United States
Department of
Agriculture

Forest Service

Pacific Northwest
Forest and Range
Experiment Station

General Technical
Report
PNW-131
July 1981

Fuels and Fire in Land-Management Planning: Part 1. Forest-Fuel Classification

Wayne **G.** Maxwell and Franklin R. Ward

Authors

WAYNE G. MAXWELL is forester (retired) and FRANKLIN R. WARD is forest technician, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Abstract

Maxwell, Wayne G.; Ward, Franklin R. Fuels and fire in land-management planning. Part 1. Forest-fuel classification. Gen. Tech. Rep. PNW-131. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 12 p.

This report describes a way to collect and classify the total fuel complex within a planning area. The information can be used as input for appraising and rating probable fire behavior and calculating expected costs and losses from various land uses and management alternatives, reported separately as Part 2 and Part 3 of this series. This total package can be used locally for fire management and as input to the land-management planning process.

Keywords: Fuels inventory, land management, management planning (forest).

Introduction

Land-management planning includes studying various use patterns and management intensities and alternatives. The alternatives should include fuels and fire-hazard potential because these potentials are affected by decisions made in the planning process. The effects can either enhance or hinder the achievement of the management-planning goals.

Questions to be answered for alternative proposals are:

- What is the expected cost of fire protection?
- What is the expected cost of fuel-treatment?
- What is the expected cost of wildfire suppression and the value of the damage?

Fire specialists need the following information to supply reasonable answers:

- A classification of fuel complexes in the planning area.
- Cost of fire protection associated with each fuel complex.
- Cost of fuel treatments associated with current management practices.
- Suppression costs and damage values for current wildfire losses.
- Acres usually damaged by wildfire under the existing fuel pattern.

This report describes a practical way to classify the total fuel complex. The objective for developing a fuel classification system was to collect on-site fuel information from total drainage areas. We recognized in the planning stage the need to describe all fuel components; the need to link fuel types to land and vegetative types; and the need for a technique that can be duplicated by technicians in field units.

A systematic means of appraising and rating probable fire behavior for local fuel conditions (Part 2) and procedures for projecting fire behavior ratings and calculating expected costs and losses from various land uses and management alternatives (Part **3)** are presented in independent reports.

The Pacific Northwest Forest and Range Experiment Station, in cooperation with the Pacific Northwest Region of the USDA Forest Service and the Siskiyou National Forest, initiated the Cal-Ore Pilot Test to develop the techniques and procedures for meeting these needs. The study was on 35,000 acres in the Illinois Valley Ranger District, Siskiyou National Forest.

How Were Fuel Types Delineated?

Availability of fuel is relatively consistent within a vegetative-type island of uniform age and stocking. Reliable maps of vegetative types or timber stands in planning units are thus necessary for fuel typing. Maps of vegetative types in the pilot-test area were neither current nor dependable, so our first step was to compile a fuel-type map.

The initial type lines were established on a 1-to-12,000 scale, black and white aerial photographs by delineating timber-cutting areas and delineating areas of differing tree size, stocking, or species.

Type lines on the photographs were verified or corrected in the field. For example, type lines were occasionally removed where a sharp change in aspect—such as a canyon bottom or sharp ridge top—appeared to be a type change. Points were viewed through binoculars along travel routes to verify or correct type lines in remote areas. Type islands were numbered on the photographs for matching of collected inventory data.

The minimum sizes of fuel-type islands recognized in the study were 20 acres for cutting areas and 200 acres for natural areas. Smaller islands were included with the most similar adjacent type.

After all type lines were verified or corrected, they were transferred to a 2-inch to 1-mile planimetric map overlay (fig. 1).

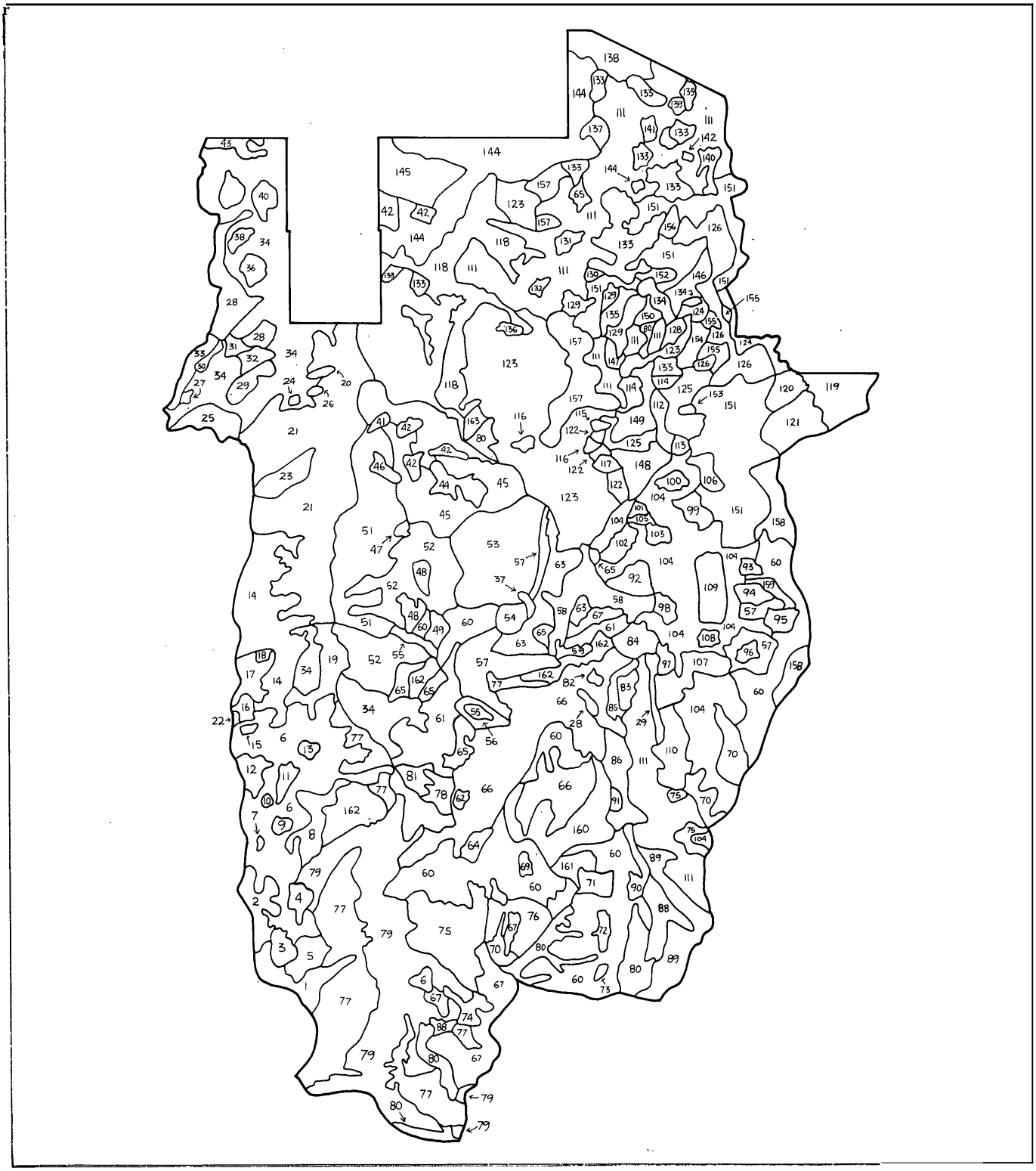


Figure 1.—Fuel-type overlay, Cal-Ore pilot-test area.

What information Was Collected and Why?

All live vegetation and dead residue may contribute to the available fuel complex. The species, quantity, and horizontal and vertical distribution of the fuel components influence fire behavior and manipulation of fuel. Our inventory was therefore designed to collect basic information on the following fuel components:

- Overstory trees (species dominance, percent crown cover, average stand height, and average crown height).
- Snags (average number of snags per acre).
- Understory trees (species dominance, percent crown cover, average stand height, and average crown height).
- Brush (species dominance, average height, and percent ground space occupied).
- Grass and forbs (species dominance and percent ground space occupied).
- Dead-and-downwoody fuel (tons per acre by size classes, average fuel depth, and percent material over 3 inches in diameter).
- Duff and litter (average depth and percent ground space occupied).

Although modern technology for assessing expected fire behavior is not sensitive to all these variables, the information helps make subjective judgments about fire crowning and spotting and in calculating difficulty of control. This information also allows linking fuel types to ecotype and to other resource types to aid in formulating land-management plans.

The form used to collect information for classifying a fuel-type island and instructions for collecting the information are shown in figure 2.

How Was Information Collected?

Guided by the aerial photos and preliminary fuel-type map, the surveyor entered the type to be classified and traveled a couple of hundred yards into the type, observing the size, quantity, and distribution of various plant species and dead residues. Selecting a point judged to be typical of the type, the surveyor stopped and recorded observations, estimates, and measurements on the classification form (fig. 2).

"Management Status" was indicated by one of the following abbreviations: U, undisturbed; PC, partial cut; C, clearcut; or PCT, precommercial thin.

If timber had been cut or a culture activity had taken place, the abbreviation was succeeded by a slash-status abbreviation: RS, red slash; OS, old slash; PB, piled-and-burned; BB, broadcast-burned; or SB, spot-burned.

For example, if the type had no obvious cutting, the management status would be "undisturbed" (U). With a partial cutting several years before and with no obvious treatment, the management status would be "partial cutting, old slash" (PC-OS).

The form provides spaces for four independent sampling locations. The number of sampling locations per type in the pilot test area was determined as follows:

Sizes	Sample locations
Acres	Number
less than 100	1
100–249	2
250–399	3
400 or more	4

When more than one sample was taken in a type, sampling was widely spread to account for transitional differences within the type.

Where appropriate, data for multisampled types were summed and averaged to represent the type as a whole. One way to estimate percentage of ground area covered is to use a photo series as a comparative guide (Maxwell and Ward 1980).

Completed forms for several different fuel situations in the pilot test area are shown in figures 3, 4, and 5.

TOTAL FUEL INVENTORY TALLY SHEET

natp_____ Estimator_____ Area **Identification** _____

Management Status _____ Ecotype or vegetation type_____

Bio Level	Item (Elevation)	Sample 1	2	3	4	Summary estimate
Overstory	Species dominance	OBSERVATION - Most abundant first, then secondary if present.				
	Crown density (%)	ESTIMATE - Overstory crown space occupied - nearest 10 percent.				
	Av. stand ht. (ft.)	MEASURE - With Abney, several typical trees, avg. to nearest 10 feet.				
	Av. crown ht. (ft.)	MEASURE - With Abney, same trees as above, avg. to nearest 5 feet.				
	Basal area	ESTIMATE OR MEASURE - With prism at least 5 plots and avg.				
	Av. stems/acre	ESTIMATE - Count stems in estimated acre area.				
	Av. DBH	MEASURE - At least 5 trees and calculate the avg.				
Dead Stndg	Snags	ESTIMATE - COUTit snags in estimated acre area.				
Understory	Species dominance	OBSERVATION - Most .abundant first, then secondary if present.				
	Crown density (%)	ESTIMATE - Understory crown space occupied - nearest 10 percent.				
	Basal area	ESTIMATE OR MEASURE - With prism at least 5 plots and avg.				
	Av. stand ht. (ft.) •	MEASURE - With Abney, several typical trees, avg. to nearest 5 ft.				
	Crown height (ft.)	MEASURE - With Abney, same trees as above, avg. to nearest 1 ft.				
Brush	Species dominance	OBSERVATION - Most abundant first, then secondary if present.				
	Av. height (ft.)	ESTIMATE - Judge relative to your height to nearest 1 ft.				
	Crown density (%)	ESTIMATE - Portion of total ground area covered by crowns, nearest 10				
Grass Herb	Species dominance	OBSERVATION - *I*lost abundant first, then secondary if preseiit.				
	Grnd. space occup. (%)	ESTIMATE - Por1:ion of total ground area covered - nearest 10%.				
Woody dead-down	0 - 1/4 inch	ESTIMATE - Using natural and activity photo series, make				
	% - 1 inch	" comparative estimates of loading in each size class,				
	1 - 3 inches	" following instructions for this procedure in the Photo				
	3 - 9 inches	" Series publications.				
	9 - 20 inches	" Since activity photo series do not include 0 to l_4'-in				
	20+ inches	" material, estimate *h* to 1-in material and use 75% of				
	Av. depth	" this amount for the 0 to %-in tonnage estimate.				
	Percent ground covered	" - Portion of total ground area covered-nearest 10 percent.				
	Percent sound o^ 3 inches	" - Kick various sizes of large material-nearest 10 percent.				
Duff Litter	Av. depth (in.)	ESTIMATE - Kick through layer in several locations - average.				
	Percent ground covered	" - Portion of total ground area covered-nearest 10%.				

Figure 2.—Total fuel field-inventory form with instructions on how to collect information.

TOTAL FUEL INVENTORY TALLY SHEET

Date 8/17/76 Estimator RYAN-MAXWELL Area Identification CAL-ORE 42-

Management Status CLEARCUT - BROADCAST BURN Ecotype or vegetation type HARDWOOD

Bio Level	Item	Sample 1	2	3	4	Summary estimate
	(Elevation)	2100				2100
Overstory	Species dominance	TANOAK				TANOAK
	Crown density (%)	80				80
	Av. stand ht. (ft.)	30				30
	Av. crown ht. (ft.)	5				5
	Basal area	—				—
	Av. stems/acre	—				—
	Av. DBH	5				5
Dead Stndg	Snags	0				0
Understory	Species dominance	TANOAK-MADRONE				TANOAK-MADRONE
	Crown density (%)	30				30
	Basal area	—				—
	Av. stand ht. (ft.)	10				10
	Crown height (ft.)	2				2
Brush	Species dominance	TANOAK-MADRONE				TANOAK-MADRONE
	Av. height (ft.)	5				5
	Crown density (%)	20				20
Grass Herb	Species dominance	BRACKEN FERN				
	Grnd. space occup. (%)	10				10
Woody dead-down	0 - ¼ inch	0.3				**0.3**
	¼ - 1 inch	1.5				1.5
	1 - 3 inches	1.**0**				1.**0**
	3 - 9 inches	4.0				4.0
	9 - 20 inches	8.0				8.0
	20+ inches	12.0				12.0
	Av. depth	0.4				0.4
						40
	Percent sound over 3 inches	**50**				50
Duff Litter	Av. depth (in.)	**0.2**				0.2
	Percent ground covered	50				50

Figure 3.—Completed inventory form for fuel-type island 42.

TOTAL FUEL INVENTORY TALLY SHEET

Date 8 19 76 Estimator KRAEMER-LOUR Area Identification CAL.-ORE. 60

Management Status UNCUT Ecotype or vegetation type MIXED CONIFER

Bio Level	Item	Sample 1	Sample 2	Sample 3	Sample 4	Summary estimate
	(Elevation)	4,700	4,480	5,000	4,650	4,700
Overstory	Species dominance	SP-NF	DF-SP	WF-SP	DF-WF	D.F.-TRUE FIR WP-SP
	Crown density (%)	40	30	20	60	38
	Av. stand ht. (ft.)	73	98	85	60	**79**
	Av. crown ht. (ft.)	38	27	17	4	22
	Basal area	200	200	80	80	170
	Av. stems/acre	23	**47**	25	75	**43**
	Av. DBH	40	28	24	14	27
Dead Stndg	Snags	1	2	2	0	1
Understory	Species dominance	DF-SP	WF-NF	IC-WF	—	LIVE OAK CHINKAPIN
	Crown density (%)	**30**	25	15	—	23
	Basal area	75	130	25	—	77
	Av. stand ht. (ft.)	38	49	45	—	44
	Crown height (ft.)	2	**4**	2	—	**3**
Brush	Species dominance	LIVE OAK	LIVE OAK	L.OAK-CHINK	L.OAK-CHINK	TRUE FIR BS-UP.
	Av. height (ft.)	1.0	1.0	3.0	4.5	2.4
	Crown density (%)	10	45	50	**30**	34
Grass Herb	Species dominance	—	—	—	—	—
	Grnd. space occup. (%)	—	—	—	—	—
Woody dead-down	0 - ¼ inch	1.5	1.0	1.5	1.1	1.3
	¼ - 1 inch	2.0	1.4	2.0	1.5	1.7
	1 - 3 inches	1.8	1.7	1.7	2.0	1.8
	3 - 9 inches	3.5	2.5	2.0	1.0	**2.3**
	9 - 20 inches	9.0	5.0	8.0	—	7.3
	20+ inches	4.0	12.0	6.0	—	7.3
	Av. depth	0.1	0.1	0.2	0.6	0.3
	Percent ground covered	65	60	80	100	76
	Percent sound over 3 inches	20	50	10	100	45
Duff Litter	Av. depth (in.)	0.1	0.2	1.2	1.0	0.6
	Percent ground covered	90	60	80	100	**83**

Figure 4.—Completed inventory form for fuel-type island 60.

TOTAL FUEL INVENTORY TALLY SHEET

Date 8/20/76 Estimator KRAEMER Area Identification CAL-ORE 76

Management Status UNCUT Ecotype or vegetation type DF 4E

Bio Level	Item	Sample 1	Sample 2	Sample 3	Sample 4	Summary estimate
	(Elevation)	5100	5400			5250
Overstory	Species dominance	DF-PO	DF-WF			DF-WF-PO
	Crown density (%)	70	80			75
	Av. stand ht. (ft.)	100	110			105
	Av. crown ht. (ft.)	42	37			39
	Basal area	640	460			550
	Av. stems/acre	66	65			66
	Av. DBH	42	36			39
Dead Stndg	Snags	2	2			2
Understory	Species dominance	—	WF			WF
	Crown density (%)	—	15			7.5
	Basal area	—				
	Av. stand ht. (ft.)	—	25			25
	Crown height (ft.)	—	3			3
Brush	Species dominance	—	ORE. GRAPE			ORE. GRAPE
	Av. height (ft.)	—	.5			.5
	Crown density (%)	—	5			2.5
Grass Herb	Species dominance	—	—			—
	Grnd. space occup. (%)	—	—			—
Woody dead-down	0 - ¼ inch	1.7	1.9			1.9
	¼ - 1 inch	3.0	3.2			3.1
	1 - 3 inches	3.0	2.5			2.8
	3 - 9 inches	2.5	3.4			2.9
	9 - 20 inches	10.	4.0			7.0
	20+ inches	10.	10.			10.0
	Av. depth	.3"	.3"			.3
	Percent ground covered	45	90			92.5
	Percent sound over 3 inches	15	10			12.5
Duff Litter	Av. depth (in.)	1.5	1.4			1.45
	Percent ground covered	90	100			95

Figure 5.—Completed inventory form for fuel-type island 76.

How Was Information Displayed?

Information from the average column of the inventory form was used to construct a profile of the fuel conditions. Information about the vertical (height or depth) and horizontal (crown cover or ground cover) characteristics of the various fuel components were plotted to construct a profile of total fuel. Dead-and-down woody fuel was graphed by size classes to provide a detailed profile of this critical fuel component. Information about dominant species of the various live fuel components, soundness of larger dead-and-down woody fuels, fuel homogeneity, and frequency of snags were recorded in the blocks on the right side of the form.

Completed profiles made from field data in figures 3, 4, and 5, are shown in figures 6, 7, and 8.

How Can Information Be Extended?

Classifying each type-island in an entire planning area would be desirable, but constraints of time and staff may not permit such an extensive effort. **All** similar types within the study area can be grouped; then, a sample of each group can be taken and each type within the sample group can be classified. Averages of each information category can then represent the group. For example, if 40 clearcuts are in the area, 10 could be sampled and the averages used for classifying all 40. Field work for such an inventory could usually be completed by an experienced fuel-management specialist in one field season. The time to accomplish our work on the pilot-test area was:

Delineation of fuel types	2 person-weeks
Ground check of fuel types	1 person-week
Inventory of fuel complex	4 person-months
Display of information	1 person-month

How Can the Information Be Used?

Fuel profiles provided the data for fuel appraisals (Part 2 of this series). The fire-behavior values resulting from the appraisals were then rated and used to produce a relatively high-resolution fire-behavior map. This map was basic information used in calculating costs and losses for management options in land-management planning (Part 3).

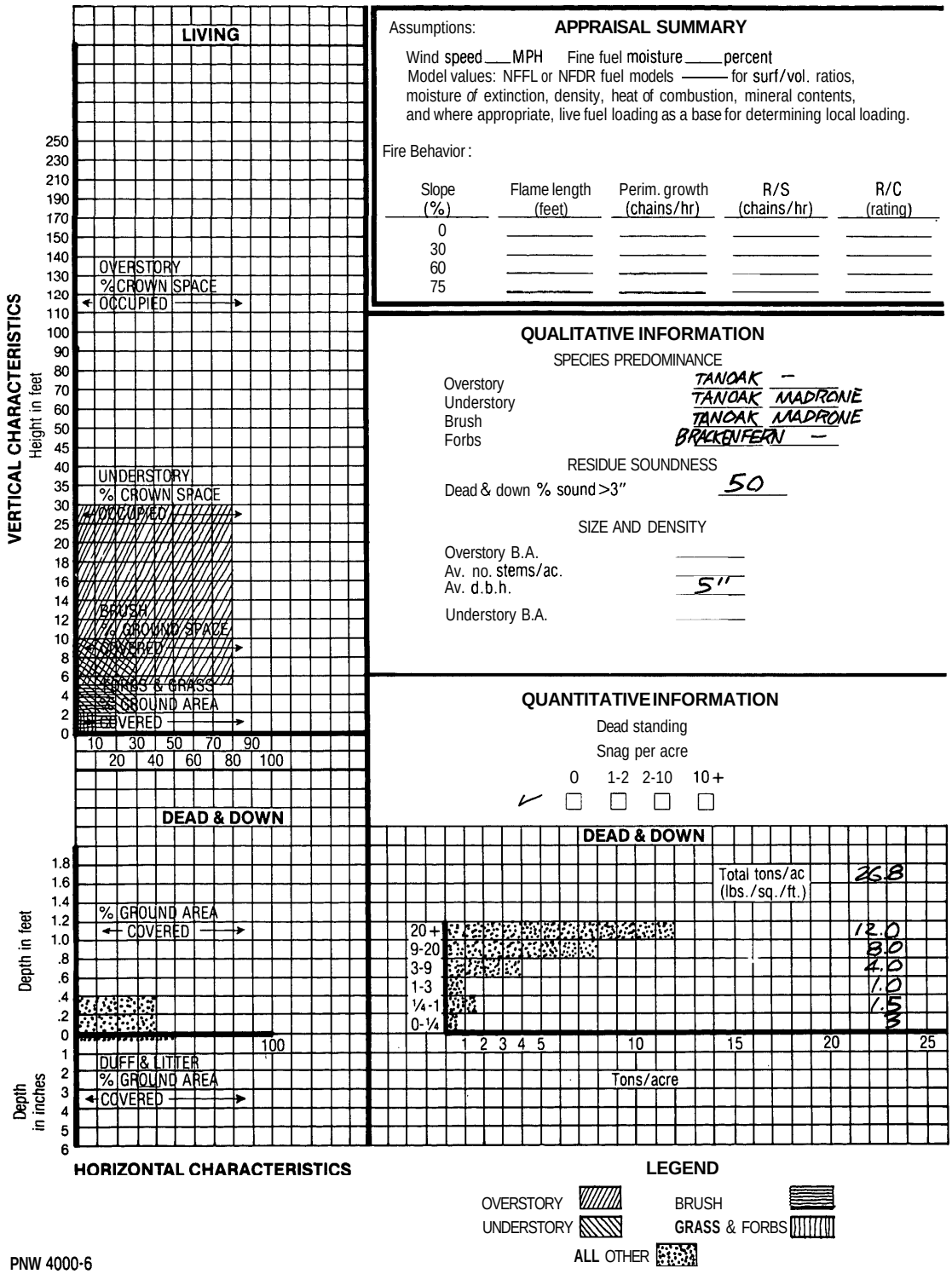
The profiles, complete with fuel appraisal information for on-site fuel types in the management unit, provide information to aid in day-to-day forest-management actions, such as:

- Deployment of forces for protection.
- Dispatch of resources for suppression.
- Setting priorities for fuel-treatment areas.
- Determination of potentials for fuel-treatment.
- Identification of fuel backlogs.
- Smoke-management reporting.
- Evaluations of wildfire behavior and damage assessments.
- Determination of potential energy in residues.
- Relating ecotype to fuel types and biomass.
- Multidisciplinary considerations of vegetation and residues in existing and proposed project areas.

Draingage CAL-ORE
Type No. 42

FOREST FUEL PROFILE AND APPRAISAL SUMMARY

Vegetative type TANOAK
Management Status OLD BB CLEARCUT
Elevation 2100
Aspect



Assumptions:

APPRAISAL SUMMARY

Wind speed ___ MPH Fine fuel moisture ___ percent
Model values: NFFL or NFDR fuel models ——— for surf/vol. ratios, moisture of extinction, density, heat of combustion, mineral contents, and where appropriate, live fuel loading as a base for determining local loading.

Fire Behavior:

Slope (%)	Flame length (feet)	Perim. growth (chains/hr)	R/S (chains/hr)	R/C (rating)
0				
30				
60				
75				

QUALITATIVE INFORMATION

SPECIES PREDOMINANCE

Overstory	TANOAK –
Understory	TANOAK MADRONE
Brush	TANOAK MADRONE
Forbs	BRACKENFERN –

RESIDUE SOUNDNESS

Dead & down % sound >3" 50

SIZE AND DENSITY

Overstory B.A.
Av. no. stems/ac.
Av. d.b.h. 5"
Understory B.A.

QUANTITATIVE INFORMATION

Dead standing
Snag per acre

0 ✓ 1-2 ☐ 2-10 ☐ 10+ ☐

LEGEND
OVERSTORY
UNDERSTORY
BRUSH
GRASS & FORBS
ALL OTHER

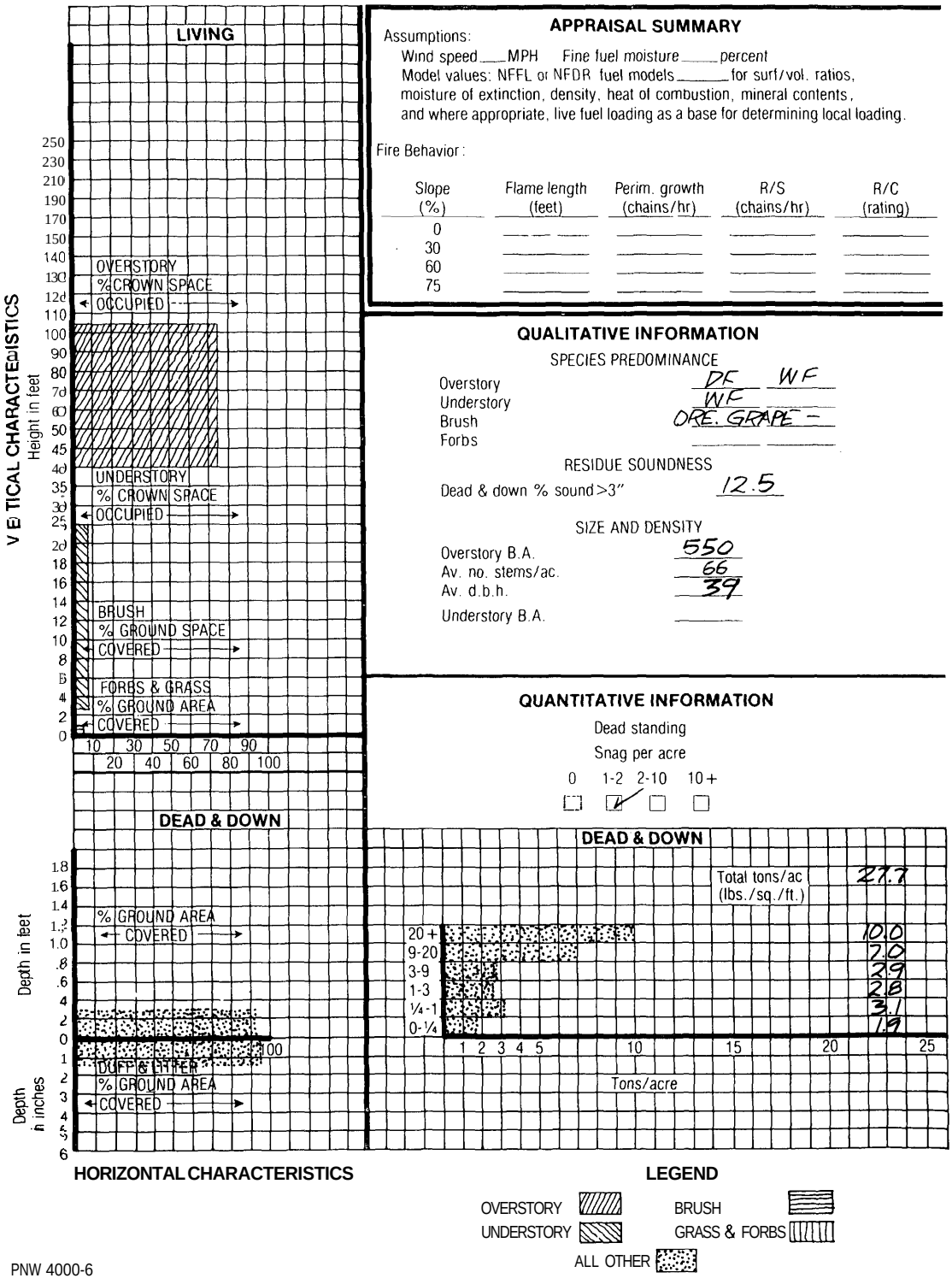
PNW 4000-6

Figure 6.—Forest-fuel profile for fuel-type island 42.

Drainage CAL-ORE
Type No 76

FOREST FUEL PROFILE AND APPRAISAL SUMMARY

Vegetative type D4 E
Management Status UNCUT
Elevation 5250
Aspect



APPRAISAL SUMMARY

Assumptions:
Wind speed ___ MPH Fine fuel moisture ___ percent
Model values: NFFL or NFDR fuel models ___ for surf/vol. ratios, moisture of extinction, density, heat of combustion, mineral contents, and where appropriate, live fuel loading as a base for determining local loading.

Fire Behavior:

Slope (%)	Flame length (feet)	Perim. growth (chains/hr)	R/S (chains/hr)	R/C (rating)
0				
30				
60				
75				

QUALITATIVE INFORMATION

SPECIES PREDOMINANCE

Overstory	DF	WF
Understory	WF	
Brush	ORE. GRAPE	
Forbs		

RESIDUE SOUNDNESS

Dead & down % sound >3" 12.5

SIZE AND DENSITY

Overstory B.A.	550
Av. no. stems/ac.	66
Av. d.b.h.	39
Understory B.A.	

QUANTITATIVE INFORMATION

Dead standing
Snag per acre

0	1-2	2-10	10+
☐	☑	☐	☐

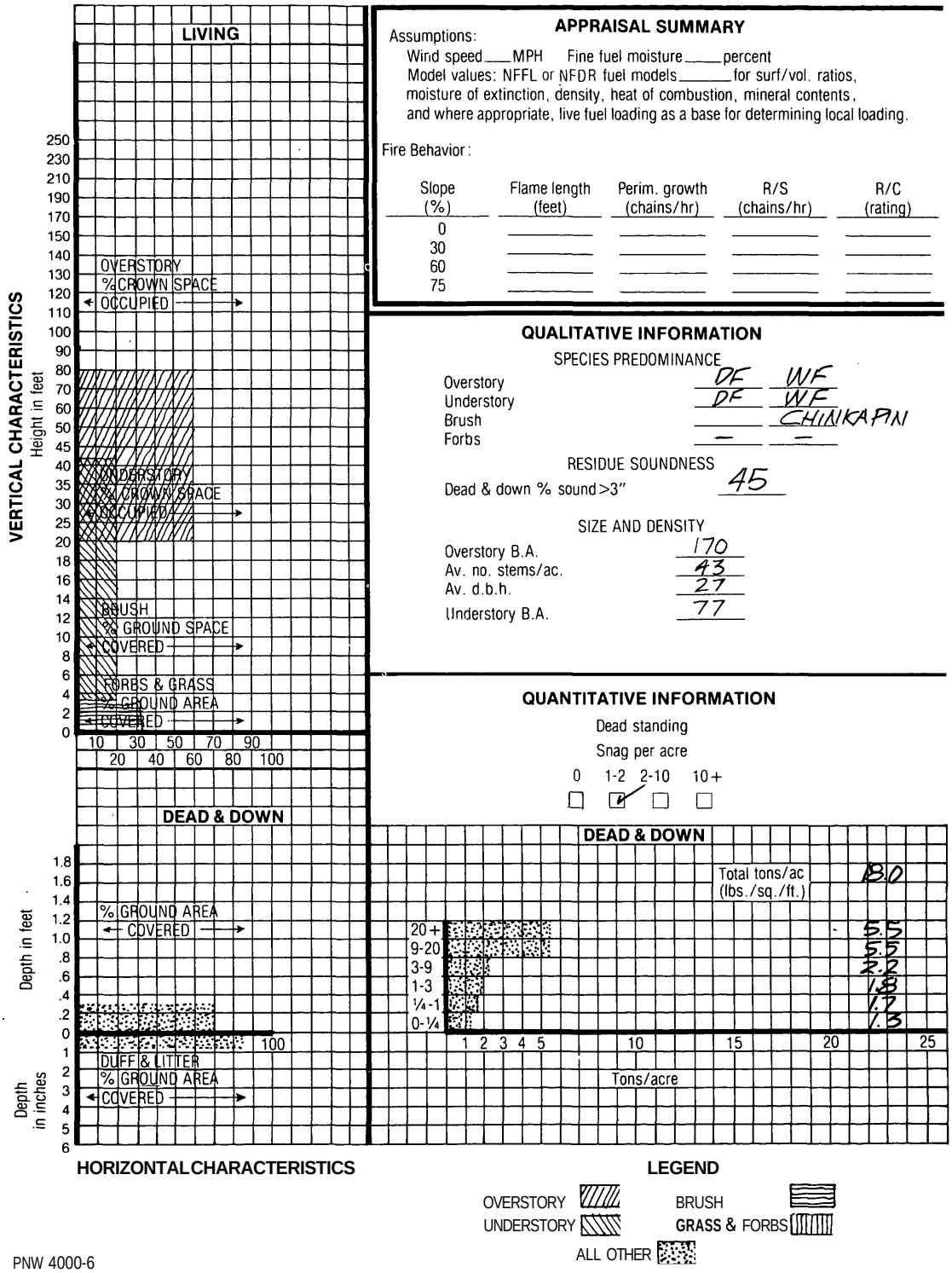
PNW 4000-6

Figure 7.—Forest-fuel profile for fuel-type island 60.

Drainage CAL-ORE
Type No 60

FOREST FUEL PROFILE AND APPRAISAL SUMMARY

Vegetative type MIXED CONIFER
Management Status
Elevation 4700
Aspect NW-N-NE



APPRAISAL SUMMARY

Assumptions:
Wind speed ___ MPH Fine fuel moisture ___ percent
Model values: NFFL or NFDR fuel models ___ for surf/vol. ratios, moisture of extinction, density, heat of combustion, mineral contents, and where appropriate, live fuel loading as a base for determining local loading.

Fire Behavior:

Slope (%)	Flame length (feet)	Perim. growth (chains/hr)	R/S (chains/hr)	R/C (rating)
0				
30				
60				
75				

QUALITATIVE INFORMATION

SPECIES PREDOMINANCE

Overstory	DF	WF
Understory	DF	WF
Brush		CHINKAPIN
Forbs	—	—

RESIDUE SOUNDNESS
Dead & down % sound >3" 45

SIZE AND DENSITY

Overstory B.A.	170
Av. no. stems/ac.	43
Av. d.b.h.	27
Understory B.A.	77

QUANTITATIVE INFORMATION

Dead standing
Snag per acre
0 1-2 2-10 10+
☐ ☑ ☐ ☐

LEGEND
OVERSTORY
UNDERSTORY
BRUSH
GRASS & FORBS
ALL OTHER

PNW 4000-6

Figure 8.—Forest-fuel profile for fuel-type island 76.

Metric Conversion

Change	To	Multiply by:
Acres	hectares	0.404 7
Chains	meters	20.12
Feet	meters	0.304 8
Inches	centimeters	2.54
Miles	kilometers	1.609
Square feet	square meters	0.092 9
Tons	metric tons	0.907 18
Yards	meters	0.914 4

Literature Cited

Maxwell, Wayne G.; Ward, Franklin R. Photo series for quantifying natural forest residues in common vegetation types of the Pacific Northwest. Gen. Tech. Rep. PNW-105. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980. 230 p.

Maxwell, Wayne G.; Ward, Franklin R. Fuels and fire in land-management planning. Part 1. Forest-fuel classification. Gen. Tech. Rep. PNW-131. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1981. 12 p.

This report describes a way to collect and classify the total fuel complex within a planning area. The information can be used as input for appraising and rating probable fire behavior and calculating expected costs and losses from various land uses and management alternatives, reported separately as Part **2** and Part **3** of this series. This total package can be used locally for fire management and as input to the land-management planning process.

Keywords: Fuels inventory, land management, management planning (forest).

Pacific Northwest Forest and Range
Experiment Station
809 NE Sixth Avenue
Portland, Oregon 97232