SOUTHWEST FUELS GUIDE PHOTO SERIES

For Mixed Conifer, Ponderosa Pine, and Piñon-Juniper Types

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Preface

This photo series was compiled by NMFWRI to show different wood fuels residues specifically in Southwest mixed conifer, ponderosa pine, and piñon-juniper. Since 2007, NMFWRI has taken data on nearly 1600 FFI/FIREMON plots across New Mexico. Beginning in 2008, Brown's transects were included in monitoring which allowed the assessment of surface fuels levels (litter, duff, 1-hour, 10-hour, 100-hour, and 1,000-hour fuels). The photos associated with these Brown's transects have been compiled into series.

For mixed conifer, ponderosa and PJ forest types, we have set up two fuels series. One is ordered based on the tons/acres of 1000-hour fuels only (more likely what would be found in a "natural" setting) and the other is ordered based on the total tons/ acre (1-hour to 1,000 hour fuels) which reflect higher levels of slash associated with thinning or other management practices. Amounts of fuels recorded are provided for all photos, as well the location in and date on which they were taken. Litter and duff are not reported because they are not identifiable in photographs, nor are stumps included in fuels estimates.

This photo guide can be used for rapid estimation of surface fuel loading for managers in the Southwest lacking the time or budget to perform more intensive assessments. A quantitative estimate can be obtained by simply finding the photo or photos that mostly closely match the characteristics seen in the field. Missing photos (gaps in the series) we hope to obtain in the future are noted in this series. Future versions will include missing photos.

For comments or questions about this photo series please contact Dr. Kent Reid. 505-426-2080 or email: rkreid@nmhu.edu.

Table of Contents

Brown's Transects Fuels Monitoring Background

Fuel loading is estimated by sampling dead and down woody debris, measuring depth of the duff/litter profile, and estimating total vegetative cover and dead vegetative cover. Down woody debris (DWD) is sampled using the planar intercept technique based on the methodology developed by James K. Brown (1974). Pieces of dead and down woody debris are tallied in the standard fire size classes: 1-hour (0 to 0.25 in.), 10-hour (0.25 to 1.0 in.), 100-hour (1.0 to 3.0 in.). Pieces greater than 3 in. in diameter are recorded by diameter and decay class. Duff and litter depth are measured at two points along each 60-foot sampling plane. Cover of live and dead vegetation is estimated at two points along each 60-foot sampling plane. Biomass of DWD, duff, litter and vegetation is calculated using available computer software (FFI/FEAT FIREMON Integrated).

Fuel loading is calculated by estimating three general components of the fuel complex: dead and down woody debris (DWD), duff and litter, and understory vegetation. Each of these components will be discussed in detail below.

Down woody materials (DWM) are an important component of forest ecosystems across the country. DWM is dead material on the ground in various stages of decay. Wildlife biologists, ecologists, mycologists, foresters, and fuels specialists are some of the people interested in DWM because it helps describe the:

- Quality and status of wildlife habitats.
- Structural diversity within a forest.
- Fuel loading and fire behavior.
- Carbon sequestration – the amount of carbon tied up in dead wood.
- Storage and cycling of nutrients and water – important for site productivity.

Down woody components and fuels estimated are: coarse woody, fine woody, litter, herb/shrubs, slash, duff, and fuelbed depth. Any field crew member can learn to collect down woody materials data. If untrained members of the crew are available to help, they can locate, measure, and flag transect lines and record the condition class information for the transect segments.

Biomass estimates of dead and down woody debris are collected for the size classes that fire scientists have found important for predicting fire behavior – 1-hour, 10-hour, 100-hour and, 1000-hour and greater. DWD measurements are based on the planar intercept methods published by Brown in 1974. The sampling area is an imaginary plane extending from the ground, vertically from horizontal (not perpendicular to the slope) to a height six feet above the ground. Pieces that intercept the sampling plane are measured and recorded. Frequently the term “line transect sampling” is used when discussing the planar intercept method. The two terms can be interchanged as long as samplers recognize that the ‘line’ is really the measuring tape laid on the litter layer while the ‘plane’ extends above and below the tape, from the top of the litter layer to a height of six feet.

Duff and litter are assessed by measuring the depth of the duff/litter profile down to mineral soil. The biomass of live and dead, woody and non-woody understory vegetation is estimated using cover and average height estimations. The data collected are used to model fire behavior or to indicate potential fire effects. Forest managers often prescribe fuel treatments, at least partially, on the data collected. The load of DWD can also be used to estimate the total carbon pool that is stored in the dead material, or DWD data can be used as an indicator of habitat for wildlife. Standing dead trees (snags) are sampled at the same time live trees are measured, not as part of the fuels data collection.

Pieces of DWD are sampled if they pass through the 6-foot (2-meter) high sampling plane. Fine woody (FWD) pieces are recorded as simple counts. Diameter and decay class are recorded for each piece of coarse woody debris (CWD). DWD biomass estimation is made using equations published by Brown. We also discuss seven optional measures for CWD: 1) residue piles, 2) diameters of the small and large ends of the log, 3) log length, 4) distance along the tape where the piece intercepts the plane, 5) the proportion of biomass lost to decay in hollow logs, 6) history of the log, and 7) proportion of the surface that is charred.

At two points along the base of each sampling plane, measurements of duff/litter depth and estimation of the proportion of the duff/litter profile that is litter are made. At these same locations the sampling crew will also estimate the cover of live and dead, herbs and shrubs as well as average height of herbs and shrubs.

The planar intercept sampling methodology was originally developed for sampling slash. Brown revised the original sampling theory to allow for more rapid fuel measurement while still capturing the intrinsic variability of forest fuels. Brown’s method was developed strictly to provide estimates of fuel load in the size classes important to fire behavior. He determined the length of the sampling plane needed for each size class and, for FWD, determined quadratic mean diameter for several species. Planar sampling has been reduced to its most fundamental and efficient level while still providing good estimates of DWD.

The planar intercept technique assumes that DWD is randomly oriented directionally on the forest floor. Typically, this assumption does not hold true (for instance in areas of high wind, trees tend to fall with the prevailing winds). We use a sampling scheme that reduces bias introduced from non-randomly oriented pieces by orienting the DWD sampling planes in different directions. This sampling design greatly reduces or eliminates the bias introduced by non-randomly oriented DWD.

DWD is notoriously variable in its distribution within and between forest stands. Frequently, the standard deviation of DWD samples exceeds the mean. This variability requires large numbers of samples for statistical tests.

The line intersect method is not practical for sampling CWD when it is part of machine-piled windrows or slash piles, or part of log "jumbles" at the bottom of steep-sided ravines. In these situations, individual pieces are impractical to tally separately and are labeled as “residue piles”. A different sampling method is used to tally and measure CWD residue piles (see below, Sampling Residue Piles).

Definition of Down Woody Materials

Two specific components of dead woody fuel are measured: Fine Woody Debris (FWD) and Coarse Woody Debris (CWD). Ecologists often refer to FWD and CWD independently because they function differently in forest ecosystems. FWD are pieces less than 3 (8 cm) inches diameter, and include 1-hour, 10-hour, and 100-hour fuels. CWD includes pieces 3 inches (8 cm) or greater in diameter and at least 3 feet (1 m) in length, also called 1000-hour and greater fire fuels (Table 1).

Characterization of fine (FWD) and coarse woody debris (CWD).

	Dead Woody Class		Piece Diameter (in.)	Piece Diameter (cm)
		1-hr	0 to 0.25	0 to 0.6
	FWD	10-hr	0.25 to 1.0	0.6 to 2.5
DWD		100-hr	1.0 to 3.0	2.5 to 8.0
	CWD	1000-hr and greater	3.0 and greater	8.0 and greater

FWD – In this inventory, FWD includes downed, dead branches, twigs, and small tree or shrub boles that are not attached to a living or standing dead source. FWD can be connected to a larger branch, as long as this branch is on the ground and not connected to a standing dead or live tree. Only the woody branches, twigs, and fragments that intersect the transect are counted. FWD can be connected to a down, dead tree bole or down, dead shrub. FWD can be twigs from shrubs and vines. FWD must be no higher than 6 feet above the ground to be counted.

Fine Woody Debris (FWD) does not include:

1) Woody pieces ≥ 3.0 inches in diameter at the point of intersection with the transect.
2) Dead branches connected to a live tree or shrub; or to a standing dead tree or dead shrub.
3) Dead foliage (i.e., pine or fir needles, or leaf petioles) or cone scales.
4) Bark fragments or other non-woody pieces that are not an integral part of a branch, twig, or small bole.
5) Small pieces of decomposed wood (i.e., chunks of cubical rot)

Coarse Woody Debris (CWD) in this inventory includes; downed, dead tree and shrub boles, large limbs, and other woody pieces that are severed from their original source of growth and on the ground. CWD also includes dead trees (either self-supported by roots, severed from roots, or uprooted) that are leaning > 45 degrees from vertical. Also included are non-machine processed round wood such as fence posts and cabin logs. For multi-stemmed woodland trees such as juniper, only tally stems that are dead, detached, and on the ground; or dead and leaning > 45 degrees from vertical.

CWD does not include:

1) Woody pieces < 3.0 inches in diameter at the point of intersection with the transect.
2) Dead trees leaning 0 to 45 degrees from vertical.
3) Dead shrubs, self-supported by their roots.
4) Trees showing any sign of life.
5) Stumps that are rooted in the ground (i.e., not uprooted).
6) Dead foliage, bark or other non-woody pieces that are not an integral part of a bole or limb. (Bark attached to a portion of a piece is an integral part).

Photo Series for Areas Dominated by 1,000 Hour Fuels

This section is ordered based on the tons/acres of 1,000-hour fuels only. These are more likely what would be found in a "natural" setting with no treatment such as thinning taking place. As mentioned previously, there are four different categories of potential wildfire fuel: one-hour, 10-hour, 100-hour and 1,000-hour. In basic terms, they're determined by size and how much moisture would be needed to make that fuel essentially fire-proof. In the case of a 1,000-hour fuel, like felled trees, they are a lot heavier, with a lot more volume to the amount of surface area. Because of the size, they are harder to ignite - unlike a 1-hour to 100-hour fuel.

	Dead Woody Class		Piece Diameter (in.)	Piece Diameter (cm)
		1-hr	0 to 0.25	0 to 0.6
	FWD	10-hr	0.25 to 1.0	0.6 to 2.5
DWD		100-hr	1.0 to 3.0	2.5 to 8.0
	CWD	**1000-hr and greater**	**3.0 and greater**	**8.0 and greater**

Mixed Conifer: 1,000-hour fuels

0.5 tons per acre

0.52 tons per acre 1000-hour fuels • 0.42 tons per acre 100-hour fuels • 0.61 tons per acre 10-hour fuels • 0.03 tons per acre 1-hour fuels
La Jicarita, near Mora, 2010

1 ton per acre

1.07 tons per acre 1000-hour fuels • 1.26 tons per acre 100-hour fuels • 0.62 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels
Coleman Ranch, near Mayhill, 2009

1.5 tons per acre

1.64 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0.91 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels
Coleman Ranch, near Mayhill, 2013

3 tons per acre

3.53 tons per acre 1000-hour fuels • 0.84 tons per acre 100-hour fuels • 2.16 tons per acre 10-hour fuels • 0.53 tons per acre 1-hour fuels
Coleman Ranch, near Mayhill, 2008

5 tons per acre

5.24 tons per acre 1000-hour fuels • 0.42 tons per acre 100-hour fuels • 0.91 tons per acre 10-hour fuels • 0.10 tons per acre 1-hour fuels
Walker Flats, near Mora, 2015

7.5 tons per acre

7.65 tons per acre 1000-hour fuels • 0.85 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels
Walker Flats, near Mora, 2015

10 tons per acre

10.89 tons per acre 1000-hour fuels • 0.42 tons per acre 100-hour fuels • 0.30 tons per acre 10-hour fuels • 0.14 tons per acre 1-hour fuels
Walker Flats, near Mora, 2015

15 tons per acre

15.06 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0.32 tons per acre 10-hour fuels • 0.23 tons per acre 1-hour fuels
Ute Valley, near Angel Fire, 2009

20 tons per acre

19.43 tons per acre 1000-hour fuels • 0.41 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.03 tons per acre 1-hour fuels
Walker Flats, near Mora, 2015

25 tons per acre

24.99 tons per acre 1000-hour fuels • 0.41 tons per acre 100-hour fuels • 3.35 tons per acre 10-hour fuels • 0.06 tons per acre 1-hour fuels
Walker Flats, near Mora, 2015

30 tons per acre

29.06 tons per acre 1000-hour fuels • 1.71 tons per acre 100-hour fuels • 2.5 tons per acre 10-hour fuels • 0.18 tons per acre 1-hour fuels
Barela (Johnson Mesa), near Gallinas, 2013

35 tons per acre

35.52 tons per acre 1000-hour fuels • 0.84 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels
Coleman Ranch, near Mayhill, 2009

40 tons per acre

THIS PHOTOGRAPH IS CURRENTLY MISSING FROM NMFWRI'S COLLECTION. IF YOU HAVE SUCH A PHOTOGRAPH, PLEASE CONTACT US.

45 tons per acre

45.91 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 0.30 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels
Walker Flats, near Mora, 2015

50 tons per acre

50.80 tons per acre 1000-hour fuels • 0.46 tons per acre 100-hour fuels • 4.39 tons per acre 10-hour fuels • 0.09 tons per acre 1-hour fuels
TyM Gallinas (Johnson Mesa), near Gallinas, 2013

55 tons per acre

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60 tons per acre

59.83 tons per acre 1000-hour fuels • 1.82 tons per acre 100-hour fuels • 3.33 tons per acre 10-hour fuels • 0.14 tons per acre 1-hour fuels
Gallinas Tierra y Montes project, near Gallinas, 2018

65 tons per acre

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70 tons per acre

70.32 tons per acre 1000-hour fuels • 3.74 tons per acre 100-hour fuels • 1.52 tons per acre 10-hour fuels • 0.16 tons per acre 1-hour fuels
Gallinas Tierra y Montes project, near Gallinas, 2018

75 tons per acre

75.74 tons per acre 1000-hour fuels • 3.74 tons per acre 100-hour fuels • 1.52 tons per acre 10-hour fuels • 0.16 tons per acre 1-hour fuels
Gallinas Tierra y Montes project, near Gallinas, 2018

80 and 85 tons per acre

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90 tons per acre

89.35 tons per acre 1000-hour fuels • 5.44 tons per acre 100-hour fuels • 1.84 tons per acre 10-hour fuels • 0.08 tons per acre 1-hour fuels
Barela (Johnson Mesa), near Gallinas, 2018

95 and 100 tons per acre

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125 tons per acre

120.15 tons per acre 1000-hour fuels • 1.66 tons per acre 100-hour fuels • 4.58 tons per acre 10-hour fuels • 0.35 tons per acre 1-hour fuels
Barela (Johnson Mesa), near Gallinas, 2010

150 tons per acre

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200 tons per acre

207.23 tons per acre 1000-hour fuels • 8.78 tons per acre 100-hour fuels • 1.84 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels
TyM Gallinas (Johnson Mesa), near Gallinas, 2013

Ponderosa Pine: 1000-hour fuels

0.5 tons per acre

0.51 tons per acre 1000-hour fuels • 1.66 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels Gallinas (Alamo Navajo), near Magdalena, 2009

1 ton per acre

0.96 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0.46 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels
Bluewater Red Canyon Showcase, near Prewitt, 2010

1.5 tons per acre

1.65 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels
Ocate A, near Ocate, 2013

3 tons per acre

3.02 tons per acre 1000-hour fuels • 1.24 tons per acre 100-hour fuels • 0.30 tons per acre 10-hour fuels • 0 tons per acre 1-hour fuels
Thunderbird P & M, near Mountainair, 2012

5 tons per acre

5.10 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 1.22 tons per acre 10-hour fuels • 0.17 tons per acre 1-hour fuels
Red Canyon, near Mountainair, 2015

7.5 tons per acre

7.96 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 0.91 tons per acre 10-hour fuels • 0.06 tons per acre 1-hour fuels
Red Canyon, near Mountainair, 2015

10 tons per acre

9.49 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.03 tons per acre 1-hour fuels
Bluewater, near Prewitt, 2011

15 tons per acre

14.78 tons per acre 1000-hour fuels • 0.87 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels
Bluewater Red Canyon Showcase, near Prewitt, 2010

20 tons per acre

20.04 tons per acre 1000-hour fuels • 0.86 tons per acre 100-hour fuels • 0.95 tons per acre 10-hour fuels • 0.08 tons per acre 1-hour fuels
Griego, near Las Dispensas, 2012

25 tons per acre

24.61 tons per acre 1000-hour fuels • 1.66 tons per acre 100-hour fuels • 1.83 tons per acre 10-hour fuels • 0.38 tons per acre 1-hour fuels
Ocate B, near Ocate, 2015

30 tons per acre

29.43 tons per acre 1000-hour fuels • 1.66 tons per acre 100-hour fuels • 0.61 tons per acre 10-hour fuels • 0 tons per acre 1-hour fuels
La Jara, near Angel Fire, 2014

35 tons per acre

36.13 tons per acre 1000-hour fuels • 1.25 tons per acre 100-hour fuels • 0.91 tons per acre 10-hour fuels • 0 tons per acre 1-hour fuels
TyM Gallinas, near El Porvenir, 2013

40 tons per acre

40.39 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 1.83 tons per acre 10-hour fuels • 0.03 tons per acre 1-hour fuels
Ocate B, near Ocate, 2010

45 tons per acre

46.70 tons per acre 1000-hour fuels • 1.67 tons per acre 100-hour fuels • 0.92 tons per acre 10-hour fuels • 0.16 tons per acre 1-hour fuels
Ruidoso Schools, near Ruidoso, 2012

50 tons per acre

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55 tons per acre

56.74 tons per acre 1000-hour fuels • 0.87 tons per acre 100-hour fuels • 4.16 tons per acre 10-hour fuels • 0.22 tons per acre 1-hour fuels
Griego, near Las Dispensas, 2013

60 tons per acre

58.53 tons per acre 1000-hour fuels • 2.08 tons per acre 100-hour fuels • 2.14 tons per acre 10-hour fuels • 0.08 tons per acre 1-hour fuels
TyM Gallinas, near Gallinas, 2018

Piñon-Juniper: 1000-hour fuels

0.5 tons per acre

0.57 tons per acre 1000-hour fuels • 0.42 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.08 tons per acre 1-hour fuels
Guadalupe Mountain, near Cerro, 2015

1 ton per acre

0.96 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0.46 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels
Fullerton-Shaw (Pelona), near Aragon, 2008

1.5 tons per acre

1.6 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0.62 tons per acre 10-hour fuels • 0.06 tons per acre 1-hour fuels
Cerro Montoso, near Questa, 2014

3 tons per acre

2.94 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.10 tons per acre 1-hour fuels
Santa Fe Open Space, near Santa Fe, 2015

5 tons per acre

4.93 tons per acre 1000-hour fuels • 0.41 tons per acre 100-hour fuels • 0.61 tons per acre 10-hour fuels • 0 tons per acre 1-hour fuels
Cerro Montoso, near Tres Piedras, 2014

7.5 tons per acre

7.10 tons per acre 1000-hour fuels • 2.94 tons per acre 100-hour fuels • 0.31 tons per acre 10-hour fuels • 0.08 tons per acre 1-hour fuels
Cerro del Aire, near Tres Piedras, 2013

10 tons per acre

9.92 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0.30 tons per acre 10-hour fuels • 0.26 tons per acre 1-hour fuels
Guadalupe Mountain, near Cerro, 2015

15 tons per acre

14.93 tons per acre 1000-hour fuels • 1.26 tons per acre 100-hour fuels • 1.53 tons per acre 10-hour fuels • 0.51 tons per acre 1-hour fuels
Cerro Montoso, near Tres Piedras, 2014

20 tons per acre

18.61 tons per acre 1000-hour fuels • 3.38 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels
Cerro del Aire, near Tres Piedras, 2013

25 tons per acre

27.94 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels
Cerro Montoso, near Tres Piedras, 2014

30 tons per acre

30.90 tons per acre 1000-hour fuels • 1.24 tons per acre 100-hour fuels • 0.30 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels
Rito, near San Ignacio, 2009

35 tons per acre

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40 tons per acre

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45 tons per acre

45.00 tons per acre 1000-hour fuels • 5.27 tons per acre 100-hour fuels • 2.90 tons per acre 10-hour fuels • 0.82 tons per acre 1-hour fuels
Turkey Springs, near Ruidoso, 2010

50 tons per acre

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55 tons per acre

56.03 tons per acre 1000-hour fuels • 0.44 tons per acre 100-hour fuels • 1.3 tons per acre 10-hour fuels • 0.83 tons per acre 1-hour fuels
Fullerton-Shaw (Pelona), near Aragon, 2010

150 tons per acre

156.83 tons per acre 1000-hour fuels • 2.18 tons per acre 100-hour fuels • 0.64 tons per acre 10-hour fuels • 0.40 tons per acre 1-hour fuels
Pelona Mountain, near Aragon, 2009

Photo Series for All Fuel Series : 1-hour, 10-hour, 100-hour and 1,000-hour

This section is ordered based all fuel types. As mentioned previously, there are four different types of potential wildfire fuel: one-hour, ten-hour, 100-hour and 1,000-hour. In basic terms, they're determined by size and how much moisture would be needed to make that fuel essentially fire-proof.

	Dead Woody Class		Piece Diameter (in.)	Piece Diameter (cm)
DWD	FWD	1-hr	0 to 0.25	0 to 0.6
		10-hr	0.25 to 1.0	0.6 to 2.5
		100-hr	1.0 to 3.0	2.5 to 8.0
	CWD	1000-hr and greater	3.0 and greater	8.0 and greater

Mixed Conifer : All fuels

0.5 tons per acre total wood fuels

0.35 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0.31 tons per acre 10-hour fuels • 0.03 tons per acre 1-hour fuels

Upper Mora Walker Flats, near Mora, 2018

1 ton per acre total wood fuels

0.97 ton per acre total wood fuels

0.60 tons per acre 1000-hour fuels • 0 tons per acre 100-hour fuels • 0.30 tons per acre 10-hour fuels • 0.06 tons per acre 1-hour fuels

La Jicarita, near Mora, 2015

1.5 tons per acre total wood fuels

1.57 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 0.61 tons per acre 10-hour fuels • 0.13 tons per acre 1-hour fuels

Walker Flats, near Mora, 2015

3 tons per acre total wood fuels

3.24 tons per acre total wood fuels

0.71 tons per acre 1000-hour fuels • 1.26 tons per acre 100-hour fuels • 0.92 tons per acre 10-hour fuels • 0.35 tons per acre 1-hour fuels

TyM Gallinas (Johnson Mesa), near Gallinas, 2013

5 tons per acre total wood fuels

4.94 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 2.49 tons per acre 100-hour fuels • 2.43 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels

La Jicarita, near Mora, 2010

7.5 tons per acre total wood fuels

7.61 tons per acre total wood fuels

1.66 tons per acre 1000-hour fuels • 3.77 tons per acre 100-hour fuels • 2.15 tons per acre 10-hour fuels • 0.03 tons per acre 1-hour fuels

La Jicarita, near Mora, 2010

10 tons per acre total wood fuels

10.48 tons per acre total wood fuels

2.22 tons per acre 1000-hour fuels • 6.30 tons per acre 100-hour fuels • 1.85 tons per acre 10-hour fuels • 0.11 tons per acre 1-hour fuels

Barela (Johnson Mesa), near Gallinas, 2013

15 tons per acre total wood fuels

15.21 tons per acre total wood fuels

10.36 tons per acre 1000-hour fuels • 2.92 tons per acre 100-hour fuels • 1.83 tons per acre 10-hour fuels • 0.10 tons per acre 1-hour fuels

Coleman Ranch, near Mayhill, 2008

20 tons per acre total wood fuels

20.63 tons per acre total wood fuels

7.17 tons per acre 1000-hour fuels • 7.90 tons per acre 100-hour fuels • 4.87 tons per acre 10-hour fuels • 0.68 tons per acre 1-hour fuels

Coleman Ranch, near Mayhill, 2008

25 tons per acre

25.09 tons per acre total wood fuels

15.81 tons per acre 1000-hour fuels • 3.02 tons per acre 100-hour fuels • 6.02 tons per acre 10-hour fuels • 0.25tons per acre 1-hour fuels

TyM Gallinas, near Gallinas, 2018

30 tons per acre

29.51 tons per acre total wood fuels

21.78 tons per acre 1000-hour fuels • 5.01 tons per acre 100-hour fuels • 2.45 tons per acre 10-hour fuels • 0.27 tons per acre 1-hour fuels

TyM Gallinas (Johnson Mesa), near Gallinas, 2013

35 tons per acre

27.03 tons per acre total fuels

27.03 tons per acre 1000-hour fuels • 5.13 tons per acre 100-hour fuels • 4.70 tons per acre 10-hour fuels • 0.15 tons per acre 1-hour fuels

Upper Mora Walker Flats, near Mora, 2018

40 tons per acre

39.43 tons per acre total wood fuels

33.11 tons per acre 1000-hour fuels • 4.16 tons per acre 100-hour fuels • 2.14 tons per acre 10-hour fuels • 0.02 tons per acre 1-hour fuels

Barela (Johnson Mesa), near Gallinas, 2013

45 tons per acre

48.04 tons per acre total wood fuels

46.57 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 0.61 tons per acre 10-hour fuels • 0.03 tons per acre 1-hour fuels

La Jicarita, near Mora, 2015

50 tons per acre

51.25 tons per acre total wood fuels

43.93 tons per acre 1000-hour fuels • 5.41 tons per acre 100-hour fuels • 1.83 tons per acre 10-hour fuels • 0.08 tons per acre 1-hour fuels

Barela (Johnson Mesa), near Gallinas, 2018

55 tons per acre

53.00 tons per acre total wood fuels

45.09 tons per acre 1000-hour fuels • 4.98 tons per acre 100-hour fuels • 2.74 tons per acre 10-hour fuels • 0.19 tons per acre 1-hour fuels

Barela (Johnson Mesa), near Gallinas, 2013

60 tons per acre

62.75 tons per acre total wood fuels
52.29 tons per acre 1000-hour fuels • 6.42 tons per acre 100-hour fuels • 3.70 tons per acre 10-hour fuels • 0.35 tons per acre 1-hour fuels
Coleman Ranch, near Mayhill, 2013

Ponderosa Pine: All fuels

0.5 tons per acre

0.46 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0.42 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels

Ocate A, near Ocate, 2013

1 ton per acre

0.95 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0.59 tons per acre 100-hour fuels • 0.31 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels

Bluewater Red Canyon Showcase, near Prewitt, 2010

1.5 tons per acre

1.5 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0.84 tons per acre 100-hour fuels • 0.61 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels

Black Range/ Sierra, near Winston, 2011

3 tons per acre

2.94 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 1.66 tons per acre 100-hour fuels • 1.22 tons per acre 10-hour fuels • 0.06 tons per acre 1-hour fuels

Ocate A, near Ocate, 2013

5 tons per acre

4.85 tons per acre total wood fuels

1.45 tons per acre 1000-hour fuels • 3.34 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.06 tons per acre 1-hour fuels

Ocate B, near Ocate, 2015

7.5 tons per acre

7.58 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 3.53 tons per acre 100-hour fuels • 3.88 tons per acre 10-hour fuels • 0.17 tons per acre 1-hour fuels

Ruidoso Schools, near Ruidoso, 2012

10 tons per acre

9.74 tons per acre total wood fuels

6.10 tons per acre 1000-hour fuels • 1.27 tons per acre 100-hour fuels • 2.18 tons per acre 10-hour fuels • 0.20 tons per acre 1-hour fuels

Northridge (Road 18), near Gallinas, 2011

15 tons per acre

15.94 tons per acre total wood fuels

4.51 tons per acre 1000-hour fuels • 4.15 tons per acre 100-hour fuels • 6.69 tons per acre 10-hour fuels • 0.59 tons per acre 1-hour fuels

Monument Canyon, near Jemez Springs, 2011

20 tons per acre

20.10 tons per acre total wood fuels

7.98 tons per acre 1000-hour fuels • 7.06 tons per acre 100-hour fuels • 4.87 tons per acre 10-hour fuels • 0.19 tons per acre 1-hour fuels

Monument Canyon, near Jemez Springs, 2011

25 tons per acre

23.53 tons per acre total wood fuels

10.22 tons per acre 1000-hour fuels • 4.16 tons per acre 100-hour fuels • 8.85 tons per acre 10-hour fuels • 0.30 tons per acre 1-hour fuels

Griego, near Las Dispensas, 2012

30 tons per acre

28.84 tons per acre total wood fuels

22.04 tons per acre 1000-hour fuels • 5.40 tons per acre 100-hour fuels • 1.22 tons per acre 10-hour fuels • 0.17 tons per acre 1-hour fuels

Ensenada, near Tres Piedras, 2016

35, 40, 45 tons per acre

THESE PHOTOGRAPHS ARE CURRENTLY MISSING FROM NMFWRI'S COLLECTION. IF YOU HAVE SUCH PHOTOGRAPHS, PLEASE CONTACT US.

50 tons per acre

47.51 tons per acre total wood fuels

34.75 tons per acre 1000-hour fuels • 6.28 tons per acre 100-hour fuels • 5.92 tons per acre 10-hour fuels • 0.57 tons per acre 1-hour fuels

Griego, near Las Dispensas, 2012

Piñon-Juniper : All fuels

0.5 tons per acre

0.48 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0.42 tons per acre 100-hour fuels • 0 tons per acre 10-hour fuels • 0.06 tons per acre 1-hour fuels

Cerro del Aire, near Tres Piedras, 2013

1 ton per acre

0.98 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0.42 tons per acre 100-hour fuels • 0.31 tons per acre 10-hour fuels • 0.26 tons per acre 1-hour fuels

Guadalupe Mountain, near Cerro, 2015

1.5 tons per acre

1.5 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 0.30 tons per acre 10-hour fuels • 0.37 tons per acre 1-hour fuels

Santa Fe Open Space, near Santa Fe, 2010

3 tons per acre

3.01 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 0.83 tons per acre 100-hour fuels • 2.13 tons per acre 10-hour fuels • 0.05 tons per acre 1-hour fuels

Cuba W, near Cuba, 2008

5 tons per acre

5.06 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 4.64 tons per acre 100-hour fuels • 0.31 tons per acre 10-hour fuels • 0.11 tons per acre 1-hour fuels

Ocate B, near Ocate, 2015

7.5 tons per acre

7.54 tons per acre total wood fuels

2.56 tons per acre 1000-hour fuels • 3.37 tons per acre 100-hour fuels • 1.54 tons per acre 10-hour fuels • 0.06 tons per acre 1-hour fuels

Cerro del Aire, near Tres Piedras, 2013

10 tons per acre

10.69 tons per acre total wood fuels

0 tons per acre 1000-hour fuels • 5.16 tons per acre 100-hour fuels • 5.04 tons per acre 10-hour fuels • 0.49 tons per acre 1-hour fuels

BLM Boy Scout, near Santa Cruz, 2013

15 tons per acre

15.39 tons per acre total wood fuels

6.87 tons per acre 1000-hour fuels • 2.97 tons per acre 100-hour fuels • 5.29 tons per acre 10-hour fuels • 0.26 tons per acre 1-hour fuels

Santa Fe Open Space, near Santa Fe, 2010

20 tons per acre

20.99 tons per acre total wood fuels

14.27 tons per acre 1000-hour fuels • 5.81 tons per acre 100-hour fuels • 0.91 tons per acre 10-hour fuels • 0 tons per acre 1-hour fuels

Cerro Montoso, near Tres Piedras, 2014

25 tons per acre

23.74 tons per acre total wood fuels

14.66 tons per acre 1000-hour fuels • 3.38 tons per acre 100-hour fuels • 5.58 tons per acre 10-hour fuels • 0.11 tons per acre 1-hour fuels

Coyote Peak, near Mogollon, 2010

30 tons per acre

32.50 tons per acre total wood fuels

23.57 tons per acre 1000-hour fuels • 2.50 tons per acre 100-hour fuels • 6.10 tons per acre 10-hour fuels • 0.33 tons per acre 1-hour fuels

Guadalupe Mountain, near Cerro, 2015

Appendix A
Fuel Transect Sampling Procedure

The Brown's fuels transect sampling procedure described here assumes that the sampling strategy has already been selected and the macroplot has already been located.

PRELIMINARY SAMPLING TASKS

There are a number of preparations that need to be made before proceeding into the field. First, all equipment and supplies for fuels sampling must be purchased and packed for transport into the field. Since travel to plots is usually by foot, supplies and equipment should be placed in a comfortable daypack or backpack. It is important that there be spares of each piece of equipment so that an entire day of sampling is not lost when something breaks. Spare equipment can be stored in the vehicle rather than the backpack. Be sure all equipment is well maintained and there are plenty of extra supplies such as plot forms, map cases, and pencils.

Plot forms should be transported into the field using a plastic, waterproof map protector or plastic bag. The day's sample forms should always be stored in a dry place (i.e., office or vehicle) and not be taken back into the field for the next day's sampling.

If the sampling project is to re-measure previously installed plots, then it is recommended that plot sheets from the first measurement be copied and brought to the field for reference. These data can be valuable for help in relocating the plot. Plot locations and/or directions should be readily available and provided to the crews in a timely fashion.

The crew boss is responsible for all sampling logistics including the vehicle, plot directions, equipment, supplies, and safety. The initial sampling tasks of the field crew should be assigned based on field experience, physical capacity, and sampling efficiency, but sampling tasks should be modified as the field crew gains experience and shared to limit monotony. Three people allow the most efficient sampling of down debris. There should never be a one-person field crew for safety reasons, and any more than three people will probably result in some people waiting for tasks to be done and cause unnecessary trampling on the plot. Assign one person as data recorder and the other two as samplers.

Monitoring for fuel loading requires 12 specific tasks for each sampling plane:

1) Layout the measuring tape, which defines the sampling plane.
2) Measure the slope of the sampling plane.
3) Count FWD.
4) Measure CWD.
5) Measure depth of the litter.
6) Measure depth of the duff.
7) Estimate cover of live woody species.
8) Estimate cover of dead woody species.
9) Estimate average height of live and dead woody species.
10) Estimate cover of live non-woody species.
11) Estimate cover of dead non-woody species.
12) Estimate average height of live and dead non-woody species.

MODIFYING SAMPLING

We suggest sampling over a 60-foot distance with an addition 15 feet of buffer provided to keep from disturbing fuels around the plot center. The 60-foot plane is the shortest recommended for sampling CWD; however, there are instances of high fuel loads, in slash for instance, where shorter planes for DWD may be justified. If the group doing the monitoring wants to use shorter (or longer) sampling planes based on research or expert knowledge, the database we use can accommodate that data.

Additionally, the field crew does not have to use the suggested locations for sampling duff/litter and vegetation. As long as they are thoughtfully placed (for instance, do not sample duff/litter in an area where you will be sampling FWD) these measurements can be made elsewhere along the sampling plane.

LOCATING AND ESTABLISHING LINE TRANSECTS

Three transects are established that originate at the plot center and extend out 75 feet horizontal distance at azimuths of 0, 135, 270 degrees. This transect configuration was chosen to avoid sampling bias on sloped land, where it is possible that CWD may be oriented in one direction. This configuration of transects should pick up CWD logs that are lying parallel to the slope, perpendicular to the slope, and across slope.

Laying Out the Measuring Tape

A measuring tape laid close to the soil surface defines the sampling plane. The sampling plane extends from the top of the forest floor to a height of six feet. When laying out the tape, crew members need to step so that they minimize trampling and compacting fuels – DWD, duff/litter and vegetation. Have one crew member stand at plot center holding the zero end of the tape, then, using a compass, he or she will guide second crew member on a bearing of 0 degrees true north. The second sampler will move away from plot center, following the directions of the first crew member, until he or she reaches the 75-foot mark on the tape. The process of laying out the tape is typically more difficult than it sounds because the tape needs to be straight (Figure 1). If the tape zigzags, the selection of pieces is biased, and re-measurement of transect lines and tally pieces for future change detection cannot be done properly. It pays to sight carefully with the compass and identify potential obstructions before rolling out the tape.

The second crew member must follow the directions given by the first in order to stay on line. Once the second crew member is at the appropriate location, the first crew member will hold the zero end of the tape over plot center while the second crew member pulls the tape tight. Together, move the tape down as close to the ground as possible without struggling to get it so close to the ground that the debris to be measured is disturbed. In most cases, the tape will end up resting on some of the DWD and low vegetation but below the crowns of shrubs, seedlings, etc.

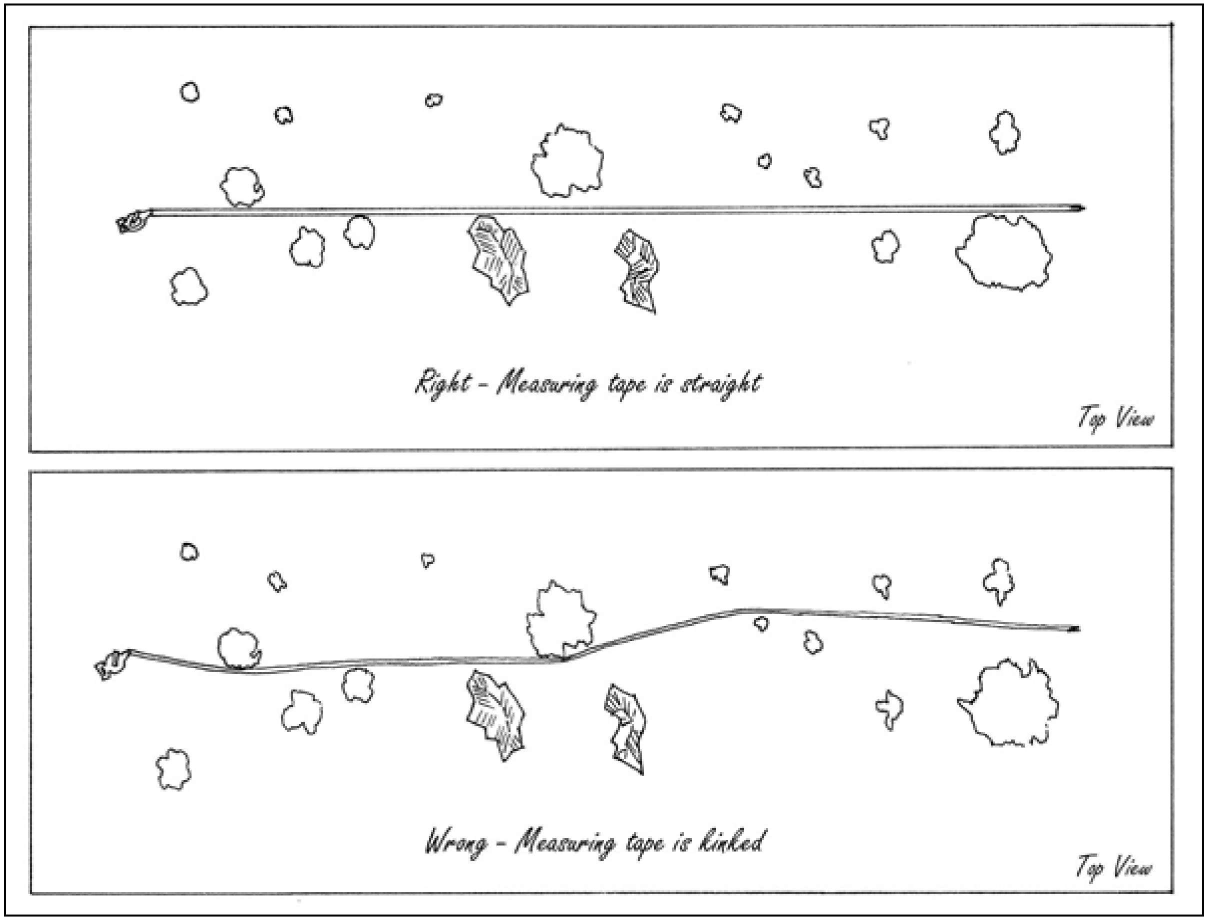


Figure 1. The measuring tape, which represents the lower portion of the sampling plane, should be as straight as possible. If the tape is not straight it needs to be offset left or right until it can be established without kinks or bends.

Once established, anchor the tape and do not move its position until all sampling is finished for the sampling plane. Most tapes have a loop on the zero end that a spike can be placed through to keep it anchored, and a spike or stick though the handle on the other end of the tape will hold it in place. Roll-up tapes usually have a winding crank that can be flipped so that the knob points toward the reel. In this position the knob will lock the reel so the tape won't unwind when it is pulled tight. Mark the 0-foot and 75-foot marks along the tape so that the plane can be easily reestablished.

DETERMINING THE SLOPE OF THE OF THE MEASURING TAPE

Once the tape has been secured, use a clinometer to measure the percent slope of the line. Aim the clinometer at the eye level of sampler at the other end of the line (Figure 2). If there is a height difference of the samplers adjust the height where you are aiming so that the slope reading is accurate. Carefully, read the percent slope from the proper scale in the instrument and report to the data recorder who will enter it in the field data sheet.

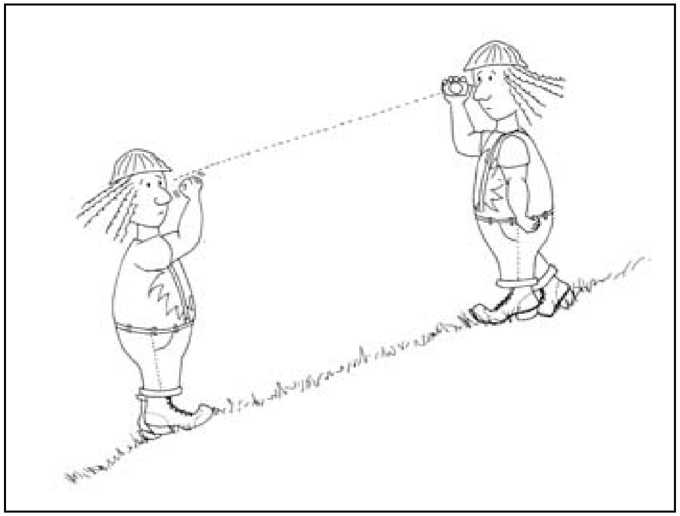


Figure 2. Measure the slope of each line by aiming the clinometer at eye level on the sampler at the opposite end of the measuring tape, then reading and recording the percent slope seen on the scale in the instrument.

PRECISION STANDARDS

Use these standards when collecting data (Table 2).

Table 2. Precision guidelines for FL sampling.

Component	Standard
Slope	+/- 5 percent
FWD	+/- 3 percent
CWD diameter	+/- 0.5 in./1 cm
CWD decay class	+/- 1 class
Duff/litter depth	+/- 0.1 in./0.2 cm
Percent litter estimation	+/- 10 percent
Vegetation cover estimation	+/- 1 class
Vegetation height estimation	+/- 0.5 ft/0.2 m

FINISHING TASKS

The most critical task before moving to the next sampling plane or plot is to make certain that all of the necessary data has been collected. This task is the responsibility of the data recorder. Also, the recorder should write down any comments that might be useful. For instance, you might comment on some unique characteristic on or near the plot that will help samplers relocate the plot. Include notes about other plot characteristics such as, “evidence of deer browse” or, “deep litter and duff around trees”. Finally, collect the sampling equipment and move ahead to start sampling the next plane.

I. DEAD and DOWN WOODY DEBRIS

Before sampling any DWD the terms “woody”, “dead” and “down” need to be understood so data gathered with the FL methods is consistent between field crews. “Woody” refers to a plant with stems, branches or twigs that persist from year to year. The structural parts support leaves, needles, cones and so forth and it’s these structural components that are tallied along the sampling plane.

“Dead” DWD has no live foliage. Sampling deciduous species in the dormant season can be a challenge and should only be done by crews with the expertise to identify dormant vs. dead trees and shrubs.

FINE WOODY DEBRIS

Pieces of FWD that are “woody”, “dead” and “down” fall into three general categories: 1) pieces that are not attached to the plant stems or tree boles where they grew and have fallen to the ground, 2) pieces that are not attached to the plant stems or tree boles where they grew but are supported above the ground by live or dead material and 3) pieces attached to stems or boles of shrubs or trees that are themselves considered “dead” and “down”. Note that it is possible for FWD to be considered “dead” even though it has green foliage attached because the rules consider any piece severed from the plant where it grew to be both “dead” and “down”. Fresh slash and broken branches are examples of green material considered “dead”. Do not sample dead pieces that are still attached to dead (unless “down”) and live shrubs and trees, even if those pieces are hanging from the plant where they grew. Piece angle of FWD is not critical in determining whether or not it is “down”. Do not tally needles, grass blades, cones, cone scales, bark pieces, etc., as they are not “woody.” This material is considered litter and is measured as part of the duff/litter profile.

COARSE WOODY DEBRIS

CWD at an angle of greater than 45 degrees above horizontal where it passes through the sampling plane should only be considered “down” if it is the broken bole of a dead tree where at least one end of the bole is touching the ground (not supported by its own branches, or other live or dead vegetation). If CWD is at an angle of 45 degrees or less above horizontal where it passes through the sampling plane then it is “down” regardless of whether or not it is broken, uprooted, or supported in that position (Figures 3 and 4).

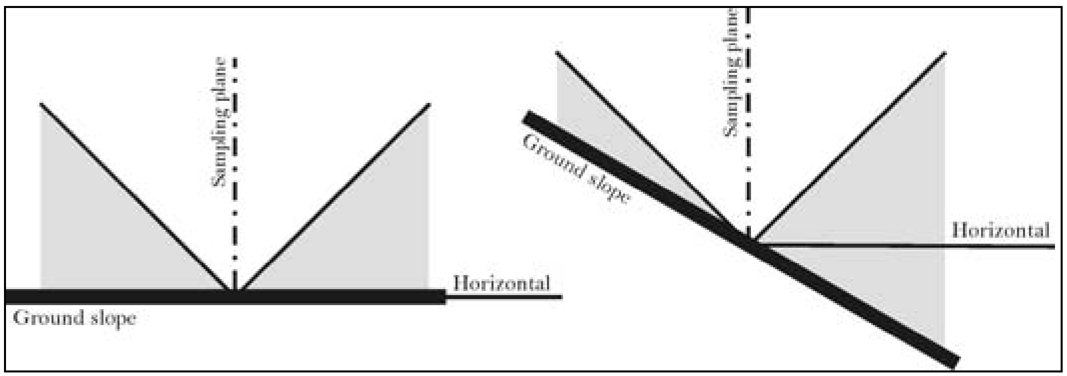


Figure 3. CWD pieces crossing through the sampling plane at an angle less than 45 degrees from horizontal (represented by the shaded areas in the figure) are always considered to be "down". Some CWD leaning greater than 45 degrees may be considered “down”. See the text for details.

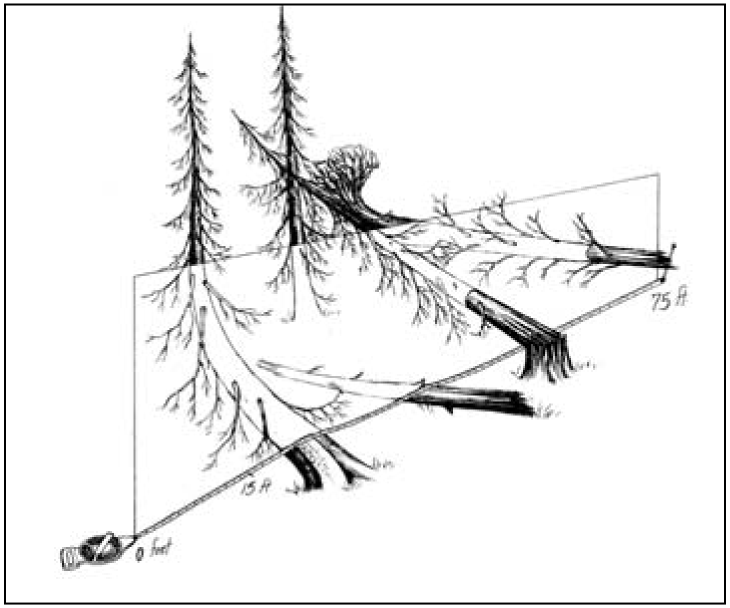
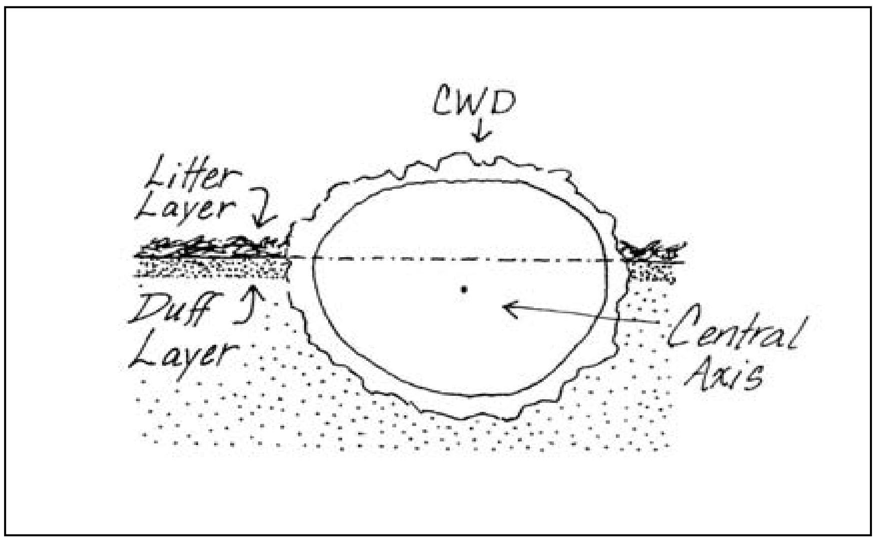


Figure 4. All of the pieces crossing through the sampling plane in this illustration would be considered "down".



Do not sample a piece of CWD if you believe the central axis of the piece is lying in or below the duff layer where it passes under the sampling plane (Figure 5).

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DETERMINING PIECE SIZE

FWD is tallied within 3 size classes: 1-hour, 10-hour, or 100-hour. Often it will be clear by just looking what size class the pieces belong in.

The go/no-go gauge is a tool that can speed up the sampling process (Figure 6). The gaps in the tool correspond to the 1-hour and 10-hour fuel sizes and they allow quick assessment of fuel size.

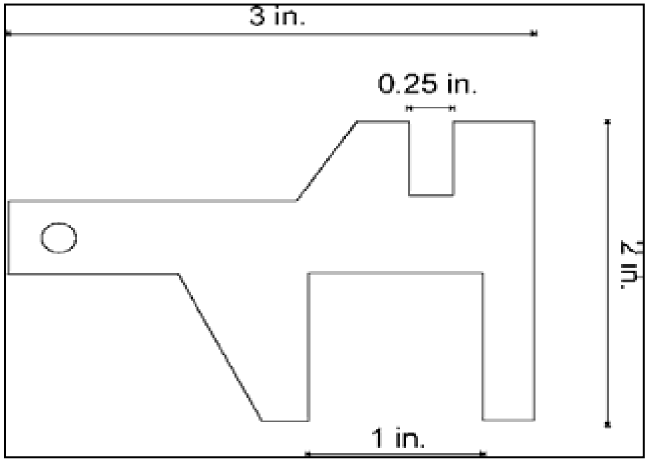

Figure 6. A go/no-go gauge can help samplers tally 1-hr, 10-hr and 100-hr fuels more quickly and accurately than wooden dowels.

DWD SAMPLING DISTANCES

DWD is sampled along a certain portion of the sampling plane based on the size of the piece (Figure 7). The 1-hour and 10-hour fuels are sampled from the 15-foot (5-meter) to the 21-foot (7-meter) marks along the plane, the 100-hr fuels are sampled from the 15-foot (5-meter) to the 50-foot (10-meter) marks and pieces 3 inches (8 cm) and larger are sampled between the 15-foot (5-meter) and 75-foot (25-meter) marks along the plane. The distances for sampling FWD are shorter than for CWD because pieces of FWD are more numerous, so a representative sample can be obtained with a shorter sampling distance. DWD is not measured along the first 15 feet (5meters) of the tape because fuels are usually disturbed around plot center by the activity of the sampling crew. Record the number of sampling planes per plot.

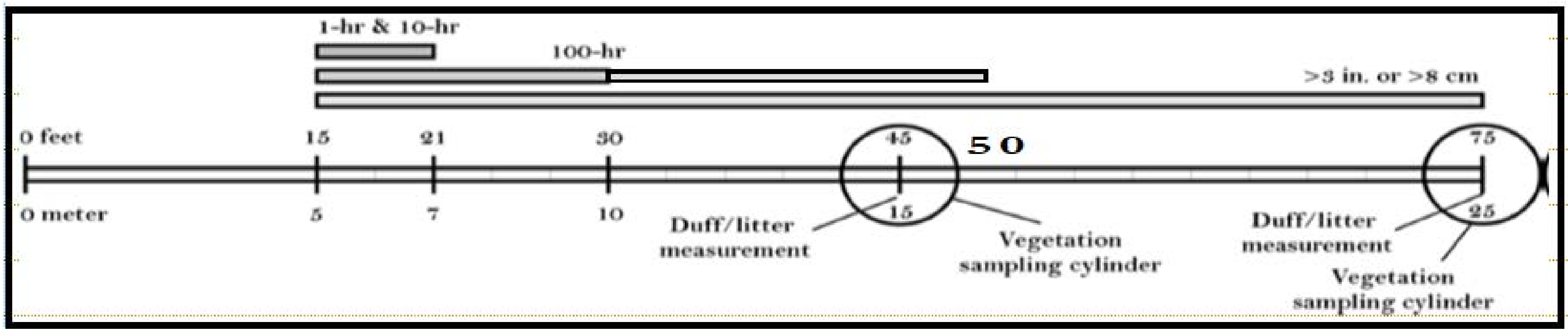

Figure 7. Dead fuels, duff/litter, and vegetation data are recorded at specific locations on or along each sampling plane. The 1-hour and 10-hour fuels are sampled from the 15-foot to the 21-foot marks along the plane, the 100-hr fuels are sampled from the 15-foot to the 50-foot marks and pieces 3 inches and larger are sampled between the 15-foot and 75-foot marks along the plane. Note: the diagram indicates measuring 100-hr fuels to only 30 feet, but we advocate measuring these out to 50 feet. Duff/litter measurements are made in a representative area within a 6-foot diameter circular area at the 45-foot and 75-foot marks. The cover of live and dead vegetation is estimated within an imaginary 6-foot diameter by 6-foot high sampling cylinder at the 45-foot and 75-foot marks.

SAMPLING FWD

Because FWD is generally present in higher densities, a shorter transect will pick up an acceptable amount of tally. The transect begins at 15 feet from the subplot center and extends out either 6 feet (slope distance), as follows:

Category of FWD	Size Class	Diameter range	Transect length (slope distance)	Transect location (slope distance)
Small FWD	1	0 in to 0.24 in	6 feet	15 to 21 feet
Medium FWD	2	0.25 in to 0.9 in	6 feet	15 to 21 feet
Large FWD	3	1.0 in to 2.9 in	35 feet	15 to 50 feet

Note that the FWD transects are slope distance not horizontal distance. The formulas used to estimate biomass from the data contain an adjustment for slope.

Count the 1-hour and 10-hour fuels that pass through the sampling plane from the 15- foot to the 21-foot marks on the measuring tape. Remember the plane extends from the top of the litter layer vertically to a height of six feet. Each piece needs to be classified as 1-hour or 10-hour fuel by the diameter where it intercepts the sampling plane, defined by one edge of the measuring tape. Samplers should use the go/no-go gauge discussed earlier to classify fuels that are close to the size class bounds. Often pieces above the ground will cover pieces below. It is important to locate all the pieces that intercept the plane in order to get accurate fuel load data (Figure 8). Report the counts, or count out loud, to the data recorder who will enter them on the data sheet.

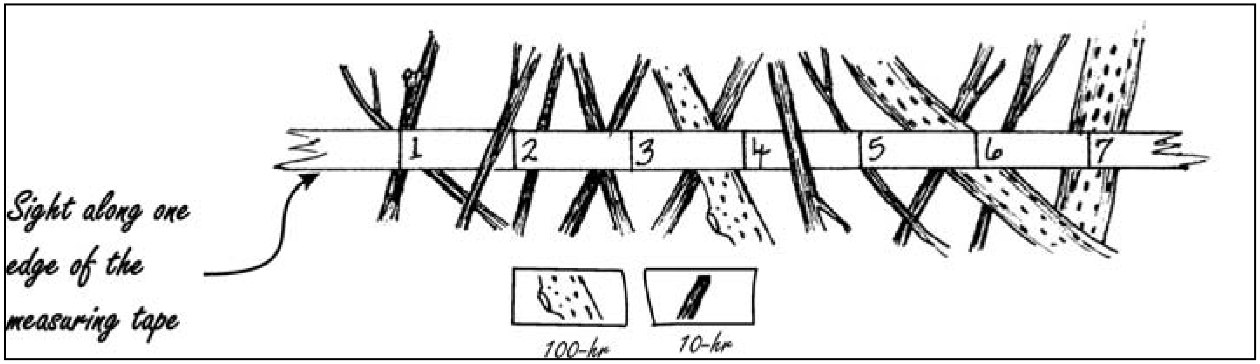

Figure 8. Tally pieces that intercept the sampling plane both above and below the measuring tape. Focus on one edge of the tape to make counting easier. Be sure to note any lower fuels that are hidden by pieces above. In this illustration there are 11 1-hour and 3 10-hour fuels.

Use the same basic procedure to count the 100-hour fuels that pass through the sampling plane from the 15-foot (5-meter) to the 50-foot (10-meter) marks on the tape. Report the information to the data recorder who will enter the count on the data sheet.

Main Points for Fine Woody Debris (FWD)

1. Only sample Fine Woody Debris (FWD) that intersects a plane from the ground to a height of 6 feet.
2. Individual diameters are not recorded for FWD.
3. Count a piece of FWD if it intersects the transect. Only count a piece if the twig, branch, wood fragment, or shrub/tree bole which are woody. Do not count pine or fir needles or cones, or non-woody parts of a tree or shrub.
4. Accumulate the number of pieces counted within each size class and enter the total count on one record for the subplot. If there is no tally on a transect, enter zeros for the count.

5. If rocks, logs, or other obstructions are present along the transect, include any FWD that is present on top of these obstructions in the respective FWD counts.
6. If a residue pile intersects the FWD transect at any point along the 15- to 21-foot section, do not measure FWD on this transect. It is too subjective determining exact boundaries of the pile, and how they relate to the exact point on the transect line. Make a note in the Comment section, and take another transect.

SAMPLING CWD

The CWD sampling plane is six feet (two meters) high and extends from the 15-foot (5-meter) mark to the 75-foot (25-meter) mark along the measuring tape. Sample CWD that intercepts the sampling plane and meets the dead, down and woody requirements discussed above. In general, at least two fields are recorded for each piece of CWD: diameter and decay class. Proportion of char, log length, diameter of the large end, point of intersect and estimations of volume lost to decay are additional data fields that may be collected for each piece of CWD. Diameter measurement and decay class are determined on each piece of CWD where its central axis passes through the sampling plane. Measure diameter perpendicular to the central axis of each piece to the nearest 0.5 inch (1 cm) (Figure 9). If a piece crosses through the sampling plane more than once, measure it at each intersection.

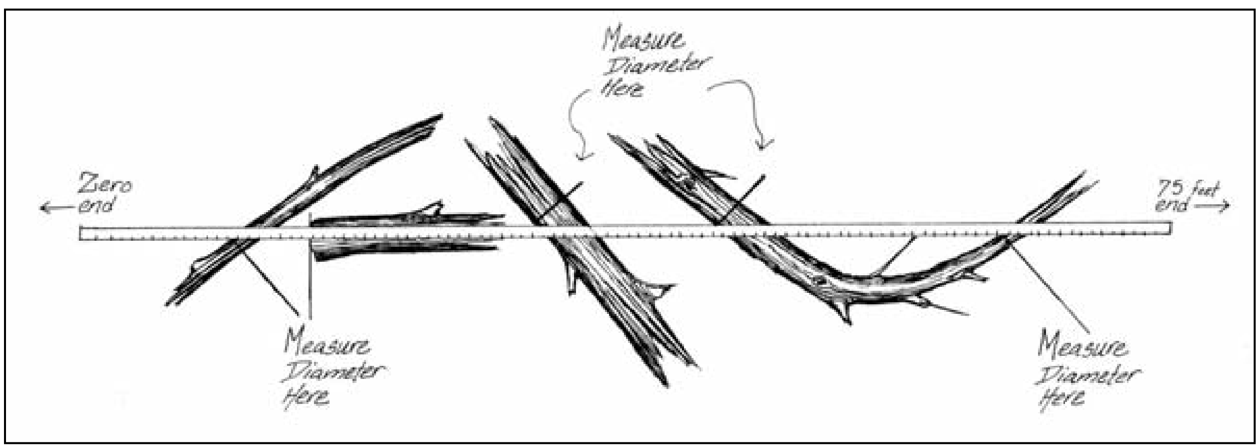

Figure 9. Measure the diameter of CWD crossing through the sampling plane perpendicular to the central axis of the piece. If a curved piece passes through the plane more than once measure its diameter at each intersection.

The diameter is most commonly measured by wrapping a diameter tape around the bole if possible, or using calipers. For pieces that are not round in cross-section because of missing chunks of wood or "settling" due to decay, measure the diameter in two directions and take an average, and enter the average in the diameter field on the data sheet. This technique applies to intersect, small-end, and large-end diameters.

If the transect intersects the log at a splintered end, record the diameter at this location as the intersect diameter. If the splintered end appears to be two separate pieces (i.e., a major split located just at the end) treat it as one log and take a diameter around the end (take two measurements if it is odd shaped).

Main Points for Coarse Woody Debris (CWD)

1. Tally a piece if its central longitudinal axis intersects the transect.

2. Tally dead trees that are leaning > 45 degrees from vertical. Do not tally live tress or standing dead trees and stumps that are still upright and leaning < 45 degrees from vertical. Most CWD will be lying on the ground.

3. The minimum length of any tally piece is 3.0 feet. When CWD pieces are close to 3 feet, measure the length to the nearest 0.1 foot to determine if it is ≥ 3.0 feet.

4. Decay class of the piece determines whether or not the piece is tallied.

For decay class 1 to 4: tally a piece if it is ≥ 3.0 inches in diameter at the point of intersection with the transect. The piece must be ≥ 3.0 feet in length and ≥ 3.0 inches in diameter along that length. If the intersect diameter is close to 3.0 inches, measure the diameter to the nearest 0.1 inch to determine if the piece qualifies (Figure 10).

For decay class 5: tally a piece if it is ≥ 5.0 inches in diameter at the point of intersection and ≥ 5.0 inches high from the ground. The piece must be ≥ 3.0 feet in length and ≥ 5.0 inches or more in diameter along that length. The reason for treating decay class 5 pieces differently is because they are difficult to identify, especially when heavily decomposed. Only pieces that still have some shape and log form are tallied—humps of decomposed wood that are becoming part of the duff layer are not tallied.

5. Tally pieces created by natural causes (examples: natural breakage or uprooting) or by human activities such as cutting only if not systematically machine-piled. Do not record pieces that are part of machine-piled slash piles or windrows, or that are part of a log "jumble" at the bottom of a steep-sided ravine in which individual pieces are impractical to tally separately.

6. Tally a piece only if the point of intersection occurs above the ground. If one end of a piece is buried in the litter, duff, or mineral soil, the piece ends at the point where it is no longer visible. Measure the diameter and length at this point.

7. If the central longitudinal axis of a piece is intersected more than once on a transect line or if it is intersected by two transect lines, tally the piece each time it is intersected (Figure 9).

8. If a piece is fractured across its diameter or length, and would pull apart at the fracture if pulled from either end or sides, treat it as two separate pieces. If judged that it would not pull apart, tally as one piece. Tally only the piece intersected by the transect line.

9. When the transect crosses a forked down tree bole or large branch connected to a down tree, tally each qualifying piece separately. To be tallied, each individual piece must meet the minimum diameter and length requirements.

10. In the case of forked trees, consider the "main bole" to be the piece with the largest diameter at the fork. Variables for this fork such as TOTAL LENGTH and DECAY CLASS should pertain to the entire main bole. For smaller forks or branches connected to a main bole (even if the main bole is not a tally piece), variables pertain only to that portion of the piece up to the point where it attaches to the main bole (see Figure 10).

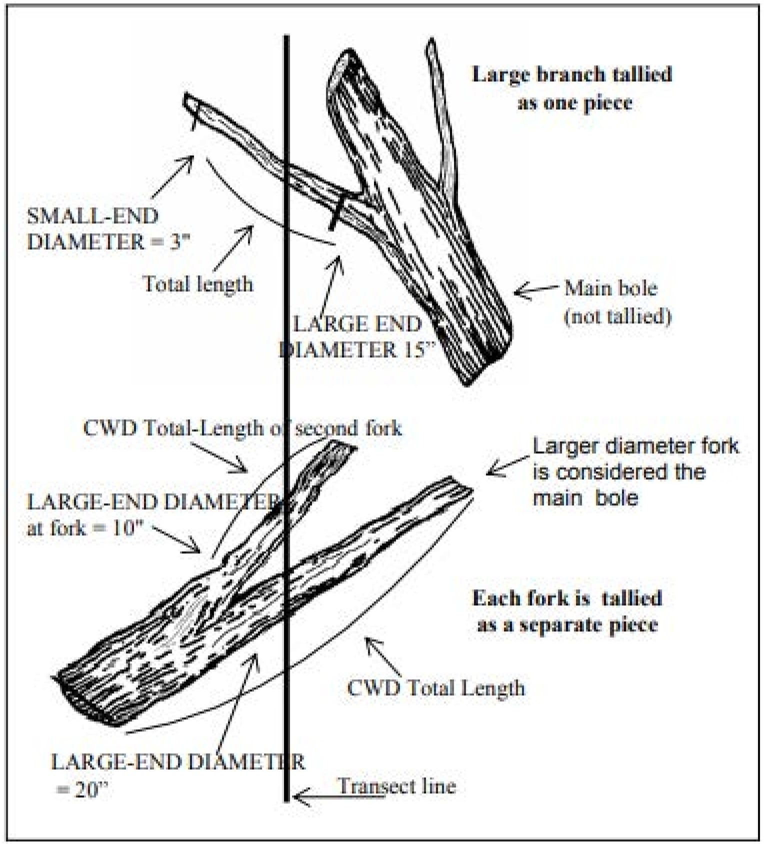

Figure 10. CWD tally rules for forked trees

Use the descriptions in Table 3 to determine the decay class for CWD at the same point where diameter measurement was made. Decay class can change dramatically from one end of a piece of CWD to the other and often the decay class at the point where the diameter measurement was taken does not reflect the overall decay class of the piece. However, by recording the decay class at the point where diameter was measured the field crew will collect a representative sample of decay classes along each sampling plane. The transect number, slope, sequential piece number (log number), diameter, and decay class for each piece are entered on the data sheet.

Table 3. Use these descriptions to determine the decay class where the log crosses the sampling plane.

Decay Class	Description
1	All bark is intact and tight. All but the smallest twigs are attached. Old needles probably still present. Solid, freshly fallen, intact logs, hard when kicked.
2	Some bark is missing (especially on fine twigs), as are many of the smaller branches. No old needles still on branches. Hard when kicked.
3	Most of the bark is missing. Most of the branches less than 1 in. in diameter also missing, but branch stubs will not pull out. Still hard when kicked, still supports its own weight, and heartwood sound.
4	Looks like a class 3 log but the sapwood is rotten. Sounds hollow when kicked and you can probably remove wood from the outside with your boot. Pronounced sagging if suspended for even moderate distances. Branch stubs pull out.
5	Entire log is in contact with the ground. Easy to kick apart but most of the piece is above the general level of the adjacent ground. If the central axis of the piece lies in or below the duff layer then it should not be included in the CWD sampling as these pieces act more like duff than wood when burned.

CWD DECAY CLASS 5 pieces can be difficult to identify because they often blend into the duff and litter layers. They must still resemble a log; therefore, the first tally rule is that they must be > 5.0 inches in diameter, > 5.0 inches from the surface of the ground, and at least 3.0 feet long. Decomposed logs that are slightly elevated 'humps' on the ground are not tallied.

If a log is case hardened (hard, intact outer sapwood shell) but the heartwood is rotten, code this log as a CWD DECAY CLASS 2. CWD DECAY CLASS 1 should be reserved for 'freshly fallen' logs that are completely intact (i.e., recent windfalls, or harvest).

II. DUFF and LITTER DEPTH MEASUREMENTS

Duff and litter are two components of the fuel complex made up of small, woody and non-woody pieces of debris that have fallen to the forest floor. The "duff/litter profile" is the cross-sectional view of the litter and duff layers. It extends vertically from the top of the mineral soil to the top of the litter layer. The depth of the duff layer, litter layer, and overall fuelbed are important components of fire models used to estimate fire behavior, fire spread, fire effects, and smoke production. The depth of the duff and litter are used to estimate the load of each component. These measurements are taken at the 45- and 75-foot locations on each transect.

DEFINITIONS

1. Litter is the layer of freshly fallen leaves, needles, twigs (< 0.25 inch in diameter), cones, detached bark chunks, dead moss, dead lichens, detached small chunks of rotted wood, dead herbaceous stems, and flower parts (detached and not upright). Litter is the loose plant material found on the top surface of the forest floor. Little decomposition has begun in this layer. Litter is defined as undecomposed or only partially decomposed organic material that can be readily identified (e.g., plant leaves, twigs, etc.).
   Litter is flash fuel – so think about it as the loose material that is exposed to the air, capable of igniting quickly and carrying a fire across the surface of the forest floor.
   Litter does not include bark that is still attached to a down log, or rotten chunks of wood that are still inside a decaying log or log end (i.e., if a decayed log end has a lot of rotten cubes or pieces laying on a log surface and exposed to air, they are considered part of the log and not litter – fire would burn differently if it hit a pile of rotten punky wood chips, cradled by the unrotted sapwood shell). If these rotten chunks have spilled out to the ground and are actually on the ground surface, then they would be included in the litter layer.
   Litter does not include animal manure.
   Microplot estimates: As you look down on the microplot, litter is the material that you see covering the surface area of the 3.0-foot radius plot.
2. Duff is the layer just below litter. It consists of decomposing leaves and other organic material. You should see no recognizable plant parts; the duff layer is usually dark decomposed organic matter. When moss is present, the top of the duff layer is just below the green portion of the moss. The bottom of this layer is the point where mineral soil (A horizon) begins.
   The duff is a soil layer dominated by organic material derived from the decomposition of plant and animal litter (pine straw, leaves, twigs, etc.) and deposited on either an organic or a mineral surface.
   As a general rule, duff depth should rarely exceed a few inches. Duff can easily weigh more than 6 times the litter.
3. The fuelbed is the accumulated mass of dead, woody material on the surface of the forest floor. It begins at the top of the duff layer, and includes litter, FWD, CWD, and dead woody shrubs. In this definition, the fuelbed does not include dead hanging branches from standing trees. We do not take a fuelbed measurement.

SAMPLING DUFF AND LITTER

The duff and litter layers lie below the sampling plane so they are not sampled using the planar intercept method. Instead, duff/litter measurements are made using a duff/litter profile at two points along each sampling plane. The goal is to develop a vertical cross-section of the litter and duff layers without compressing or disturbing the profile.

Duff/litter depth measurements are made at a point within 3 feet (1 meter) of the 45-foot (15-meter) and 75-foot (25-meter) marks along the tape. Follow the same instructions for each duff/litter measurement. At each location, select a sampling point within a 3-

foot (1-meter) radius circle that best represents the duff/litter characteristics inside the entire circle. Try to preserve the conditions of this location by walking around this point.

Samplers can make the profile using a trowel or boot heel. Carefully expose a shallow profile of the forest floor by digging out an area at the sample point using a knife, hatchet, or even your fingernails. As you dig the hole for this measurement, if you encounter a rock, root, or buried log, stop digging and take the measurements. If a boot is used, drive the heel down and drag it toward you. Mineral soil is usually lighter in color than the duff and coarser in composition, often sandy or gravelly. It is important to not disturb the profile by compacting it on successive scrapes. The profile that is exposed should allow an accurate measurement of duff/litter depth (Figure 11).

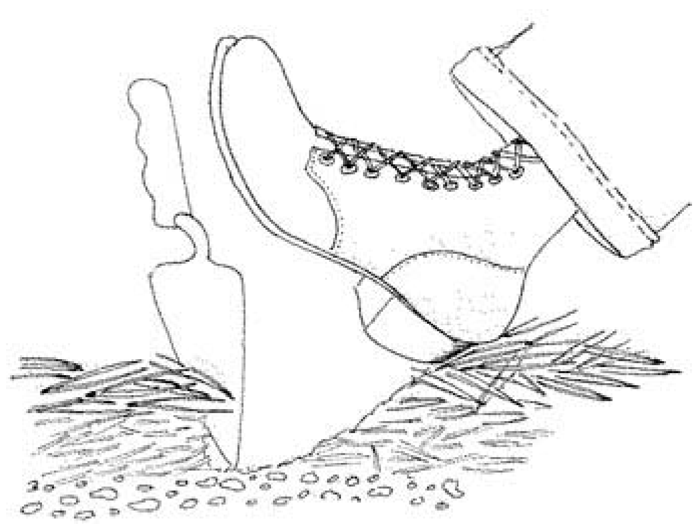

Figure 11. Use you boot to carefully pull the litter and duff layers away, until you are down to mineral soil.

Use a plastic ruler to take separate measurements of the depths of the duff and litter to the nearest 0.1 in. (0.2 cm) (Figure 12). The height of the litter should be measured from the top of the loose material located at the sample point. Crews should be absolutely sure they are measuring deep duff depths, instead of mineral soil layers or parts of the litter layer. If unsure of the bottom of the duff layer, crews should feel the texture of the suspect material in their hand, and reject it if it feels like soil. Report the duff/litter depth measurements to the data recorder who will enter the data on the field form.

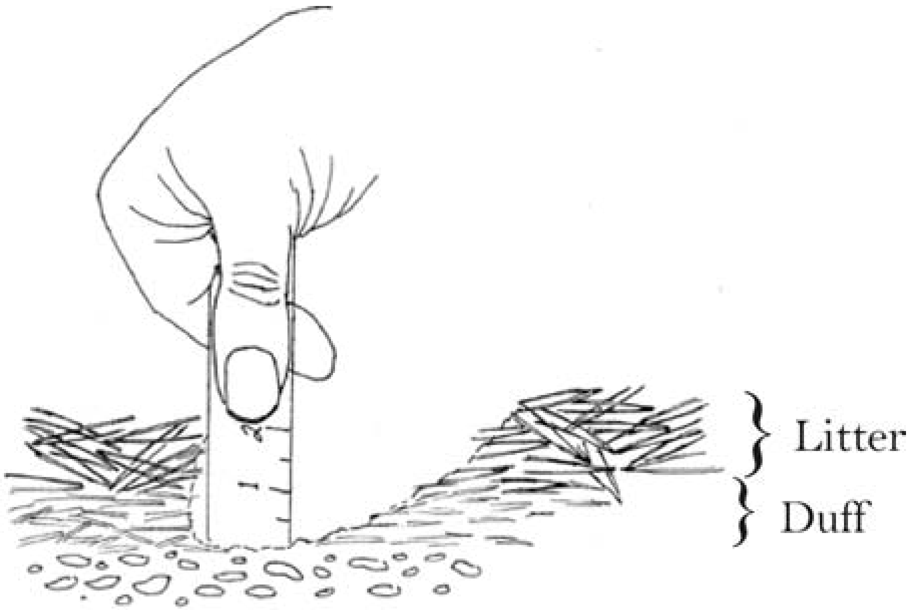

Figure 12. Use a clear plastic ruler to measure duff and litter depth. Here, both measurements are about 1 in.

Duff and litter measurements are most easily and accurately made on the vertical portion of the profile as long as that portion of the profile is representative of the true duff/litter depth (it wasn't negatively impacted when the profile was developed). Sometimes the most vertical part is where the back of the trowel blade or boot heel went in, as depicted in Figures 11 and 12 and sometimes it is along one side of the profile.

III. BIOMASS OF UNDERSTORY MATERIAL

The final component of the total fuel loading on a plot to be sampled is the biomass of live and dead understory material. The 6.0-foot diameter microplot will be used to estimate the percent cover and height of live and dead shrubs, live and dead herbs (includes grasses) and litter.

Both trees and shrubs are woody species. They are easily identified because their stems persist and growth does not have to start at ground level each growing season. Trees generally have a single, unbranched stem near ground level. Shrubs, which include woody vines, generally have multiple stems near ground level.

Herbs are non-woody herbaceous plants, but also include ferns, mosses, lichens, sedges, and grasses. Although the aerial portions of many forbs and grasses die by the end the growing season, an estimate of live and dead biomass on a given date will help fire modelers predict the life stage of herbaceous material during the year, allowing them to estimate fire danger patterns across the landscape. One way to help identify non-woody plants is to remember that, in general, factors like wind, rain, snow, and so forth, collapse herb foliage and stems back to or near the ground between growing seasons.

Small trees, shrubs, and herbs influence fire behavior because their branches and foliage are suspended above the ground, allowing efficient heating and burning of the parts. Dense, suspended fuels can lead to fires that are difficult or impossible to control. By estimating the cover and heights of woody and non-woody vegetation, fire managers can estimate the volume, density and biomass of vegetation. All three of the characteristics are strongly associated with fire behavior.

Sampling Vegetation Cover and Height

Estimate vegetation cover and height at the 45-foot and 75-foot marks on the measuring tape. Field crews will estimate the vertically projected cover of vegetation within a 6-foot tall by 6-foot diameter imaginary sampling cylinder. Use the marks on the measuring tape to help visualize the 6-foot diameter. For instance, when standing at the 45-foot mark, the 42-foot and 48-foot marks will identify the boundary of the cylinder along the tape. Use that measurement to get a good idea of the distance needed on each side, perpendicular to the tape, required to form the imaginary base of the cylinder. Most people have an arm's width spread that is about six feet. Each sampler should measure his or her arm span and use that measurement to help them visualize the sampling cylinder.

The cover of plants, especially of the foliage, is a function of the life stage of the plant. Early in the season many plants may not have completely leafed out, in mid-season plant cover reaches its maximum and then in late season plant material, especially herbaceous vegetation, moves from the live to dead class. Clearly, where vegetation is concerned, it is important to sample at the same life stage when repeat monitoring, and this should be taken into account when starting a monitoring program. For example, in the Southwest, fires historically burned in the spring, so the best assessment of surface fuels, in terms of potential fire fuels, probably would be made in the spring. However, other factors may keep monitoring crews from working in the spring, making life stage only one of many factors in designing a monitoring program.

Eight attributes are measured at each vegetation sampling point. These values are four cover estimations for vegetation: 1) live woody species (trees and shrubs), 2) dead woody species, 3) live non-woody species (herbs) and 4) dead non-woody species; and the corresponding height measurements for each component. “Cover” is the vertically projected cover contributed by each of the four categories within the sampling cylinder.

For live fuels, estimate the percent of the microplot area that is covered by live plant material. Include whole plants that are entirely green (or alive) and the live branches on plants that are a mixture of live and dead plant parts. Include live branches or leaves that extend into the microplot area from a plant that is actually rooted outside of the microplot. Do not include material above 6 feet.

For dead fuels, estimate the percent cover using the same procedures as live fuels, but include plants that are entirely dead and branches or leaves that are dead but still attached to a live plant. Dead plant material must be clearly visible. Do not include dead material that has fallen to the ground. Cover estimates are made by visualizing an outline around the dead material and accumulating this across the microplot.

For both live and dead fuels, estimate cover by imagining a bright light above the microplot and casting shadows on the ground. The percent of the ground covered by the vegetation shadows inside the 6-foot (2-meter) diameter sampling area is being estimated. Do not include the cover of the cross-sectional area of upright stems in the live or dead woody cover estimate. Fire acts upon upright stems differently than it does upon the more horizontal fuels; thus, upright stems are not included in cover estimates.

Microplot (3 ft radiuus) Cover Estimation Guide (Hint: 8.5” x 11” = about 2.3% coverage)

%	Area (sq ft)	Diameter (ft)	Square (ft)
1	0.28	0.60	0.53
10	2.83	1.90	1.68
20	5.65	2.28	2.38
30	8.48	3.29	2.91
40	11.31	3.79	3.36
50	14.14	4.24	3.76
60	16.96	4.65	4.12
70	19.79	5.02	4.45
80	22.62	5.37	4.75
90	25.45	5.69	5.04
100	28.27	6.00	5.32

Two conditions make cover estimations difficult and, frequently, inaccurate. First, the equations used to estimate biomass assume that all of the plant parts for each species are included in the cover and height estimation. In other words, when looking at the cover of a woody shrub species, samplers need to estimate the cover of all the parts, even things like the foliage, which are not "woody". Second, estimating cover is not something people do very often; it is only with practice and experience that good estimations of plant cover can be made. Fortunately, the cover classes used here are typically 10 percent, so the precision of cover estimates are secondary to accuracy (Table 4).

Table 4. Cover of each of the four vegetation categories is recorded in one of the following classes.

Code	Cover
0	No cover
0.5	>0-1 percent cover
3	>1-5 percent cover
10	>5-15 percent cover
20	>15-25 percent cover
30	>25-35 percent cover
40	>35-45 percent cover
50	>45-55 percent cover
60	>55-65 percent cover
70	>65-75 percent cover
80	>75-85 percent cover
90	>85-95 percent cover
98	>95-100 percent cover

In addition to the cover estimates, samplers will make four height estimates at each vegetation sampling location, two for the average heights of the live and dead woody species and two for the average heights of the live and dead non-woody species. Make your height estimate by noting the maximum height of all the plants in the class and then recording the typical or average of all the maximum heights. Some people like to envision a piece of plastic covering just the plants in one class then estimating the average height of the plastic above the ground. A fast way to make accurate height assessments is for samplers to measure their ankle, knee and waist heights then estimate vegetation height based on those points. Estimate height to the nearest 0.1 foot (0.2 m). Maximum height is 6 feet.

IV. OPTIONAL MEASURES

These variables are not usually measured, but could be collected in special cases. Only use these measures if specifically stated.

SAMPLING RESIDUE PILES

The line transect method is not practical when sampling CWD within piles and windrows. Piles and windrows are located and sampled on the plot, whether or not they intersect a transect.

Piles and windrows created directly by human activity, and log piles at the bottom of steep-sided ravines in which individual pieces are impossible to tally separately, are more efficiently sampled by using the following instructions. However, loose CWD in piles created by wind throw, landslides, fires, and other natural causes should be tallied using line transects unless it is physically impossible to measure the pieces in the natural pile.

For a pile to be tallied, the following criteria must be met:

- The pile's center must be within 24.0 horizontal feet of plot center, and
- It contains pieces of CWD ≥3 inches diameter that would be impossible to tally separately.

Use the PILE DENSITY variable to estimate the percent of the pile that contains woody material ≥ 3 inches. The pile is assigned to the condition class in which the pile center lies.

Apply the following steps to determine the center of a pile or windrow:

1. Determine the longest axis of a pile.
2. Determine the midpoint of this axis.
3. Project a line through this midpoint that is perpendicular to the axis determined in step 1.
4. Determine the midpoint of the segment of this projected line that crosses the pile.
5. This is the center of the pile.

Piles that cross the 24.0-foot fixed-radius subplot boundary: If the center of a pile is within 24.0 horizontal feet of plot center, tally the pile, recording the dimensions of the entire pile even if part of the pile is beyond 24.0 feet. If the center of a pile is more than 24.0 horizontal feet of subplot center, do not tally the pile or any portion of the pile.

DIAMETER AT THE SMALL END OF LOG

Record the code indicating the diameter at the piece's small end. The diameter is recorded to the nearest inch. The DIAMETER AT THE SMALL END occurs either at (1) the actual end of the piece, if the end has a diameter ≥ 3.0 inches, or (2) at the point where the piece tapers down to 3.0 inches in diameter. If the end is splintered or decomposing (sloughing off), measure the diameter at the point where it best represents the overall log volume.

DIAMETER AT LARGE END OF LOG

Measured for wildlife concerns. Record the diameter of the large end of the log to the nearest 0.1 inch. The large end will occur either at a broken or sawn end, at a fracture, or at the root collar. If the end is splintered or decomposing (sloughing off), measure the diameter at the point where it best represents the overall log volume. If a piece is broken but the sections are touching consider that one log. If the broken sections are not touching then consider them two logs and record the diameter of the large end of the piece that is passing through the sampling plane.

LOG LENGTH

Important for wildlife concerns and useful for rough determination of piece density. CWD TOTAL LENGTH is the length of the piece that lies between the piece's recorded DIAMETER AT THE SMALL END and DIAMETER AT THE LARGE END. For curved logs, measure along the curve. The minimum log length is 3.0 feet before it is a valid tally log. Record length of CWD to the nearest 0.1 feet. If a piece is broken but the two parts are still touching then record the length end-to-end (A) or sum the lengths for broken pieces not lying in a straight line (B). If piece is broken and the two parts are not touching then only measure the length of the piece that intercepts the sampling plane (C).

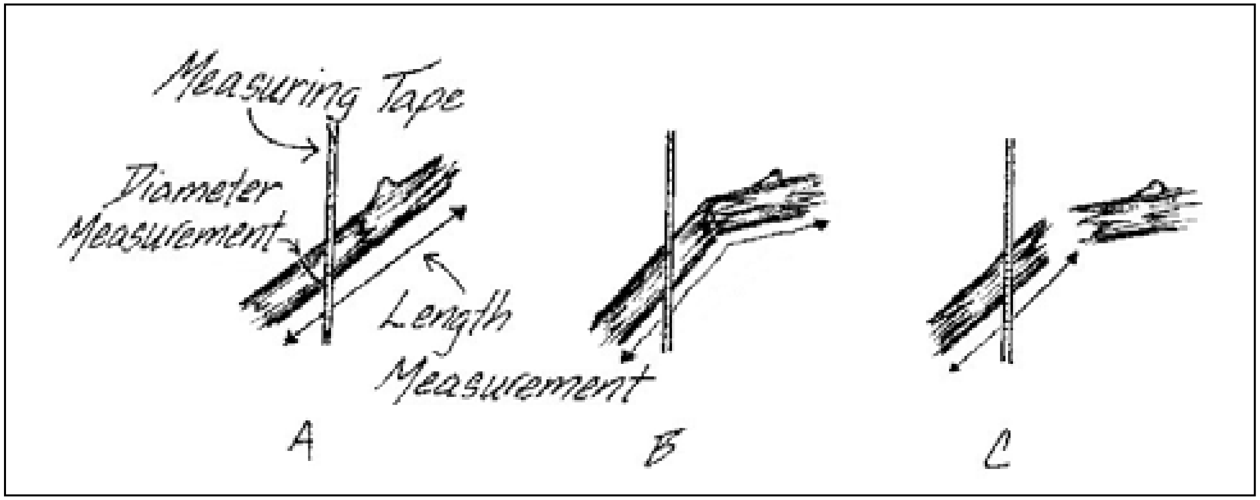

Figure 13. Log length and diameter measurement for optional CWD data. In each case the diameter measurement is made at the same point. In A and B the broken pieces are touching so length includes both pieces. In C, only the piece crossed by the measuring tape is measured for length.

DISTANCE FROM BEGINNING OF TRANSECT TO LOG

This measurement makes relocation of specific logs easier. Frequently, logs that were included in pre-fire sampling roll away from the sampling plane during a fire while other logs, not originally sampled, roll into the plane. Recording the distance from the start of the line, in addition to permanently marking the logs with tags, will make post-fire sampling easier. Record the distance from the start of the measuring tape to the point where the diameter was measured.

PROPORTION OF LOG THAT IS HOLLOW

This characteristic is important for wildlife concerns but also allows more accurate estimates of carbon. Estimate the percent diameter and percent length that has been lost to decay.

A piece is considered hollow if a cavity extends at least two feet along the central longitudinal axis of the piece, and the diameter of the entrance to the cavity is at least one-quarter of the diameter of the piece where the entrance occurs. The entrance occurs at the point where the circumference of the cavity is whole -- the point where wood is present completely around the circumference of the cavity. The length of the cavity begins at this point.

Table 5. Use these classes for recording the percent of diameter and length lost to rot in CWD.

Class	Lost to decay
0	No Loss
0.5	>0-1 percent lost
3	>1-5 percent lost
10	>5-15 percent lost
20	>15-25 percent lost
30	>25-35 percent lost
40	>35-45 percent lost
50	>45-55 percent lost
60	>55-65 percent lost
70	>65-75 percent lost
80	>75-85 percent lost
90	>85-95 percent lost
98	>95-100 percent lost

REFERENCES

This appendix, including the illustrations, is a combination of these two documents:

Fuel Load Sampling Methods (0.6 MB) from the FIREMON Sampling Methods web page, accessed at http://frames.nbii.gov/portal/server.pt/community/firemon/286/sampling_methods/490

DWM *Field Manual for 2004* (2.4 MB) from the USDA-Forest Service Northern Research Station web page, accessed at http://www.nrs.fs.fed.us/fia/topics/dwm/data-collection/

An additional useful reference is

Brown, J.K., R.D. Oberheu, and C.M. Johnston. 1982. Handbook for Inventorying Surface Fuels and Biomass in the Interior West. USDA-Forest Service General Technical Report INT-129.

This document is available online at
http://www.fs.fed.us/rm/publications/titles/int_gtr.html