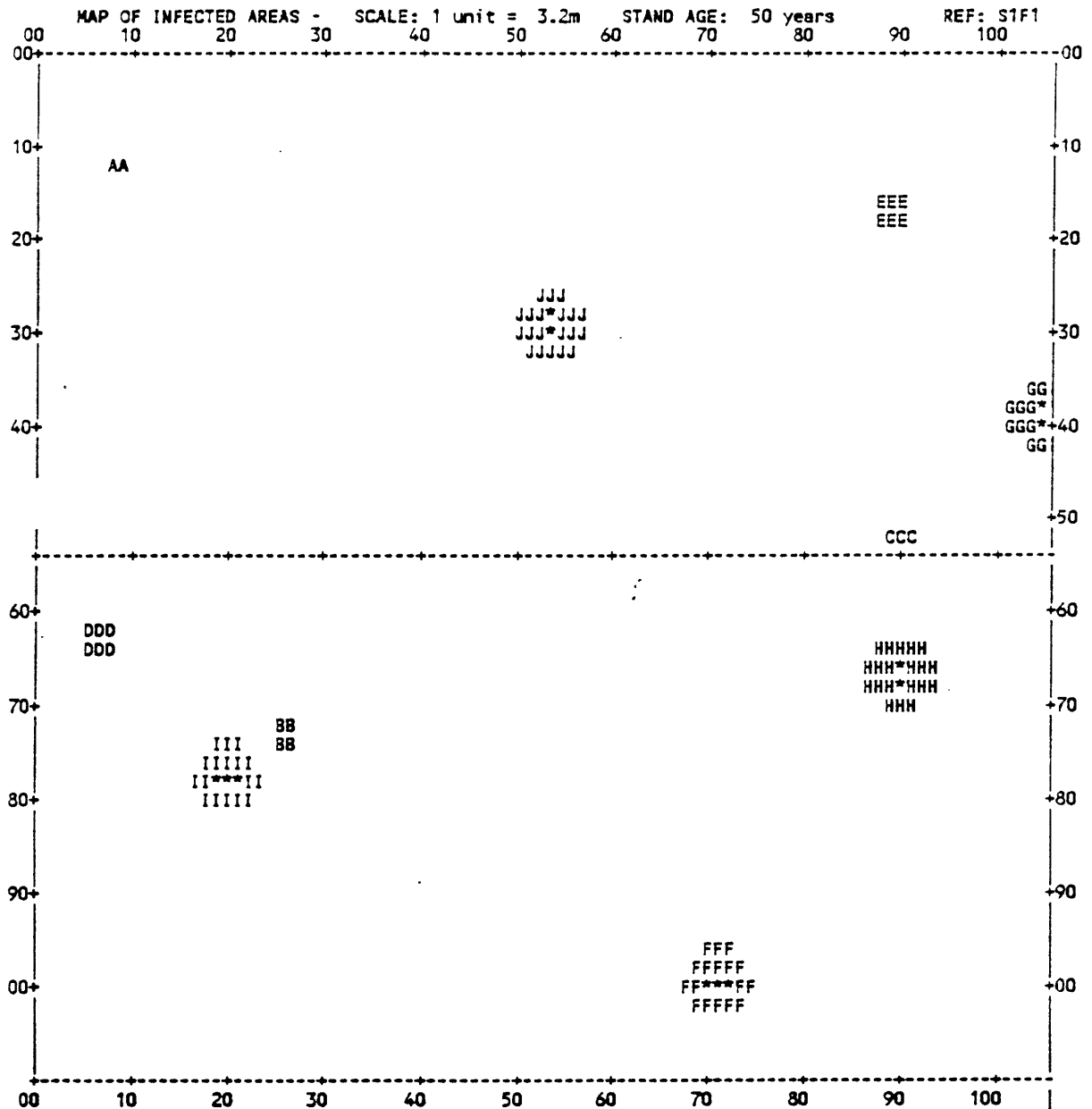
PATHOGRAM OF PHELLINUS ROOT ROT

Severity Class V. LIGHT

Frequency Class 1 (≤ 1.0 centers/ha)

Stand Area = 10 ha

Stand Age = 50 yr



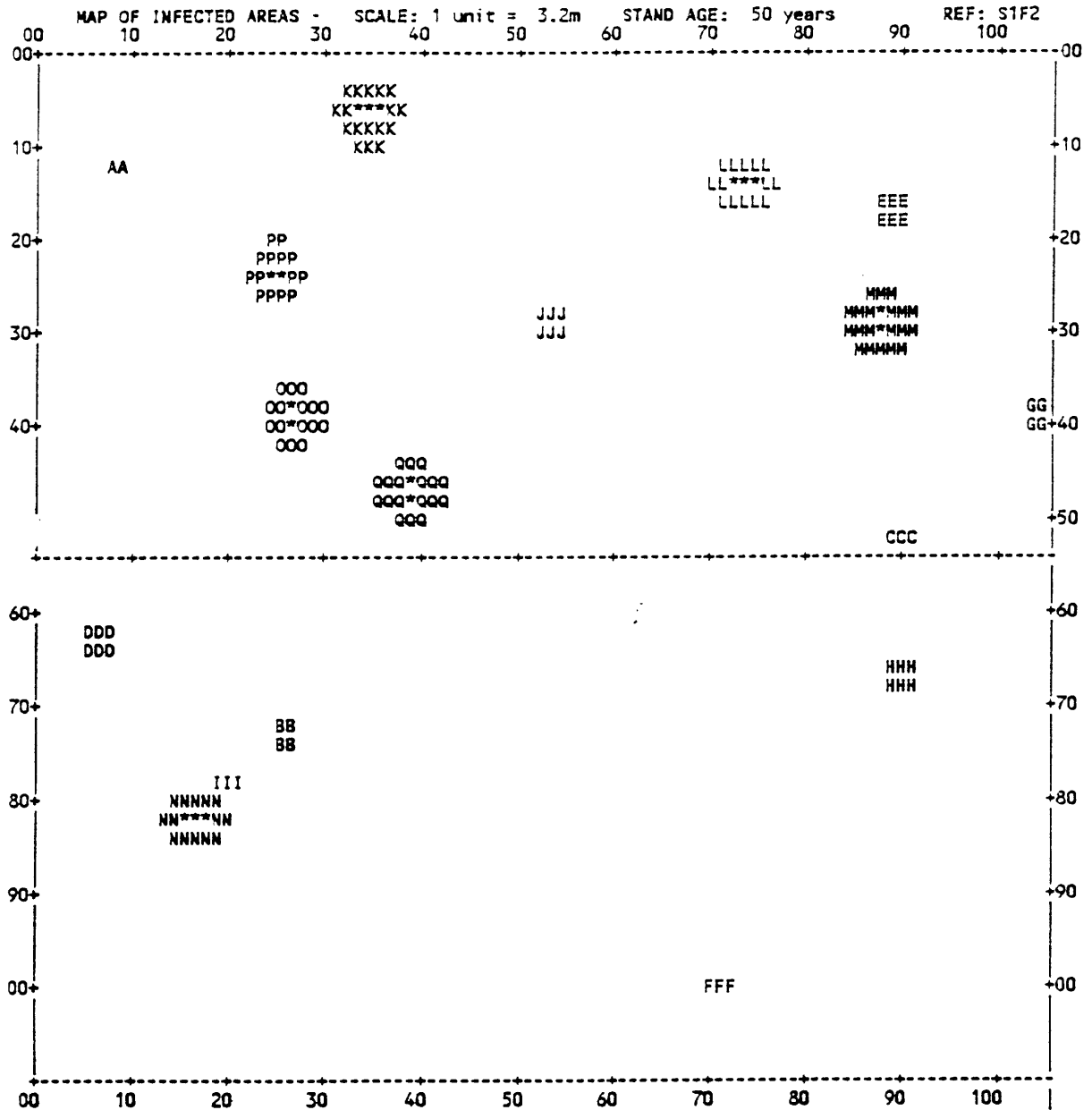
PATHOGRAM OF PHELLINUS ROOT ROT

Severity Class LIGHT

Frequency Class 2 ($\geq 1.0 > 4.0$ centers/ha)

Stand Area = 10 ha

Stand Age = 50 yr



PATHOGRAM OF PHELLINUS ROOT ROT

Severity Class MODERATE

Frequency Class 1 ($\geq 1.0 > 4.0$ centers/ha)

Stand Area = 10 ha

Stand Age = 50 yr

