Description of the 13 Fuel Models

SOURCE: Adapted from Anderson. H.E. 1982. *Aids to determining fuel models for estimating fire behavior.* United States Department of Agriculture Forest Service General Technical Report INT-122.

GRASS GROUP

Fire Behavior Fuel Model 1

Fire spread is governed by the fine, very porous, and continuous herbaceous fuels that have cured or are nearly cured. Fires are surface fires that move rapidly through the cured grass and associated material. Very little shrub or timber is present, generally less than one-third of the area. Grasslands and savanna are represented along with stubble, grass-tundra, and grass-shrub combinations that met the above area constraint. Annual and perennial grasses are included in this fuel model.

This fuel model correlates to 1978 NFDRS fuel models A, L, and S.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	0.74
Dead fuel load, ¼-inch, tons/acre	.74
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	1.0

Figure A-108. Western annual grasses such as cheatgrass, medusahead ryegrass, and fescues.

Figure A-109. Live oak savanna of the Southwest on the Coronado National Forest.

Figure A-110. Open pine—grasslands on the Lewis and Clark National Forest.

GRASS GROUP

Fire Behavior Fuel Model 2

Fire spread is primarily through the fine herbaceous fuels, either curing or dead. These are surface fires where the herbaceous material, in addition to litter and deaddown stemwood from the open shrub or timber overstory, contribute to the fire intensity. Open shrub lands and pine stands or scrub oak stands that cover one-third to two-thirds of the area may generally fit this model; such stands may include clumps of fuels that generate higher intensities and that may produce firebrands. Some pinyon-juniper may be in this model.

This fuel model correlates to 1978 N FDRS fuel models C and T.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	4.0
Dead fuel load, ¼-inch, tons/acre	2.0
Live fuel load, foliage, tons/acre	0.5
Fuel bed depth, feet	1.0

Figure A-111. Open ponderosa pine stand with annual grass understory.

Figure A-112. Scattered sage within grasslands on the Payette National Forest.

GRASS GROUP

Fire Behavior Fuel Model 3

Fires in this fuel are the most intense of the grass group and display high rates of spread under the influence of wind. Wind may drive fire into the upper heights of the grass and across standing water. Stands are tall, averaging about 3 feet (1 m), but considerable variation may occur. Approximately one-third of more of the stand is considered dead or cured and maintains the fire. Wild or cultivated grains that have not been harvested can be considered similar to tall prairie and marshland grasses.

This fuel correlates to 1978 NFDRS fuel model N.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	3.0
Dead fuel load, ¼-inch, tons/acre	3.0
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	2.5

Fires in the grass group fuel models exhibit some of the faster rates of spread under similar weather conditions. With a windspeed of 5 mi/h (8 km/h) and a moisture content of 8 percent, representative rates of spread (ROS) are as follows:

Model	Rates of Spread (chains/hour)	Flame Length (feet)
1	78	4
2	35	6
3	104	12

As windspeed increases, model 1 will develop faster rates of spread than model 3 due to fineness of the fuels, fuel load, and depth relations.

Figure A-113. Fountaingrass in Hawaii; note the dead component.

Figure A-114. Meadow foxtail in Oregon prairie and meadowland.

Figure A-115. Sawgrass "prairie" and "strands" in the Everglades National Park, Florida.

SHRUB GROUP
Fire Behavior Fuel Model 4

Fires intensity and fast-spreading fires involve the foliage and live and dead fine woody material in the crowns of a nearly continuous secondary overstory. Stands of mature shrubs, 6 or more feet tall, such as California mixed chaparral, the high pocosin along the east coast, the pinebarrens of New Jersey, or the closed jack pine stands of the north-central States are typical candidates. Besides flammable foliage, dead woody material in the stands significantly contributes to the fire intensity. Height of stands qualifying for this model depends on local conditions. A deep litter layer may also hamper suppression efforts.

This fuel model represents 1978 NFDRS fuel models B and O; fire behavior estimates are more severe than obtained by models B or O.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	13.0
Dead fuel load, ¼-inch, tons/acre	5.0
Live fuel load, foliage, tons/acre	5.0
Fuel bed depth, feet	6.0

Figure A-116. Mixed chaparral of southern California; note dead fuel component in branchwood.

Figure A-117. Chaparral composed of manzanita and chamise near the Inaja Fire Memorial, California.

Figure A-118. Pocosin shrub field composed of species like fetterbush, gallberry, and the bays.

Figure A-119. High shrub southern rough with quantity of dead limbwood.

SHRUB GROUP

Fire Behavior Fuel Model 5

Fire is generally carried in the surface fuels that are made up of litter cast by the shrubs and the grasses or forbs in the understory. The fires are generally not very intense because surface fuel loads are light, the shrubs are young with little dead material, and the foliage contains little volatile material. Usually shrubs are short and almost totally cover the area. Young, green stands with no dead wood would qualify: laurel, vine maple, alder, or even chaparral, manzanita, or chamise.

No 1978 NFDRS fuel model is represented, but model 5 can be considered as a second choice for NFDRS model D or as a third choice for NFDRS model T. Young green stands may be up to 6 feet (2 m) high but have poor burning properties because of live vegetation.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	3.5
Dead fuel load, ¼-inch, tons/acre	1.0
Live fuel load, foliage, tons/acre	2.0
Fuel bed depth, feet	2.0

Figure A-120. Green, low shrub fields within timber stands or without overstory are typical. Example is Douglas-fir–snowberry habitat type.

Figure A-121. Regeneration shrublands after fire or other disturbances have a large green fuel component, Sundance Fire, Pack River Area, Idaho.

SHRUB GROUP

Fire Behavior Fuel Model 6

Fires carry through the shrub layer where the foliage is more flammable than fuel model 5, but this requires moderate winds, greater than 8 mi/h (13 km/h) at midflame height. Fire will drop to the ground at low wind speeds or at openings in the stand. The shrubs are older, but not as tall as shrub types of model 4, nor do they contain as much fuel as model 4. A broad range of shrub conditions is covered by this model. Fuel situations to be considered include intermediate stands of chamise, chaparral, oak brush, low pocosin, Alaskan spruce taiga, and shrub tundra. Even hardwood slash that has cured can be considered. Pinyon-juniper shrublands may be represented but may overpredict rate of spread except at high winds, like 20 mi/h (32 km/h) at the 20-foot level.

The 1978 NFDRS fuel models F and Q are represented by this fuel model. It can be considered a second choice for models T and D and a third choice for model S.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	6.0
Dead fuel load, ¼-inch, tons/acre	1.5
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	2.5

Figure A-122. Pinion-juniper with sagebrush near Ely, Nev.; understory mainly sage with some grass intermixed.

Figure A-123. Southern harwood shrub with pine slash residues.

Figure A-124. Low pocosin shrub field in the south.

Figure A-125. Frost-killed Gambel Oak foliage, less than 4 feet in height, in Colorado.

SHRUB GROUP

Fire Behavior Fuel Model 7

Fires burn through the surface and shrub strata with equal ease and can occur at higher dead fuel moisture contents because of the flammability of live foliage and other live material. Stands of shrubs are generally between 2 and 6 feet (0.6 and 1.8 m) high. Palmetto-gallberry understory-pine overstory sites are typical and low pocosins may be represented. Black spruce-shrub combinations in Alaska may also be represented.

This fuel model correlates with 1978 NFDRS model D and can be a second choice for model Q.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	4.9
Dead fuel load, ¼-inch, tons/acre	1.1
Live fuel load, foliage, tons/acre	0.4
Fuel bed depth, feet	2.5

The shrub group of fuel models has a wide range of fire intensities and rates of spread. With winds of 5 mi/h (8 km/h), fuel moisture content of 8 percent, and a live fuel moisture content of 100 percent, the models have the values:

Model	Rates of Spread (chains/hour)	Flame Length (feet)
4	75	19
5	18	4
6	32	6
7	20	5

Figure A-126. Southern rough with light to moderate palmetto understory.

Figure A-127. Southern rough with moderate to heavy palmetto-gallberry and other species.

Figure A-128. Slash pine with gallberry, bay, and other species of understory rough.

TIMBER GROUP

Fire Behavior Fuel Model 8

Slow-burning ground fires with low flame lengths are generally the case, although the fire may encounter an occasional "jackpot" or heavy fuel concentration that can flare up. Only under severe weather conditions involving high temperatures, low humidities, and high winds do the fuels pose fire hazards. Closed canopy stands of short-needle conifers or hardwoods that have leafed out support fire in the compact litter layer. This layer is mainly needles, leaves, and occasionally twigs because little undergrowth is present in the stand. Representative conifer types are white pine, and lodgepole pine, spruce, fir, and larch.

This model can be used for 1978 NFDRS fuel models H and R.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	5.0
Dead fuel load, ¼-inch, tons/acre	1.5
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	0.2

Figure A-129. Surface litter fuels in western hemlock stands of Oregon and Washington.

Figure A-130. Understory of inland Douglas-fir has little fuel here to add to dead-down litter load.

Figure A-131. Closed stand of birch-aspen with leaf litter compacted.

TIMBER GROUP

Fire Behavior Fuel Model 9

Fires run through the surface litter faster than model 8 and have longer flame height. Both long-needle conifer stands and hardwood stands, especially the oak-hickory types, are typical. Fall fires in hardwoods are predictable, but high winds will actually cause higher rates of spread than predicted because of spotting caused by rolling and blowing leaves. Closed stands of long-needled pine like ponderosa, Jeffrey, and red pines, or southern pine plantations are grouped in this model. Concentrations of dead-down woody material will contribute to possible torching out of trees, spotting, and crowning.

NFDRS fuel models E, P, and U are represented by this model. It is also a second choice for models C and S.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	3.5
Dead fuel load, ¼-inch, tons/acre	2.9
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	0.2

Figure A-132. Western Oregon white oak fall litter; wind tumbled leaves may cause short-range spotting that may increase ROS above the predicted value.

Figure A-133. Loose hardwood litter under stands of oak, hickory, maple and other hardwood species of the East.

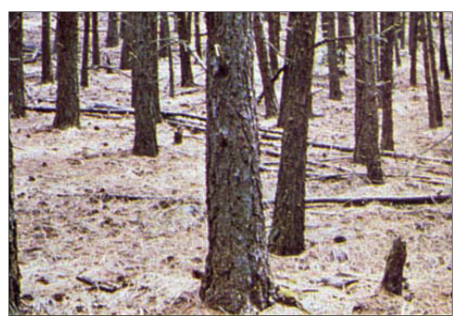

Figure A-134. Long-needle forest floor litter in ponderosa pine stand near Alberton, Montana.

TIMBER GROUP
Fire Behavior Fuel Model 10

The fires burn in the surface and ground fuels with greater fire intensity than the other timber litter models. Dead-down fuels include greater quantities of 3-inch (7.6-cm) or larger limbwood resulting from overmaturity or natural events that create a large load of dead material on the forest floor. Crowning out, spotting, and torching of individual trees are more frequent in this fuel situation, leading to potential fire control difficulties. Any forest type may be considered if heavy down material is present; examples are insect- or disease-ridden stands, windthrown stands, overmature situations with deadfall, and aged light thinning or partial-cut slash.

This fuel correlates to 1978 NFDRS fuel model G.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	12.0
Dead fuel load, ¼-inch, tons/acre	3.0
Live fuel load, foliage, tons/acre	2.0
Fuel bed depth, feet	1.0

The fire intensities and spread rates of these timber litter fuel models are indicated by the following values when the dead fuel moisture content is 8 percent, live fuel moisture is 100 percent, and the effective windspeed at midflame height is 5 mi/h (8 km/h):

Model	Rates of Spread (chains/hour)	Flame Length (feet)
8	1.6	1.0
9	7.5	2.6
10	7.9	4.8

Fires such as above in model 10 are at the upper limit of control by direct attack. More wind or drier conditions could lead to an escaped fire.

Figure A-135. Old-growth Douglas-fir with heavy ground fuels.

Figure A-136. Mixed conifer stand with deaddown woody fuels.

Figure A-137. Spruce habitat type where succession or natural disturbance can produce a heavy downed fuel load.

LOGGING SLASH GROUP
Fire Behavior Fuel Model 11

Fires are fairly active in the slash and herbaceous material intermixed with the slash. The spacing of the rather light fuel load, shading from overstory, or the aging of the fine fuels can contribute to limiting the fire potential. Light partial cuts or thinning operations in mixed conifer stands, hardwood stands, and southern pine harvests are considered. Clearcut operations generally produce more slash than represented here. The less-than-3-inch (7.6-cm) material load is less than 12 tons per acre (5.4 t/ha). The greater-than-3-inch (7.6-cm) is represented by not more than 10 pieces, 4 inches (10.2 cm) in diameter, along a 50-foot (15-m) transect.

This fuel correlates to 1978 NFDRS fuel model K.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	11.5
Dead fuel load, ¼-inch, tons/acre	1.5
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	1.0

Figure A-138. Slash residues left after skyline logging in western Montana.

Figure A-139. Mixed conifer partial cut slash residues may be similar to closed timber with down woody fuels.

Figure A-140. Light logging residues with patchy distribution seldom can develop high intensities.

LOGGING SLASH GROUP

Fire Behavior Fuel Model 12

Rapidly spreading fires with high intensities capable of generating firebrands can occur. When fire starts, it is generally sustained until a fuel break or change in fuels is encountered. The visual impression is dominated by slash and much of it is less than 3 inches (7.6 cm) in diameter. The fuels total less than 35 tons per acre (15.6 t/ha) and seem well distributed. Heavily thinned conifer stands, clearcuts, and medium or heavy partial cuts are represented. The material larger than 3 inches (7.6 cm) is represented by encountering 11 pieces, 6 inches (15.2 cm) in diameter, along a 50-foot (15-m) transect.

This model corresponds to 1978 NFDRS model J and may overrate slash areas when the needles have dropped and the limbwood has settled. However, in areas where limbwood breakup and general weathering have started, the fire potential can increase.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	34.6
Dead fuel load, ¼-inch, tons/acre	4.0
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	2.3

Figure A-141. Ponderosa pine clearcut east of Cascade mountain range in Oregon and Washington.

Figure A-142. Cedar-hemlock partial cut in northern Idaho, Region 1, USFS.

Figure A-143. Lodgepole pine thinning slash on Lewis and Clark National Forest. Red slash condition increases classification from light to medium.

LOGGING SLASH GROUP

Fire Behavior Fuel Model 13

Fire is generally carried across the area by a continuous layer of slash. Large quantities of material larger than 3 inches (7.6 cm) are present. Fires spread quickly through the fine fuels and intensity builds up more slowly as the large fuels start burning. Active flaming is sustained for long periods and a wide variety of firebrands can be generated. These contribute to spotting problems as the weather conditions become more severe. Clearcuts and heavy partial-cuts in mature and overmature stands are depicted where the slash load is dominated by the greater-than-3-inch (7.6-cm) diameter material. The total load may exceed 200 tons per acre (89.2 t/ha) but fuel less than 3 inches (7.6-cm) is generally only 10 percent of the total load. Situations where the slash still has "red" needles attached but the total load is lighter, more like model 12, can be represented because of the earlier high intensity and quicker area involvement.

This fuel correlates to 1978 NFDRS fuel model I. Areas most commonly fitting this model are old-growth stands west of the Cascade and Sierra Nevada Mountains.

Figure A-144. West coast Douglas-fir clearcut, quality of cull high.

Figure A-145. High productivity of cedar-fir stand can result in large quantities of slash with high fire potential.

Fuel model values for estimating fire behavior:

Total fuel load, < 3-inch dead and live, tons/acre	58.1
Dead fuel load, ¼-inch, tons/acre	7.0
Live fuel load, foliage, tons/acre	0
Fuel bed depth, feet	3.0

For other slash situations:
Hardwood slash .... Model 6
Heavy "red" slash .... Model 4
Overgrown slash .... Model 10
Southern pine clearcut slash .... Model 12

The comparative rates of spread and flame lengths for the slash models at 8 percent dead fuel moisture content and a 5 mi/h (8 km/h) midflame wind are:

Model	Rates of Spread (chains/hour)	Flame Length (feet)
11	6.0	3.5
12	13.0	8.0
13	13.5	10.5

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