Southeast Coast Network

National Park Service
Inventory and Monitoring Division

Standing Operating Procedure 1.4.12

Fuel Load Measurements—Version 1.1

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Summary

This standard operating procedure (SOP) describes how to collect information on downed woody material and other fuel load measures. This procedure is implemented as part of the vegetation community monitoring protocol. Coarse woody debris, fine woody debris, and litter/duff/fuel beds are components of fuel load measurements.

The datasheet used for this SOP includes *SECN Veg Form 7—Fuel Load Measurements*. It is included in Appendix A of this SOP.

Revision Log

Revision Date	Author	Changes Made	Reason for Change	New Version #
April 2024	M.F. Boyle	* Added a few minor clarifications to field techniques	* Increase efficiency of collecting this data in the field	1.1

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Overview

The methods and measures presented here are based on the Forest Inventory and Analysis (FIA) Field Guide for Down Woody Materials (USFS 2004) and the FIREMON protocol developed by the Department of Interior and the U.S. Forest Service (Lutes et al. 2006). These methods are designed to collect data that can be used for fire-planning purposes. The components measured during fuel load sampling include coarse woody debris (CWD), fine woody debris (FWD), inorganic debris (IOD), litter (LTR), and duff (DUF). Fuel bed depth (FBD) can be estimated from these measurements.

These data are also used to characterize wildlife habitat components, enable better understanding of wildland fire risk, and help further characterize the vegetative characteristics of sampling locations. This SOP is only initiated in the following broad habitat types in SECN parks:

- Semi-natural/successional uplands
- Coastal Plain and Piedmont nonalluvial wetlands
- Maritime, Coastal Plain, or Piedmont upland forests and shrublands
- Coastal Plain or Piedmont open uplands and woodlands (foredune and backdune habitat excluded)

For measuring fuel loads, utilize three 25-meter (82-foot [ft]) transects starting from the center of the vegetation plot, as described in SOP 1.4.10 *Site Selection, Plot Establishment, and Return Visits* (Boyle 2019).

SOP Source and How It Was Modified

This SOP is an adaptation of SOP 8 *Coarse Woody Debris—Version 1.3* of the *Cumberland Piedmont Network Vegetation Monitoring Protocol* (White et al. 2011) and the FIREMON protocol for sampling coarse and fine woody debris and duff and litter depths. For a general explanation of how the Southeast Coast Network (SECN) modified the Cumberland Piedmont Network (CUPN) protocol and its SOPs, see the SECN *Terrestrial Vegetation Monitoring in Southeast Coast Network Parks Protocol Implementation Plan* (Boyle et al. 2019). With regards to this SOP, the Southeast Coast Network made three specific modifications to the CUPN SOPs, including (1) additional fuel types are sampled; (2) there are three 25-meter (82-ft) fuel transects used in the Southeast Coast Network and they are arrayed similar to the CWD design in the Northeast Temperate Network's forest monitoring protocol (Tierney et al. 2016); and (3) the SECN SOP is applied only within plots located in fire-prone habitats (i.e., natural fire return interval is less than 200 years). The detailed list of modifications to CUPN SOP 8 is in Appendix B of this SOP.

Definitions

Coarse Woody Debris (CWD) includes downed trees and large branches that are either lying prone on the ground, or at least one end of the broken bole of a dead tree is touching the ground at an angle of greater than 45° from vertical. Coarse woody debris includes pieces of wood greater than 8 centimeters (3.1 inch [in]) in diameter (approximately 1,000-hour fuel class).

The **duff** layer lies below the litter layer and above mineral soil. It is made up of litter material that has decomposed to the point where individual pieces are no longer identifiable. In general, the duff layer is darker than the litter layer.

Fine Woody Debris (FWD) are pieces of wood less than 8 centimeters (3.1 in) in diameter. They are either (1) not attached to the woody stem where they once grew and have fallen to the ground, (2) not attached to the stem where they once grew and are supported off the ground by live or dead material, or (3) attached to stems of woody material that are themselves considered 'dead' and 'down.' Fine woody debris is composed of the following fire size classes: 1-hour fuels (0–0.64 centimeters [0–0.2 in]), 10-hour fuels (0.64–2.54 centimeters [0.2–1 in]), and 100-hour fuels (2.54–8.1 centimeters [1–3.2 in]).

The **litter** layer is made up of twigs, dead grasses, recently fallen leaves, and pine or other needles where the individual pieces are still identifiable and not altered by decomposition.

Data Collection Procedures

Laying Out Fuel Load Transects

Three 25-meter (82-ft) fuel transects are established from the center of the vegetation plot, and follow 0°, 135°, and 225° bearings (Figure 1). Refer to SOP 1.4.10 *Site Selection, Plot Establishment, and Return Visits* (Boyle 2019) for directions on how to most efficiently set up the fuel transects and vegetation plot simultaneously.

Starting from the origin of each transect (plot center), place pin flags at the 5, 7, 10, 15 and 25-meter (16.4, 23, 32.8, 49.2 and 82 ft) position of the fiberglass tape. Use a clinometer to measure the percent slope of the transect line. Aim the clinometer at the eye level of sampler at the other end of the line. 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.

Coarse Woody Debris, Fine Woody Debris, and Duff or Litter Measurements

The following procedures are adapted from the Fuel Load (FL) section of the *FIREMON: Fire Effect Monitoring and Inventory System* (Lutes et al. 2006). See Figure 2 for visual reference. The 'sampling plane' for counting coarse woody debris and fine woody debris extends from the top of the duff layer vertically to a height of 2 meters (6.6 ft). The transect tape represents the extent of the 'sampling plane.' All data are recorded on the *SECN Veg Form 7—Fuel Load Measurements* datasheet.

1. Starting at the 5-meter (16.4-ft) mark of the transect, count the number of 1-hour, 10-hour, 100-hour, and 1,000-hour fuels that pass through the 'sampling plane' (Figure 2). The best way to identify the pieces intercepting the plane is to lean over the tape so that the eye is positioned vertically a few feet over the measuring tape at the 5-meter mark. Then, while looking at one edge of the tape, the measurer maintains their head in that same vertical position over the line and moves toward the 7-meter (23-ft) mark while making separate counts for each fuel class. Each piece needs to be classified as 1-hour, 10-hour, 100-hour, or 1,000-hour fuels by the diameter where it intercepts the sampling plane, defined by one edge of the measuring tape. Often pieces above will cover pieces below. It is important to locate all the pieces that intercept the plane to get accurate fuel load data. For any 1,000-hour (CWD) fuel that crosses the plane anywhere along the entire transect (5 to 25 meters [16.4 to 82 ft]), additional measurements must be taken. These include (1) diameter value of the CWD piece where it crosses the 'sampling plane' measured perpendicular to the central axis to the nearest 1-centimeter (0.4 in; use a diameter tape), and (2) decay class at the same site where diameter is taken. See Table 1 for definitions of CWD decay classes.

2. Once the count has reached the 7-meter (23-ft) mark along the transect, the tally of 1-hour and 10-hour fuels is complete. Continue counting 100-hour and measuring 1,000-hour fuels until reaching the 10-meter (32.8 ft) mark along the transect (Figure 2).

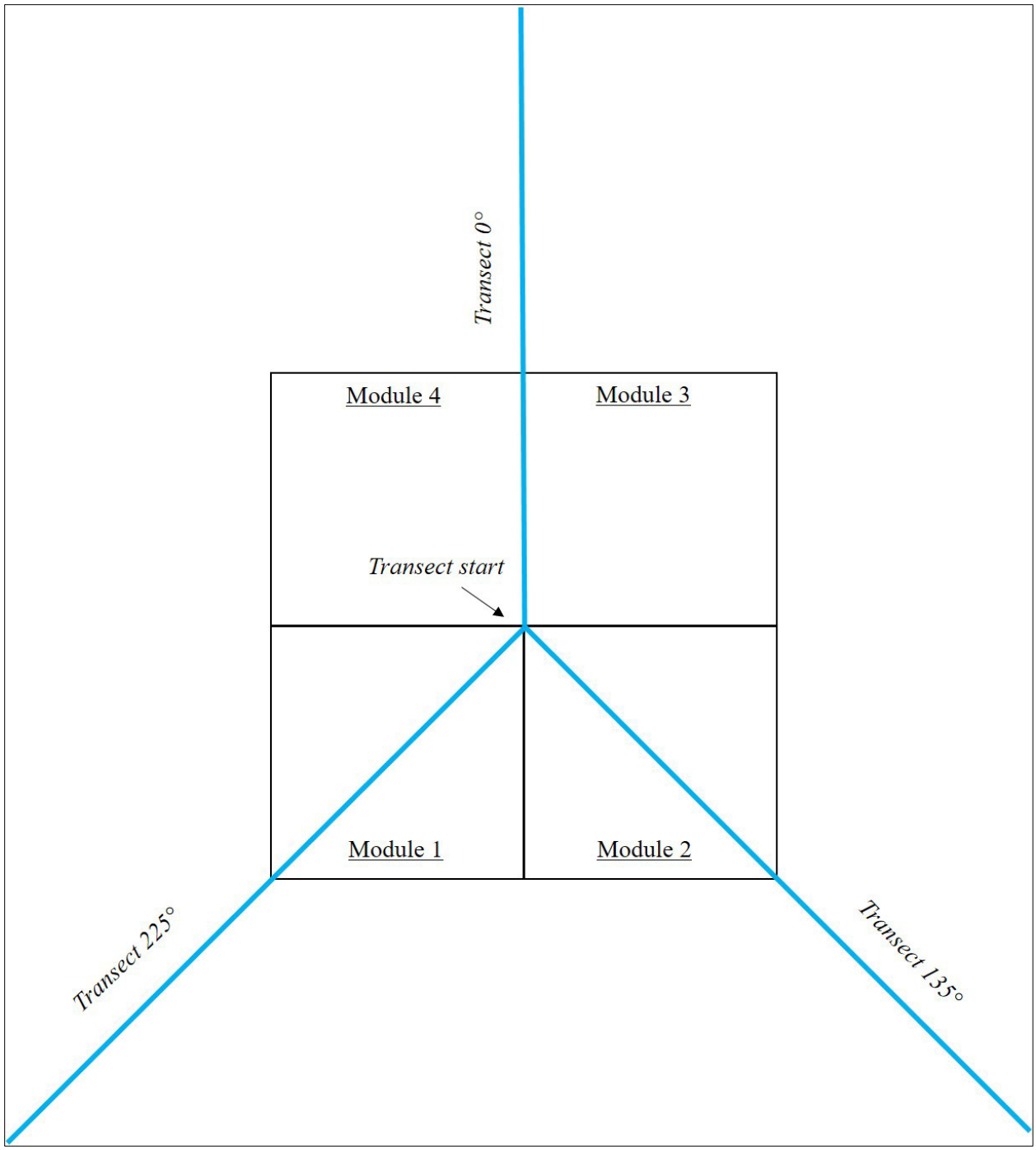

Figure 1. Location of the fuels sampling transects in relation to the 20 × 20-meter (65.6 × 65.6 ft) vegetation plot.

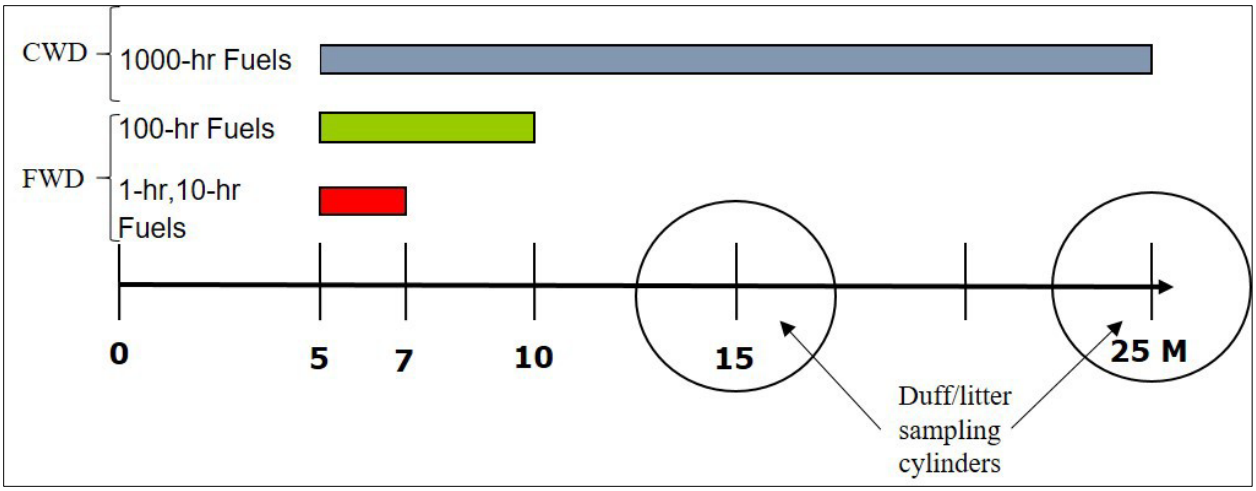

Figure 2. Fuel load sampling plane layout, based on Lutes et al. 2006.

3. Once the count has reached the 10-meter (32.8-ft) mark along the transect, the tally of 100-hour fuels is complete. Continue measuring 1,000-hour fuels that cross the 'sampling plane' until the end of the transect (25 meters [82 ft]) has been reached (Figure 2).

4. Duff and litter measurements are made within 0.9-meter (3-ft) diameter cylinders located at the 15-meter (49.2-ft) and 25-meter (82-ft) marks along the transect (Figure 2). A sampling point within the cylinder that best represents the duff or litter characteristics inside the entire circle is selected for where the measurement is taken. Use the blade of the trowel to lightly scrape just the litter layer to one side. Then return the blade to the point where the litter scrape was started, push the trowel straight down as far as possible through the duff layer and move the material away from the profile. Use the trowel to work through the duff layer until mineral soil is noted at the bottom of the profile. Mineral soil is usually lighter in color than the duff and coarser in composition, often sandy or gravelly. It is important not to disturb the profile by compacting or pulling it apart on successive scrapes. The profile exposed should allow an accurate measurement of duff and litter depth. Use a ruler to measure total depth of the duff and the litter profile to the nearest 0.2 centimeter (0.08 in). Place the zero end at the point where the mineral soil meets the duff layer, then move either your index finger or thumb down the ruler until it is level with or just touches the top of the litter. While keeping your finger in the same position on the ruler, lift the ruler out of the profile and note the duff depth, indicated by your finger. Next, examine the duff and litter profile and measure the depth of the litter using the same technique. Duff and litter measurements are most easily and accurately made on the vertical portion of the profile if that portion of the profile is representative of the true duff and litter depth (it was not negatively impacted when the profile was developed).

5. Repeat Steps 1–4 for the other fuel transects.

Table 1. CWD Decay Class values and definitions used by the Southeast Coast Network, modified from Cumberland Piedmont Network (White et al. 2011).

Decay Class	Structural Integrity	Bark	Texture of Rotten Portions	Wood Color	Invading Roots	Branches/Twigs/Leaves
1	Sound, freshly fallen, intact logs; hard when kicked	Intact	Intact, no rot; conks of stem decay absent	Original color	Absent	If branches are present, fine twigs are still attached and have tight bark; needles / leaves occasionally present
2	Sound; hard when kicked	Some missing	Mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	Original color	Absent	If branches are present, many fine twigs (i.e., less than 1 inch) are gone and remaining fine twigs have peeling bark; needles / leaves absent
3	Heartwood sound, piece supports its own weight; hard when picked	Most missing	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish-brown or original color	Sapwood only	Branch stubs will not pull out; needles / leaves absent
4	Heartwood rotten, piece does not support its own weight but maintains its shape; sounds hollow when kicked and kick removes pieces of sapwood	Most missing	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Through out	Branch stubs pull out; needles / leaves absent
5[a]	None, piece no longer maintains its shape, spreads out on the ground; easy to break apart with boot	Most missing	Soft; powdery when dry	Red-brown to dark brown	Through out	Branch stubs and pitch pockets have usually rotted down; needles / leaves absent

[a] in decay class 5, 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.

Table 2. Datasheet field descriptions for SECN *Veg Form 7—Fuel Loads*.

Field Name	Field Description
Data Taker Initials	Initials of individual collecting the data. In most cases one person calls tallies (field crew leader), while another records data. Data taker initials should be the field crew leader, who is responsible for correct species ID.
Reviewed by	Initials of individual who reviewed completed data sheet for SOP 1.4.12 elements. In most situations, this should be someone other than individual who recorded data on this portion of datasheet. Field crew leader can conduct this review while recording cover values.
Transect X and Y lengths	Default value should be 25 meters (82 ft) for both transects. However, if a longer or shorter length is used, write the new length in this section. Be sure to record justification in Notes section.
1, 10, 100, 1,000-hour length	Default value should be 2, 5, and 20 meters (6.6, 16.4 and 65.6 ft) for 1-, 10-, 100, and 1,000-hour fuels, respectively. If a different length is used to sample each category, record this new length in the space provided, and provide a justification in the Notes section.
1, 10, 100-hour counts	Provide the number of each fuel type encountered along transect x and y in the space provided.
Litter/Duff depth	Record the depth of litter and duff in the space provided.
CWD counts	Circle the transect that the CWD piece is located on and record its diameter and decay class in the space provided.

Equipment List

- Two 30-meter (98.4 ft) fiberglass measuring tapes
- Chaining pins
- Pin (wire) flags
- Ruler, w/ “0” at the base and no gap from base to “0”
- DBH Tape (w/ centimeter units)
- Digging tool/trowel
- Two 1-meter (3.3 ft) sticks
- Field datasheets (*SECN Veg Form 7—Fuel Loads*)
- Pencil

Literature Cited

Boyle, M.F. 2019. Site selection, plot establishment, and return visits—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.4.10. Southeast Coast Network, Athens, Georgia. Available at: https://irma.nps.gov/DataStore/Reference/profile/2260350 (last accessed June 2024).

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Appendix A. Field Data Forms

SECN Vegetation Monitoring Protocol
Veg Form 7 Fuel Load Measurements

Plot ID _____
(plot acronym + GRTS Order #)

Start Date _____
(mm/dd/yy)

SOP VEG06 – Fuel Loads Data taker initials _____ Reviewed by: _____

Transect 0°	Length (25 m default) _____	Slope (%) _____
Transect 135°	Length (25 m default) _____	Slope (%) _____
Transect 225°	Length (25 m default) _____	Slope (%) _____

Fuels

1-hour	Length (2 m default)	_____
10-hour	Length (2 m default)	_____
100-hour	Length (5 m default)	_____
1000-hour	Length (20 m default)	_____

NOTES

Transect	1-hour count (0-0.6 cm)	10-hour count (0.6-2.5 cm)	100-hour count (2.5-8 cm)	Litter Depth (0.2 cm precision) 15 m	Litter Depth (0.2 cm precision) 25 m	Duff Depth (0.2 cm precision) 15 m	Duff Depth (0.2 cm precision) 25 m
0°							
135°							
225°							

Transect	CWD Diameter (> 8 cm) (1 cm precision)	Decay Class

Decay Class	Structural Integrity	Bark	Texture of Rotten Portions	Wood Color	Invading Roots	Branches / Twigs / Leaves
1	Sound, freshly fallen, intact logs; hard when kicked	Intact	Intact, no rot; conks of stem decay absent	Original color	Absent	If branches are present, fine twigs are still attached and have tight bark; needles / leaves occasionally present
2	Sound; hard when kicked	Some missing	Mostly intact; sapwood partly soft (starting to decay) but can't be pulled apart by hand	Original color	Absent	If branches are present, many fine twigs (i.e., <1in) are gone and remaining fine twigs have peeling bark; needles / leaves absent
3	Heartwood sound, piece supports its own weight; hard when picked	Most missing	Hard, large pieces; sapwood can be pulled apart by hand or sapwood absent	Reddish-brown or original color	Sapwood only	Branch stubs will not pull out; needles / leaves absent
4	Heartwood rotten, piece does not support its own weight but maintains its shape; sounds hollow when kicked and kick removes pieces of sapwood	Most missing	Soft, small blocky pieces; a metal pin can be pushed into heartwood	Reddish or light brown	Throughout	Branch stubs pull out; needles / leaves absent
5	None, piece no longer maintains its shape, spreads out on the ground; easy to break apart with boot	Most missing	Soft; powdery when dry	Red-brown to dark brown	Throughout	Branch stubs and pitch pockets have usually rotted down; needles / leaves absent
6	Rock or trash (including anything man-made: plastic, wood, paper, etc.)					

SECN_Vegetation_Monitoring_Protocol
Data_Form_20190510

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Figure A-1. Sample Veg Form 7—Fuel Load Measurements.

Appendix B. Modifications to CUPN SOP 8 for SECN SOP 1.4.12

The CUPN SOP 8 was modified to create SECN SOP 1.4.12. The major modifications to these SOPs are listed and explained below.

Expanding the SOP to include additional fuel types

The CUPN SOP 8 includes methods for sampling Coarse Woody Debris (CWD). Because of the influence of additional fuel types on fire behavior within the SECN geography, this SECN SOP 1.4.12 includes procedures for measuring Fine Woody Debris (e.g., 1-, 10-, and 100-hour fuels) and Duff/Litter types, as well as maintaining the procedure for measuring Coarse Woody Debris.

Utilizing transect lengths described in the FIREMON protocol

The CUPN records Coarse Woody Debris (CWD) along two 40 meter transects that run across the primary vegetation plot. The Southeast Coast Network has chosen to employ the transect design of the FIREMON protocol (Lutes et al. 2006) to account for additional fuel types that are more meaningful to fire behavior in the Southeastern Coastal Plain—duff/litter, fine, as well as coarse woody debris. The Southeast Coast Network has chosen to record Fuel Load variables across three 25-meter-long transects that start at the plot center of the vegetation plot and are arrayed similar to CWD transects used by the Northeast Temperate Network (Tierney et al. 2016).

Procedure only applied in a priori defined habitats

Coarse Woody Debris is sampled in all vegetation plots monitored by the Cumberland Piedmont Network. The Southeast Coast Network has chosen to sample fuel loads only in plots that occur in vegetation types that are either subjected to recurring prescribed fire management or occur in habitats with an average fire return interval of less than 200 years. Habitats that occur in ‘fire shadows’ across the landscape, and that don’t typically burn, include floodplain alluvial forests and dry sparse open upland vegetation of the Maritime Fringe (e.g., foredunes and backdunes). Southeast Coast Network vegetation plots located in these habitat types will not be sampled for fuel loads.

Appendix B Literature Cited

Lutes, D. C., R. E. Keane, J. F. Caratti, C. H. Key, N. C. Benson, S. Sutherland, and L. J. Gangi. 2006. FIREMON: fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, Colorado. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

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