Alberta Wildland Fuels Inventory Program

Field Sampling Manual

FireSmart Program

Wildfire Prevention Section

Wildfire Management Branch

Alberta Agriculture and Forestry

Alberta Wildland Fuels Inventory Program 2020
Edmonton, Alberta, Canada

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Overview

Alberta Environment and Sustainable Resource Development's Wildland Fuels Inventory Program (initially called the Fire and Vegetation Monitoring Program) began in 2006. The purpose of this program is to collect fuel load, fuel moisture, vegetation response and fire behaviour data to supply a provincial database and act as a decision support system for prescribed burn, wildfire and FireSmart planning in Alberta. To date, the program has 62 project locations (Fig 1.1) with an approximate total of 610 plots throughout the province.

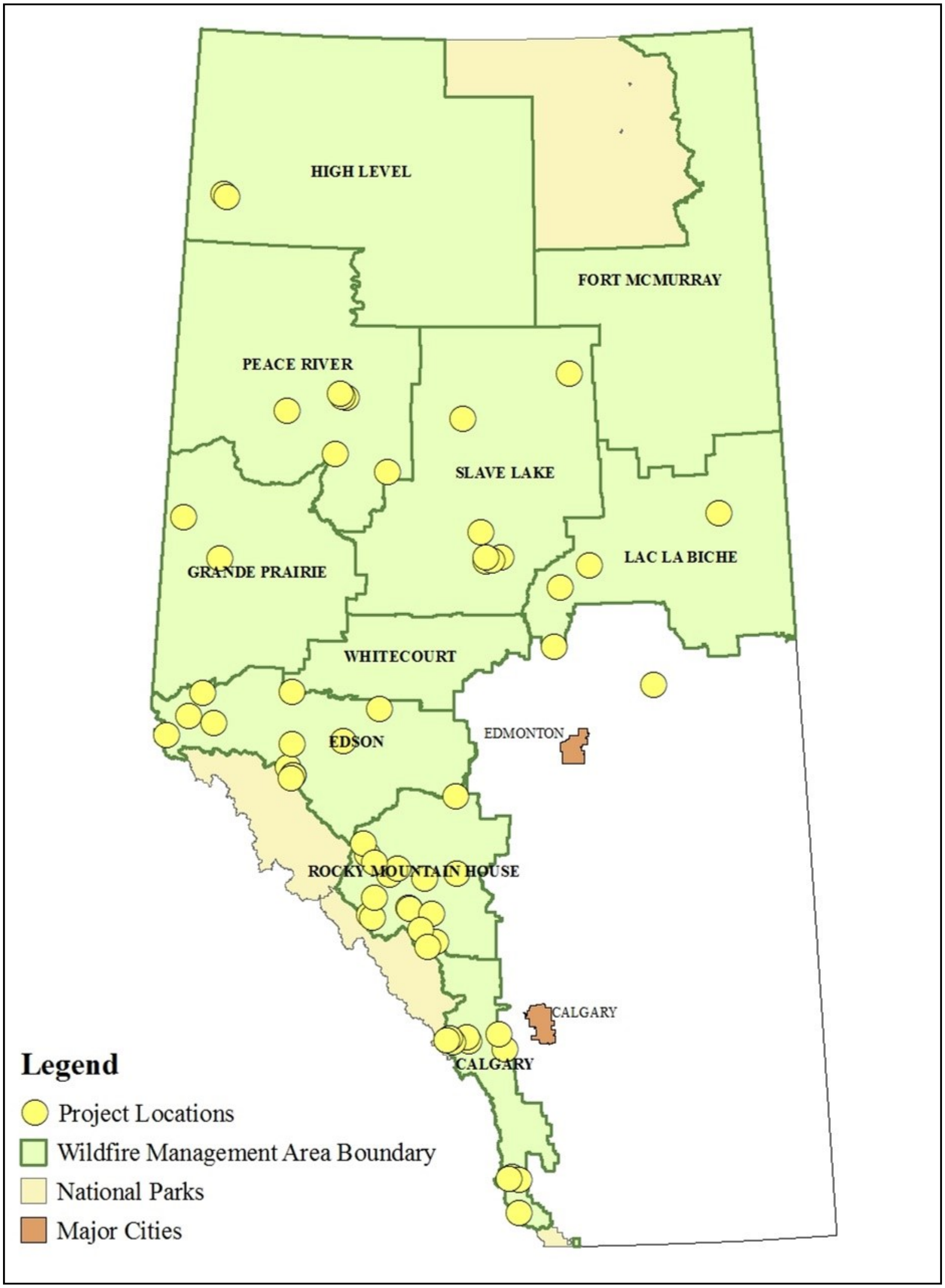

Fig 1.1 AWFIP Projects by Wildfire Management Area. The program has plots in 62 project locations throughout the 10 management areas.

Sampling for the Alberta Wildland Fuels Inventory Program (AWIFP) is stratified according to the Alberta Natural Region and Natural Subregion classification system (see Table 1.1 and Figure 1.1). Natural Regions are defined geographically based on vegetation, soils, and physiographic features. They are the largest mapped ecological units in Alberta (Natural Regions Committee, 2006). Natural Subregions are smaller units within Natural Regions which are defined by vegetation, climate, elevation, and latitudinal or physiographic differences within the region (Natural Regions Committee, 2006).

Table 1.1 Natural Regions and Subregions of Alberta.

Natural Region	Natural Subregion
Rocky Mountain	Alpine
	Subalpine
	Montane
Boreal	Central Mixedwood
	Dry Mixedwood
	Northern Mixedwood
	Boreal Subarctic
	Peace-Athabasca Delta
	Lower Boreal Highlands
	Upper Boreal Highlands
	Athabasca Plain
Foothills	Lower Foothills
	Upper Foothills
Canadian Shield	Kazan Uplands
Parkland	Foothills Parkland
	Peace River Parkland
	Central Parkland
Grassland	Dry Mixedgrass
	Foothills Fescue
	Northern Fescue
	Mixedgrass

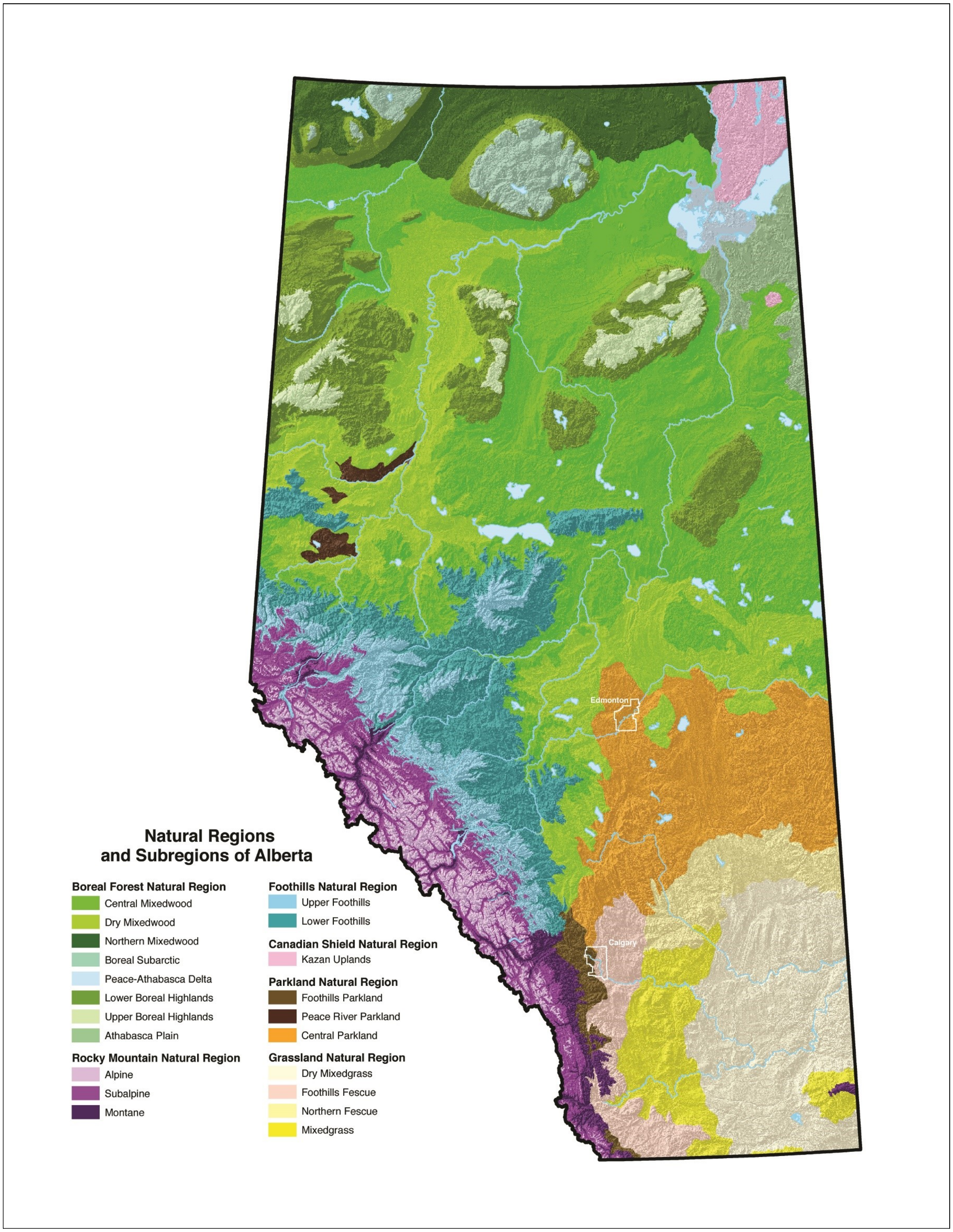

Fig. 1.1 Natural Regions and Subregions of Alberta. The province is divided into seven regions and further divided into twenty-one subregions. Alberta Wildland Fuels Inventory Program (AWFIP) currently has plots in 7 of these subregions.

Locations sampled within each Natural Subregion are further stratified by fuel type and aspect. The Canadian Forest Fire Behaviour Prediction (FBP) system (see Table 1.2) uses mathematical equations to relate fire behaviour characteristics to wind, fuel, moisture, and topographic features for 16 general fuel types (Taylor et.al., 1997). FBP is one of two primary subsystems of the Canadian Forest Fire Danger Rating System (CFFDRS), the other being the Fire Weather Index (FWI) system (Taylor & Alexander, 1996). Detailed examples and descriptions of FBP fuel types are found in the appendices of the manual, or refer to the *Field Guide to the Canadian Forest Fire Behaviour Prediction (FBP) System*.

Table 1.2 Fuel types of the Canadian Forest Fire Behaviour Prediction System organized by coniferous, deciduous, mixedwood, slash and open descriptions.

FBP Fuel Type	Code	Description
Coniferous	C-1	Spruce-lichen woodland
	C-2	Boreal spruce
	C-3	Mature jack or Lodgepole pine
	C-4	Immature jack or Lodgepole pine
	C-5	Red and White pine
	C-6	Conifer plantation
	C-7	Ponderosa pine/Douglas-fir
Deciduous	D-1	Leafless aspen
Mixedwood	M-1	Boreal mixedwood-leafless aspen
	M-2	Boreal mixedwood-green
	M-3	Dead balsam fir mixedwood-leafless
	M-4	Dead balsam fir mixedwood-green
Slash	S-1	Jack or Lodgepole pine slash
	S-2	White spruce/Balsam slash
	S-3	Coastal cedar/hemlock/Douglas-fir slash
Open	O-1a	Matted grass
	O-1b	Standing grass
****See Field Guide to the Canadian Forest Fire Behaviour Prediction (FBP)***		

The methodologies used by this program are a combination of those used by the United States Firemon Inventory System, the Alberta Permanent Sample Plot (PSP) program, the Alberta Prescribed Burn Fuel Sampling Handbook, Canada's National Forest Inventory Ground Sampling Guidelines, as well as methodologies used in various fire research work. References for the methodologies used can be located at the end of each chapter

Chapter 1 — Plot Establishment

Equipment Checklist			
	Global Positioning System (GPS)		Topographical map of area
	Compass		Digital camera (5.0 Megapixel or better)
	Suunto Clinometer		Camera tripod
	Four 25-meter Loggers tapes		Clipboard
	5 center pins		Pencil
	Moisture regime reference sheet		Sharpie
	Photocards		Plot Description Sheet
	Vertex Hypsometer		

When establishing a plot, start with the Plot Description sheet. This sheet contains all the plot variables that will not change between sampling events including Plot ID, Plot Details, Plot Location, Plot Topography, Plot Photos, Plot Access, Plot Characteristics, Plot Slopes, and Plot Ecosite.

1.1 Plot ID

A plot ID must be recorded at the top of every data sheet at the time of plot establishment. Plot IDs include the two identifiers listed below and should be written using a sharpie or felt pen in order for it to clearly stand out on the page.

Note: It is important to remember that the plot ID is formulated using coordinates in the Degrees Decimal Minutes format, not Decimal Degrees.

Location Code – a two letter acronym based on the general location and/or name of the treatment unit. The Location Code will always be consistent for all plots located within the same project area/treatment unit.

Coordinate Code – a unique eight digit identifier based on the plot's latitude and longitude coordinates. The identifier is created from the first four digits of minutes of Latitude followed by the first four digits of minutes of Longitude. In some special circumstances where plots may be very close to one another (e.g. single transect plots), this code may need to be extended to 10 digits in order to differentiate between plots.

Example:
You have established a plot in the Meadowland Creek prescribed burn unit located in the Willmore Wilderness Park. The plot coordinates are 53˚13.789 N (latitude) by 119˚50.381 W (longitude). See Fig. 1.2.

Location Code = MC (Meadowland Creek)
Coordinate Code = 1378-5038
Plot ID = MC-1378-5038

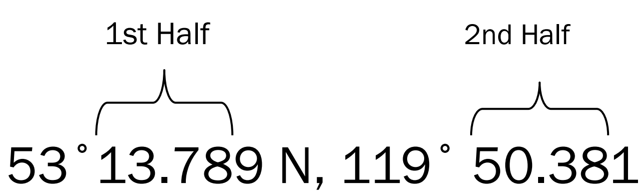

Fig. 1.2 Obtaining the coordinate code. The first half of the code comes from the first four digits of the minutes of latitude. The second half comes from the first four digits of the minutes of longitude.

1.2 Transect Assembly

Transect lines are laid out using four 25 meter loggers tapes either in a) each of the four cardinal directions if on flat ground; OR b) if on a slope >15%, uphill, down-hill and cross slope, where transect 3 extends downhill and in the direction of slope aspect.

When setting up the transect lines, use a compass to determine the direction the line will go from plot center (Alexander, 2006). Keep the line as straight as possible by ensuring it goes under/through/over, rather than around vegetation along the transect line (Fig. 1.3). Should there be a tree directly in the path of the transect line, keep the line as close to the tree as possible and then return to the compass heading once you are around the tree. For pre-treatment sampling of prescribed burn projects, depth of burn pins are inserted at the 25 meter mark of each transect to mark the line (additional pins will be inserted at each 5 meter mark immediately preceding any treatment that AWFIP crews are present for). For all other projects, center pins will be used at the Pins should be inserted such that the cross bars lie level with the top of the duff layer. A piece of flagging should be tied around the top of the pin as well, to aid in future re-sampling. If it is not possible to insert them to this depth then they can be cut to the appropriate length using wire clippers. To reduce compaction and disturbance to ground cover along the transect line, try to walk only on the left hand side of the transect line and take measurements on the right hand side. Be sure to record the azimuth of each transect in the plot photos box on the front data sheet as well.

Figure 1.3. Laying out a transect line (Lutes et al. 2005). Keep the line straight and as low as possible by going under, through and over vegetation.

Small and large tree sampling is completed using circular plots, rather than linear transect lines (Fig 1.4). The radius for these plots will vary depending on the density of the trees in the area to be sampled, where the small tree plot is embedded within the large tree plot. Data should be collected for a minimum of 20 large trees and also 20 small trees in the smallest radius available in order to improve efficiency but still ensure accuracy. More details on tree plots can be found in chapters 6 and 7.

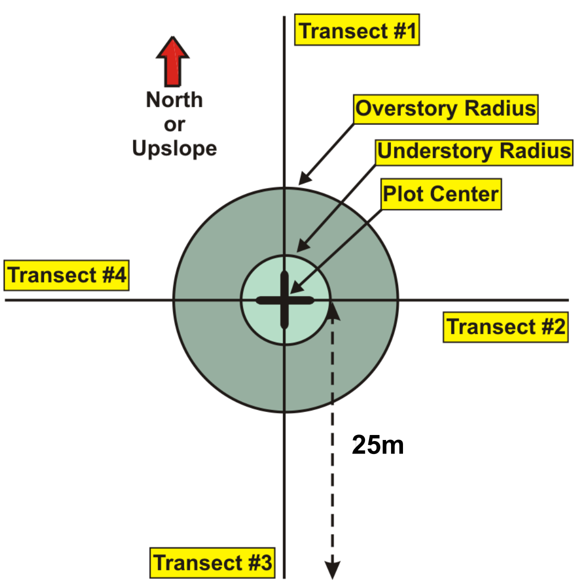

Figure 1.4 Tree plots overlayed on the transect layout. Overstory radius includes all large trees, and understory radius includes all small trees (seedlings and saplings).

1.3 Plot Details

There are **three types of treatments** that can be sampled depending on the project objectives:

- FireSmart (mechanical, hand, mulch, thin, prune, etc.)
- Prescribed burn
- Wildfire

For each of these treatment types there are **three types of sample events** that can occur:

- Control (CO)
- Pre-treatment (PR)
- Post-treatment (PO)

The sample event code identifies the sampling event and includes the number of times the sample event has occurred. It is formed from the first two letters of the sample event, followed by the number of the visit. For example if the site has been visited two times after treatment, the second visit would be recorded as PO2. Record on the data sheet both the treatment type and the sample event. If a plot is being sampled prior to treatment (i.e. a pre-treatment site), the treatment type will always be recorded as "Natural". If a plot is being sampled for the first time, but is in a treated area, it will be deemed a post-treatment 1 site.
See Appendix 3 for important guidelines when re-visiting plots.

Location/Project name will be reflective of the area and treatment being sampled. This title should be determined by the supervisor beforehand and kept consistent for all plots within the sampling area.

Fire Behaviour Prediction (FBP) fuel type is recorded using the *Field Guide to the Canadian Forest Fire Behaviour Prediction (FBP) System* and/or the detailed descriptions and pictures provided in Appendix 2 at the back of the manual.

Agency refers to the organization conducting the field sampling, which in our case will almost always be ESRD.

1.4 Plot Location

Location information is mandatory and must be recorded for all plots. Plot coordinates are obtained using a handheld Global Positioning System (GPS) on site or are previously designated beforehand. Coordinates should be taken while standing overtop of plot center. Be sure to record the declination from the GPS unit as this changes depending on location within the province. World Geodetic System 1984 (WGS84) is the recommended Map Datum to use. Degrees Decimal Minutes (hddd˚mm.mmm') is the position format for recording Latitude and Longitude coordinates on the data sheets. GPS accuracy is also recorded from your GPS unit and recorded in this section.

The GPS error should be kept to 10 meters of less, if you are experiencing errors greater than 10 meters then wait to acquire more satellites. You can also try the following to reduce GPS error:

- Give your GPS time to acquire satellites. When you start up your GPS allow it to acquire at least three satellites before you start using it.
- Face south as most satellites orbit the USA which means that the most satellites will be in the southern part of our horizon.
- Don't block your GPS unit. If you are having trouble acquiring satellites hold the GPS away from your body and other equipment. If you are in an area with a thick canopy or steep mountainous terrain it may be difficult to avoid poor satellite reception, climbing to higher ground or an area where the canopy is not as dense may assist in correcting this.

See Appendix 3 for important guidelines when re-visiting plots.

1.5 Plot Access

Document GPS coordinates, distance to and compass bearing from the helipad or parking spot to the plot and the type of access (heli or vehicle). GPS coordinates should have been stored in the GPS unit before you began hiking. If this was not initially recorded, then you can collect it at the end of the day when you return to the helipad or truck. This will help in relocating the plot for future sampling. There is also room at the bottom of the sheet to include any other relevant information related to the plot location and site access.

1.6 Plot Topography

The fire behaviour triangle is made up of fuel, weather and topography. Site topography includes the aspect (magnetic), slope %, slope shape, and general topographical location. Topography and other biophysical characteristics significantly affect the spread of fire across the landscape. Plot relief and topographic location are recorded based on the characteristics present at the plot but should also be reflective of the area as a whole. Elevation (m) is taken at plot center with the GPS unit.

Aspect refers to the general direction in which the plot is facing (Lutes et al 2005). If the plot is located on a hillside, then the direction that the slope is facing will be the aspect of the plot. If the plot is located on flat ground, then aspect will simply become the azimuth of transect three (see *Transects* section below for more information on transect setup). When using the compass it is important to ensure that you are not wearing or in close proximity to any metal objects or magnets as these can skew the reading from the compass.

Plot slopes are measured on each of the four transects using a hypsometer or clinometer. One person will stand over plot center with the hypsometer and a second person will stand 10m down the transect. The person at center will aim to a spot where *their own* eye level is on the second person and take a reading of the slope (Fig 1.5). Slope should be recorded as a percentage. Slope will be zero on flat ground.

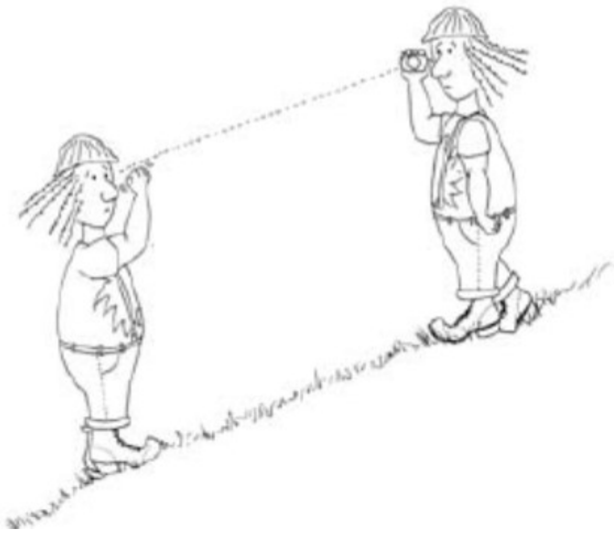

Figure 1.5 Measuring slope using a clinometer or hypsometer (Lutes et al. 2005). Ensure measurements are being taken at the same height when determining slope.

Slope shape describes the general contour of the terrain. From the center of your plot, survey the ground upslope, down-slope and cross-slope. Determine the shape class (see Fig. 1.6) that best describes the upslope/down-slope (vertical component) and cross slope (horizontal component) of the site and record this on the datasheet.

A. Convex
B. Concave
C. Linear

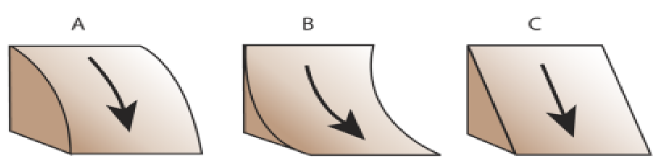

Fig. 1.6 Three basic slope shapes. (A) convex, (B), concave, and (C) linear (esri.com, 2010.)

Topographic location refers to the position of the plot in relation to the terrain. There are four options to choose from for topographic location:

- Hollow
- Flat
- Slope
- Hilltop

1.7 Plot Characteristics

Moisture regime provides information regarding the amount of moisture available on a site for plant growth (Nesby, 1997). Drainage provides information regarding plot position, soil texture, humus depth, location of water table, permeability and water storage capacity (ESRD, 2005). The AWFIP has combined these two site descriptors into one for the purpose of assessing overall moisture composition of the site. Use Figure 1.7 and Table 1.4 (following page) to determine overall drainage and moisture regime for the plot.

Erosion severity describes the level of erosion present on the site at the time of sampling. This information is most important for future sampling, as it will indicate the effect the treatment had on the stability of the site (i.e. was stability compromised?). The Alberta Wildland Fuels Inventory Program (AWFIP) categorizes erosion severity into six classes:

Table 1.3 Erosion codes and level of severity at the soil surface.

Erosion Code	Erosion Type	Erosion Description
0	None	No sign of erosion
1	Low	< 25% of upper 20 cm of soil surface eroded
2	Moderate	25—75% of upper 20 cm of soil surface eroded
3	High	> 75% of upper 20 cm of soil surface eroded
4	Very High	All of the upper 20 cm of soil surface eroded

1.8 Plot Ecosite

Each plot is assessed for its ecosite type using one of the Canadian Forestry Service's three field guides for Alberta. These include:

- *Field Guide to Ecosites of Northern Alberta*
- *Field Guide to Ecosites of West-central Alberta*
- *Field Guide to Ecosites of Southwestern Alberta*

Each field guide contains information on the ecological areas specific to that region of Alberta. Ecosite, ecosite phase, plant community type, and soil type can all be keyed out for each plot after selecting the appropriate guide. The guide chosen will depend on the geographic location of the plot within Alberta. It is recommended that the ecosite classification be left until post completion of the plot sampling in order to first collect other plot data (e.g. soils, ground cover, shrubs) that can subsequently be used to determine ecosite, ecosite phase, etc. That being said, the classification should still be completed in the field in order to best remember the setting and details of the plot. For more information on ecosites, review the field guides listed above (see references).
Note: You will likely not find a suitable ecosite for post-treatment or post-burn plots. Ecosite to the best of your ability what the ecosite would have been before the FireSmart treatment/burn. Past datasheets or unaltered stands around the treatment site may help.

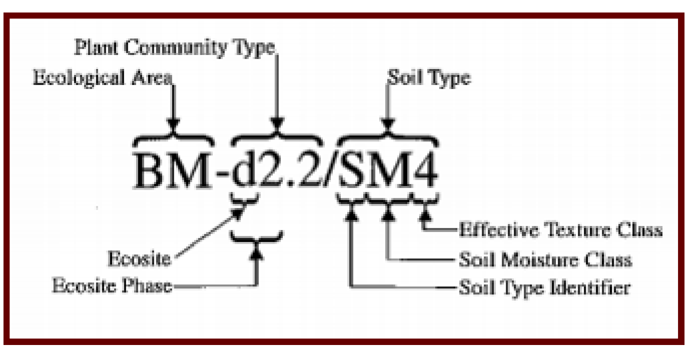

Fig. 1.8 Ecological unit identification code (Beckingham, 1996). This format divides into the three main components: ecological area, plant community type, and soil type. For the purposes of AWFIP, the entire string is referred to as "Plot Ecosite".

Table 1.3 Drainage and Moisture Regime Codes and Descriptions (*adapted* Nesby 1997).

Moisture Regime	Drainage	Description	Primary Water Source	Slope Position	Soil Properties: Texture	Soil Properties: Depth to Impermeable Layer	Soil Properties: Humus Depth	Soil Properties: Water Storage Capacity	Slope Gradient
Very Xeric (1)	Very Rapidy	Water removed extremely rapidly in relation to supply; soil is moist for a negligible time after precipitation.	Precipitation	Ridge crests	Very coarse, abundant course fragments	Very shallow < 0.5m	Very shallow	Extremely Low	Very steep, especially on south aspects (>70%)
Xeric (2)	Rapidly	Water removed very rapidly in relation to supply; soil is moist for short periods following precipitation	Precipitation					Very low	
Subxeric (3)	Well	Water removed rapidly in relation to supply; soil is moist for short periods following precipitation	Precipitation	Upper slopes	Coarse to moderately coarse, few coarse fragments	Shallow < 1.0m	Shallow	Low	Steep (31-70%)
Submesic (4)	Moderately	Water removed readily in relation to supply; water available for moderately short periods following precipitation	Precipitation						
Mesic (5)	Imperfectly	Water removed somewhat slowly in relation to supply; soil may remain moist for a significant, but sometimes short period of the year; available soil moisture reflects climatic inputs	Precipitation	Mid-slopes normal to rolling flat	Moderate to fine, few coarse fragments	Moderately deep 1.0—2.0m	Moderately deep	Moderate	Moderate (2-30%)
Subhygric (6)	Poorly	Water removed slowly enough to keep the soil wet for significant part of the growing season; some temporary seepage and possibly mottling below 20cm	Precipitation	Depression		Deep > 2.0m	Deep	High	Slight (2-9%)
Hygric (7)	Very Poorly	Water removed slowly enough to keep the soil wet for most of the growing season; permanent seepage and mottling present; possibly weak gleying	Seepage	Lower slopes	Variable depending on seepage	Variable depending on seepage		Variable depending on seepage	
Subhydric (8)	Wet	Water removed slowly enough to keep the water table at or near the surface for most of the year; gleyed mineral soils or organic soils; permanent seepage less than 30cm below the surface	Seepage or permanent water table						
Hydric (9)	Very Wet	Water removed so slowly that the water table is at or above the soil surface all year; greyed mineral soils or organic soils	Permanent water table						Flat (<2%)

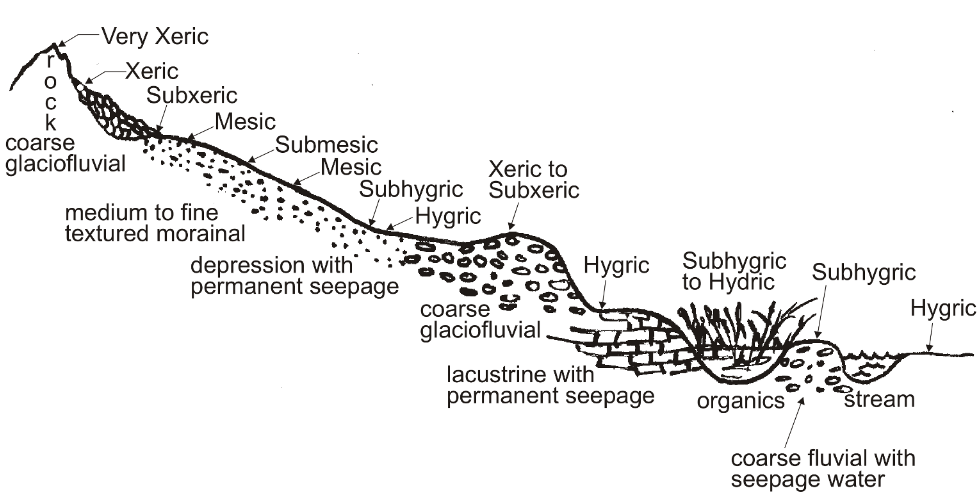

Fig 1.7 Ecological Moisture Regime (Nesby 1997).

1.9 Plot Photographs

Photographs of the site are taken from plot center towards the end of each transect in a clockwise fashion. The center of the camera lens should be positioned 1.3 meters above the ground directly over the center pin. A total of nine photos are taken: one of the Plot Description sheet (Fig 1.8), and two of each transect, one horizontal and one vertical (Fig. 1.9). The purpose of the first photo is to have a visible copy of the essential details in case the corresponding picture numbers are lost. The Plot Details and Plot Location boxes should be filled out prior to taking the photo.

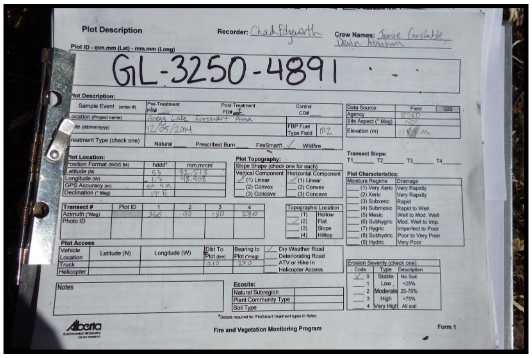

Fig. 1.8 Photo of Plot Description sheet. This photo is taken first and should have the Details and Location boxes filled in before the photo is captured.

A numbered photocard is included in each transect picture (Fig. 1.9) and is placed at 5m. This photocard should be clearly visible from plot center. If vegetation is obscuring the line of sight, gently push it aside (taking care not to disturb the area around the transect as much as possible); or the photocard can be raised using a pin or by setting it on a log. The photocard should be at the bottom of the frame—or if it was raised, slightly above the bottom—because the objective is to include the area from the ground at 5m and up.

In the Plot Photographs box on the data sheet, be sure to record the two picture numbers ("photo ID") from the camera for each transect, as well as the transect's azimuth.

Fig. 1.9 Vertical and horizontal photographs of transect 1 taken from plot center. Subsequent photos are taken in a clockwise direction. The photocard is placed at 5m and is centered at the bottom of the photo. In order to achieve this, the camera is tilted slightly upwards and held at a height of 1.3m.

1.10 Notes

Notes are an extremely important aspect of our data collection! This is a crucial link between the field work and data analysis at the end of the season. Relevant details to record could include:

- any and all changes made to protocols while adapting to conditions in the field
- reasonings for choosing locations of new plots
- if post-treatment, any interesting treatment observations
- any relevant information regarding the surrounding area that may affect the plot
- if missing any data be sure to record *why*
- any questions/uncertainties about any of the sampling procedures (and take those to the supervisor)
- breakdowns or malfunctions of equipment/materials
- presence of anything out of the ordinary: unusual topographical features, unexpected species, presence/proximity to bodies of water, unusually high numbers of saplings/seedlings, abnormally deep organic horizons, etc.

Notes should be succinct, but include enough information for the person reviewing the data to understand what is being

1.11 References

Alberta Sustainable Resource Development. 2005. *Permanent Sample Plot (PSP) Field Procedures Manual*. Public Lands and Forests Division, Forest Management Branch, Edmonton, Alberta.

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Nesby, R. 1997. *Alberta Vegetation Inventory Standards Manual*. Alberta Sustainable Resource Development, Environmental Protection Resource Data Division. Edmonton, Alberta.

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Chapter 2 — Soil Measurements

2.1 Introduction

Ground fuels are an important consideration in determining fire behaviour. The three sides of the fire triangle – fuel, heat and oxygen – are required for a fire to burn. Organic surface horizons (litter and duff) are the only soil horizons with both fuel and oxygen available. Duff is defined as the layer of organic material on the forest floor (the fibric and humic layers) between the litter and the mineral soil (Van Wagner 1972, Soil Classification Working Group 1998). See figure 2.1. In the boreal forest duff is made up of both litter and mosses (Miyanishi 2002). For the purposes of the Alberta WIldland Fuels Inventory Program (AWFIP), soil measurements **focus only on organic surface horizons**. Measurements of mineral horizons are not required.

Organic horizons encompass both LFH horizons and Of, Om and Oh horizons. Our program focuses on the litter and duff layers, where litter is the L or Of horizon and duff is considered the F/H or Om/Of horizon (Fig 2.1).

LFH Horizons (Folic Materials) – Organic horizons developed primarily from the accumulation of leaves, twigs and woody material with or without a minor component of mosses. LFH horizons are normally associated with upland forested soils.

L (Litter) – Characterized by an accumulation of organic matter in which the original structures (leaves, twigs and woody material) are easily discernible.
F (Fibric) – Characterized by an accumulation of partly decomposed organic matter. Some of the original structures are difficult to recognize.
H (Humic) – Characterized by an accumulation of decomposed organic matter in which the original structures are indiscernible. It is frequently intermixed with mineral grains, especially near the junction with a mineral horizon.

O Horizons (Peat Materials) – Organic horizons developed mainly from mosses, sedges, rushes, and other hydrophytic vegetation. O horizons are normally associated with organic soils saturated with water for prolonged periods.

Of (Fibric) – Consists largely of fibric materials that are readily identifiable as to botanical origin.
Om (Mesic) – Consists of mesic material, which is at a stage of decomposition intermediate between fibric and humic materials. The material has been altered both physically and biochemically.
Oh (Humic) – Consists of humic material, which is at an advanced stage of decomposition. The horizon has the lowest amount of fiber, the highest bulk density, and the lowest saturated water holding capacity of the O horizons. The rubbed fiber volume is 10% or less.

On prescribed burns and wildfires depth of burn and soil consumption are important severity measures that can be related to physical, biological and ecological fire effects. The magnitude of soil consumption is a product of the fire type (ground, surface or crown), intensity and residence time. It is determined primarily by bulk density, moisture content and depth.

Prescribed burn projects: At the time of plot establishment one depth of burn (DoB) pin is inserted at the 25 meter mark on each of the four transects. Prior to burn activities (<2 weeks preceding ignition activities) additional DoB pins should be inserted at each 5 meter mark along all four transects (and the pin at the 25 meter mark reset, such that the crossbar is again level with the top of the duff horizon) to determine average depth of burn throughout the plot.

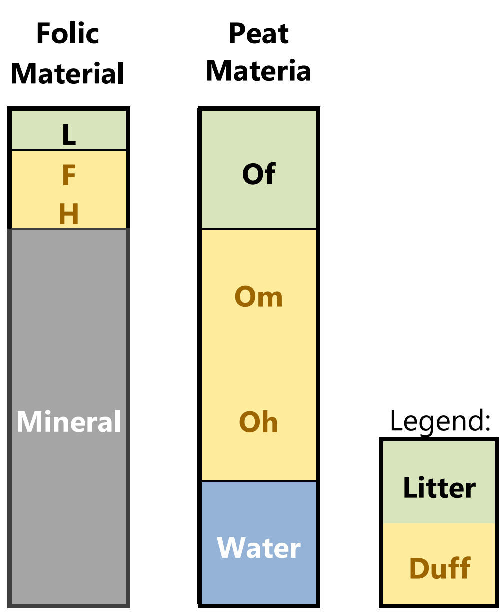

Fig. 2.1 AWFIP is primarily interested in the collection of litter and duff — the LFH or Of/Om/Oh horizons of either mineral, organic or cryosolic (not displayed) soils. LFH horizons are generally associated with folic materials and mineral soils. Of, Om and Oh horizons are usually associated with peat materials and organic soils. Both litter and duff are considered organic surface horizons.

Equipment Checklist			
	Four 25-meter Loggers tapes		Mini-rod measuring tape (2m)
	Ruler (30cm)		Folding handsaw
	Trowel (small)		“Shapka” soil sampler
	Ziploc bags		Sharpie marker
	Flagging tape		Clipboard
	Pencil		Soil Measurements Data Sheet

2.2 Sampling Design

Four 25 meter transect lines are oriented in one of two ways depending on slope and aspect: If the site is flat (slope ≤ 15%) the four transect lines run north, south, east and west from plot center. If the slope is > 15% the four transect lines run up-slope, cross-slope to the right, down-slope and cross-slope to the left from plot center (Alexander 2006). Transect numbers start at the top (North or upslope) and are numbered successively in clockwise direction.

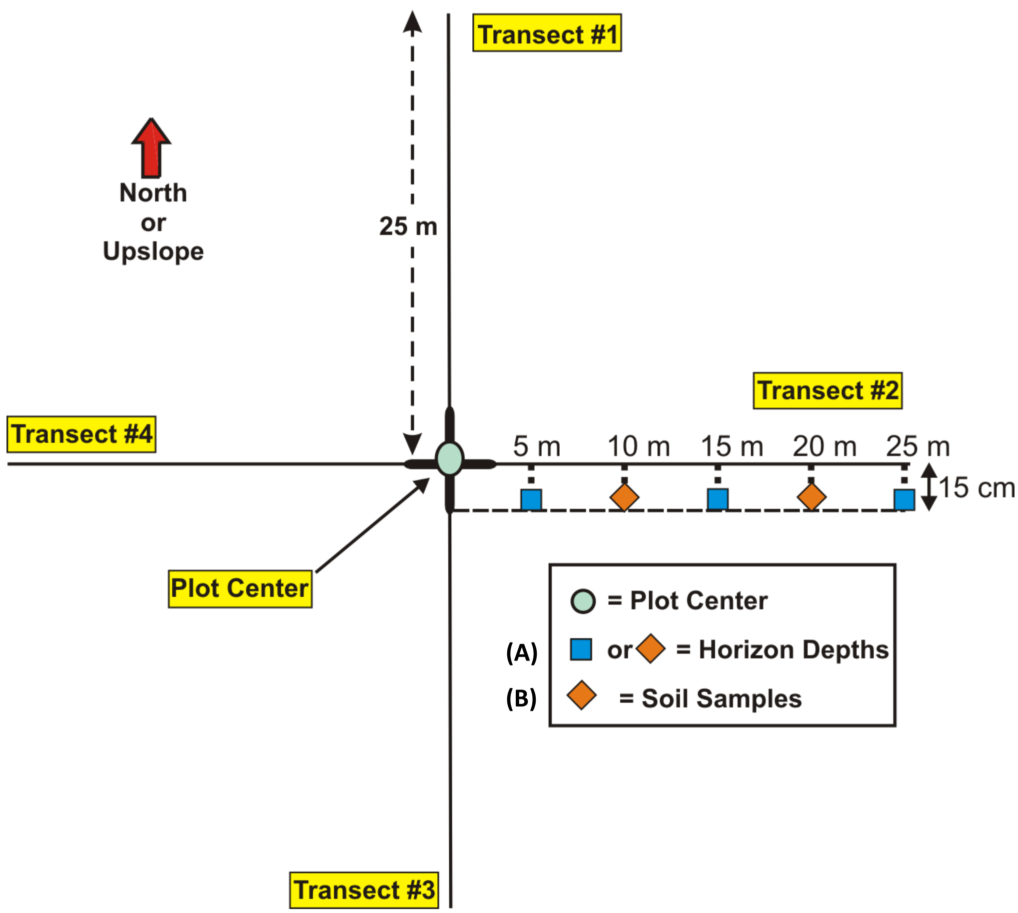

Figure 2.2 Layout of soil measurements sampling design. Soil depth measurements (A) are taken at 5, 10, 15, 20 and 25m and soil core samples (B) are collected at 10 and 20m. Measurements should be carried out 15cm to the right of the transect tape.

2.3 Methodology

2.3.1 Classifying Soil Type, Texture and Color

Soil Type

AWFIP classifies soil types in one of following three categories:

Mineral Soil – Soil composed of A, B and C mineral horizons with the exception of Regosolic soils which do not contain a recognizable B horizon. Organic surface horizons (LFH) are shallow if present. Mineral horizons contain 17% or less organic carbon (about 30% organic matter) by weight. The following soil orders are considered mineral soils: Brunisolic, Chernozemic, Gleysolic, Luvisolic, Podzolic, Regosolic, Solonetzic and Vertisolic.

Organic Soil – Soil composed largely of organic material. Most organic soils are saturated with water for prolonged periods and are composed of organic horizons (Of, Om, Oh and/or LFH). Organic soils contain more than 17% organic carbon (30% or more organic matter) by weight. They include most of the soils commonly known as peat, muck, bog, and fen soils. Organic horizons generally extend to a depth of at **least 40 cm**. Organic soils are easily distinguished from Mineral soils by the depth of their organic horizons.

Cryosolic Soil – Soil formed in either mineral or organic material that has permafrost within 1 meter of the surface. Cryosolic soils predominate north of tree line, in subarctic forest areas, and in some boreal forest and alpine areas. These soils have a mean annual temperature of <0˚C. The depth of the permafrost layer must be determined to identify Cryosolic soils.

Soil Texture

(A)

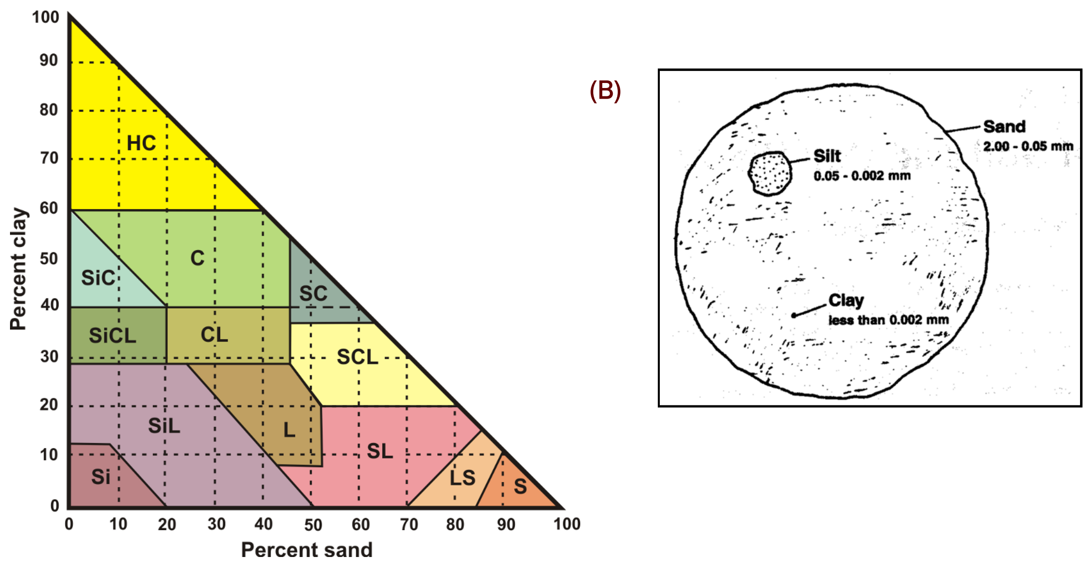

Figure 2.3 (A) Soil texture classes triangle (Soil Classification Working Group 1998). Si, silt; SiL, silt loam; SiCL, silty clay loam; SiC, silty clay; HC, heavy clay; C, clay; CL, clay loam; SC, sandy clay; SCL, sandy clay loam; L, loam; SL, sandy loam; LS, loamy sand; S, sand. (B) Relative sizes of clay, silt and sand particles.

Soil texture is defined as the relative proportions of sand, silt and clay particles within a **mineral** soil (Watts 1952). Organic soils are not given a soil texture classification. Clay particles are the smallest, being 0.002mm or less in diameter. Silt is the intermediate, ranging in diameters from 0.002mm to 0.05mm. Particles of sand are the largest, being between 0.05mm and 2mm. Anything greater than 2mm, such as gravel, cobble and stone, is considered a coarse fragment. Soil texture can consist of one type of particle or some combination of the three particles (Fig. 2.3).

Soil Color

Soil color is classified using a simplified version of Munsell soil color charts. The soil color is based off of a soil color values scale and can be recorded as one of 3 colors: dark, medium, light; or as not applicable. Refer to Table 2.1 for further information. Fig. 2.4 can be used as a rough guide in determining Munsell soil color values.

Table 2.1 Soil color codes for estimating soil color using Munsell's color system.

Soil Color Code	Munsell color value (when moist)	Soil Color Description
D	<4	Dark, chocolate brown or black
M	>4 and <6	Medium, intermediate color
L	>6	Light, very pale soil
N	N/A	No color (bedrock, no soil)

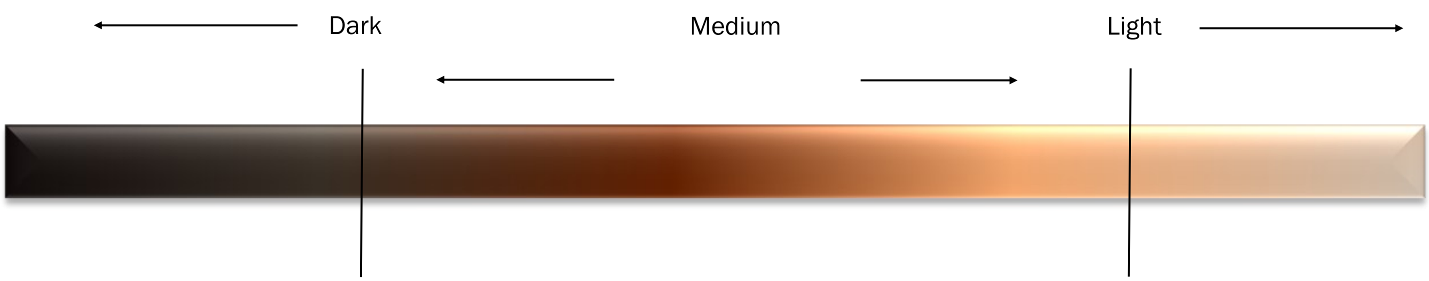

Figure 2.4 Determining soil color values. This figure provides an estimate of soil color based on three categories—light, medium and dark.

Figure 2.5 Soil core sample. Crew member has already cut and removed the soil core from the ground, and is now preparing to place the sample in a ziplock bag with its corresponding flagging tape label. In this case, mineral soil was hit less than 10cm down and thus the whole soil core cube was not filled with sample.

2.3.2 Soil Measurements

(A) Locate your soil-depth measurements at 5, 10, 15, 20 and 25 meters from plot center along each transect (Fig 2.5). Each measurement should be taken 15 cm to the right and perpendicular to the transect line (Figure 2.1) (Alexander 2006).
Note: In pre-treatment sites where there is no mulch present, cross out the mulch depth column on the Soil Measurements data sheet and do not record zero values. If the site *has* been mulched, determine if the mulch and litter and/or duff layers are mixed, then measure and record the depths of the mixture at 5, 10, 15, 20 and 25m etc. If they are not mixed, then measure the depth of each layer separately. It is important to record in the notes section the presence or absence of this mixing.
Note: If visiting a site post-burn, litter measurements and samples should only include material that is available for combustion. Do not include 100% burned material in litter depth measurements or litter samples. (described in B)).

(B) Place the edge of the "Shapka soil sampler", otherwise known as the 10x10cm soil core, 15 cm to the right of the transect line at the sampling location (10 or 20m). With the handsaw, cut along the four sides of the sampler, deep enough to fully submerge the soil core until the top is flush with the litter layer. Use a trowel and/or your hands to remove the sampler (including organic material inside – the sample). **Be gentle when removing sampler to avoid compacting or loosening the organic surface horizons.** Should the sample depth exceed 10 cm, only collect the uppermost 10 cm of litter and duff. If the soil sample is not a full 10 cm, only collect what is there, do not collect any mineral soil. The ideal method for labeling samples involves jotting down the

- plot id
- transect number
- sample material (litter or duff)
- sample position (10 or 20m)

on a piece of flagging and placing it in a ziplock bag along with the sample. This method benefits us two-fold: ziplocks bags can then be re-used; and the piece of piece of flagging can be transferred and kept with the sample through the drying process because it will not melt in the ovens.

Note: At 10 and 20m both soil depth measurements (A) are taken, and soil core samples (B) are collected. The exposed soil profile from the soil core provides an excellent, clearly visible surface and should be used to measure litter and duff depths (A).

Soil core samples are oven dried for 24 hours at 105˚C. Re-weigh samples immediately after they are removed from the oven as oven dried samples will start absorbing water from the surrounding air as soon as they are removed from the oven. Soil bulk density will be over-estimated if this occurs. (NOTE: This is done by a lab technician in Edmonton once samples are brought in from the field).

2.3.3 Soil Measurement Guidelines

Follow these guidelines when measuring soil depths (A) and collecting litter and duff samples (B):

Table 2.2 Moss as a component of surface organic horizons in mineral and organic soils		
	Mineral Soils	**Organic Soils**
Moss	Minor component	Major component
Live (green) Moss	Part of the L horizon (litter)	Part of Of horizon (litter)
Dead Moss	Part of F+H horizon (duff)	Part of Om + Oh horizon (duff)

- When taking the depth measurements of organic horizons, each layer should be measured separately, not collectively.
- Using a 30cm ruler, a depth is recorded for litter, for duff and, if present, for mulch (see Fig. 2.6). In circumstances where litter and/or duff are mixed with mulch, the depth of this mixture layer should be recorded and made note of.
- Moss is included as part of the organic horizon, where live moss is a component of the litter, and dead moss is a constituent of the duff layer (Table 2.2).
- Measurements of the duff layer will extend down to mineral soil or to water (whichever is reached first); or, if the depth of the duff layer exceeds 40cm, no further digging is necessary and a depth of 40.0cm+ is simply recorded. This is to avoid spending time digging to excessive depths.
- When collecting soil core samples at 10 and 20cm, a percent composition of litter must also be recorded, disclosing the sample's relative proportions of foliage (Fo), moss (Mo), and lichen (Li) to a total of 100%.

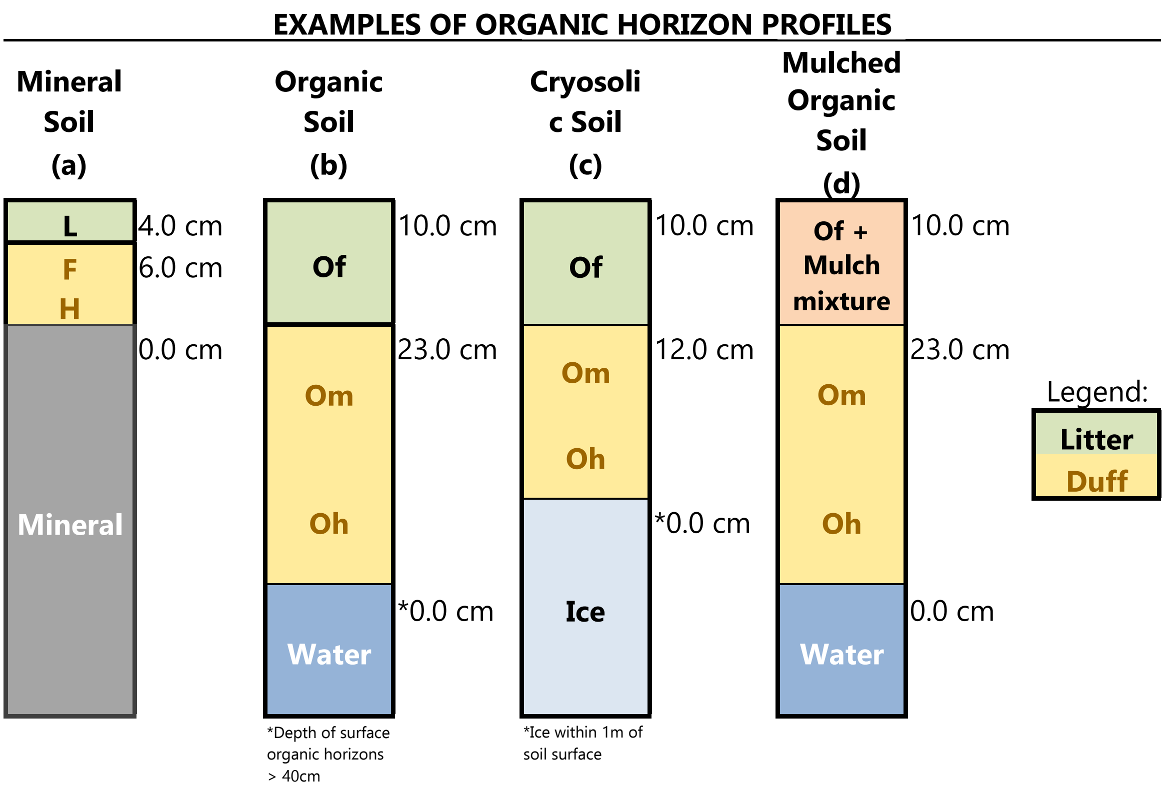

Figure 2.6
Example measurements and recordings of surface horizon depths for mineral, organic, and cryosolic soils. In (a), the litter layer is 4.0 cm deep and the duff is recorded as 6.0cm. In (b) the litter depth is 10.0cm and the duff is 23.0 before water is hit. In (c) , ice is hit 22.0 cm down; litter depth is 10.0cm and duff is 12.0cm. In (d) the site has been treated and mulch and litter have been integrated. This mixture is a depth of 10.0cm and the duff layer below is

2.4 Precision Standards

Record organic horizon depths to the nearest 0.1 cm.
Record oven dried soil samples to the nearest 0.01 g.

2.5 Calculations

For Litter or Duff:

Bulk Density (kg/m^3) = Oven dried Weight (kg) ÷ Volume (m^3)
Volume = 10cm * 10cm * Average Depth of Sample per Plot (cm)

Fuel Load (kg/m^2) = Bulk Density (kg/m^3) * Average Soil Depth per Plot

Average Depth (cm) by plot = $\sum$ All depths (measured AND sampled) ÷ 20

2.6 References

Alexander, M.E. 2006. *Alberta Prescribed Burn Fuel Sampling Handbook*. Wildland Fire Operations Research Group. Forest Engineering Research Institute of Canada – Western Division. Hinton, Alberta.

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Chapter 3 — Dead and Down Woody Material

3.1 Introduction

Measuring dead and down woody material at a site can provide important fuel load information related to making decisions regarding prescribed burn plans, fire hazard reduction, fire behaviour and many other fuel management issues (Brown 1974). Down woody material includes all the twigs, branches, stems and boles of trees that lie on or above the forest floor (Brown 1974).

There are two categories for dead woody material: fine woody debris (FWD) and coarse woody debris (CWD) (Table 3.1). FWD is down woody material that is smaller than 7.0 cm in diameter. FWD has five diameter size classes: 0.0-0.5 cm, 0.6-1.0 cm, 1.1-3.0 cm, 3.1-5.0 cm and 5.1 to 7.0 cm diameter (Delisle and Woodard 1998). CWD is all down woody material with less than a 45˚ angle to the ground and larger than 7.0 cm in diameter (Hely et.al. 2000). All CWD is considered size class 6, either sound or rotten (see Table 3.2).

Dead and down woody material can be classified as either “Natural” or ‘Slash” (Nalder et al 1999). Natural refers to downed material that has fallen naturally to the ground, and Slash refers to material that is on the forest floor because it has been cut for harvesting (i.e. in cutblocks).

Equipment Checklist			
	Counter		Four 25-meter Loggers tapes
	Mini-rod measuring tape (2m)		Dead and Down Data Sheet
	DBH tape		Go-No-Go Gauge
	Clipboard		Pencil

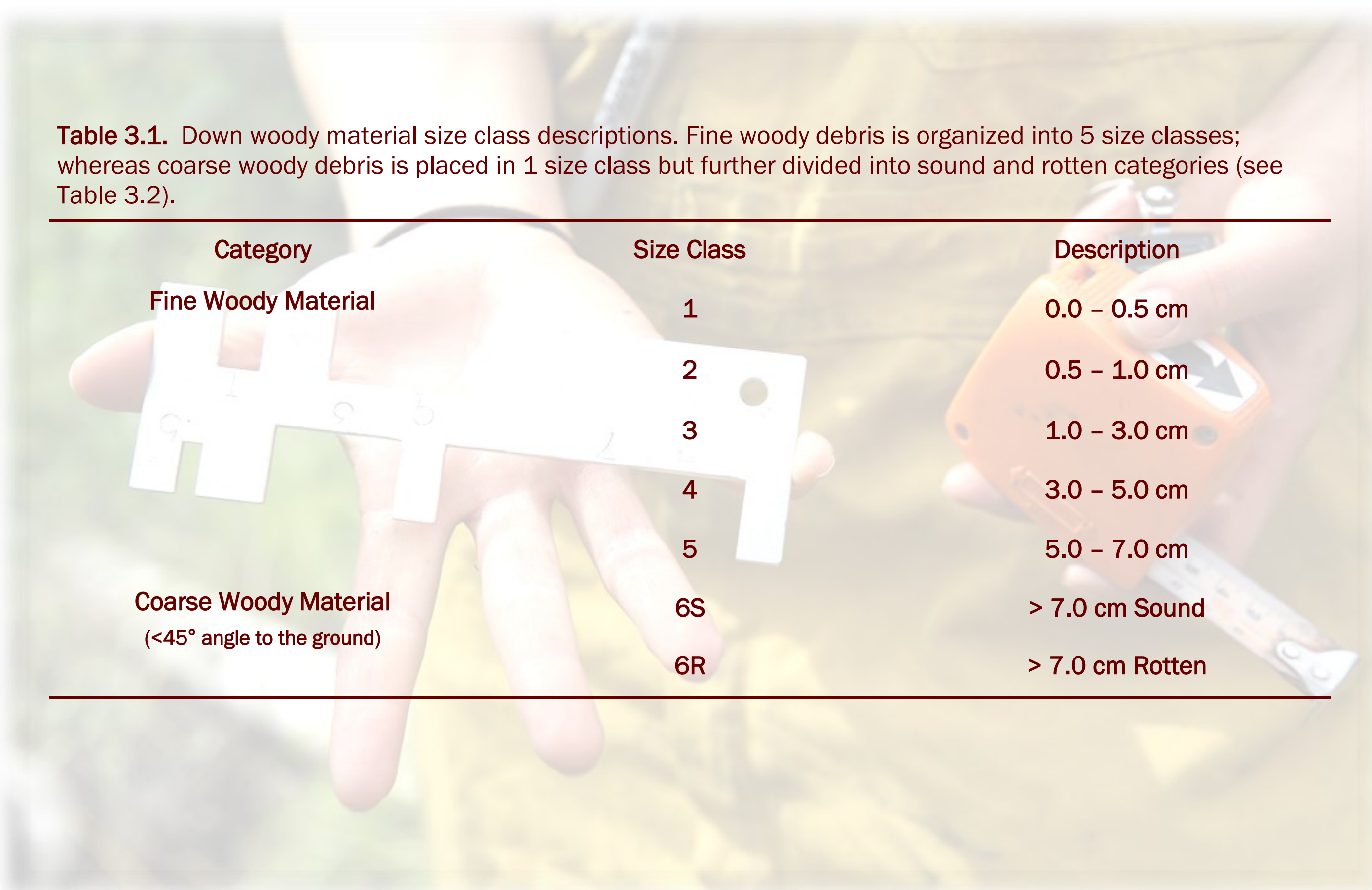

Table 3.1. Down woody material size class descriptions. Fine woody debris is organized into 5 size classes; whereas coarse woody debris is placed in 1 size class but further divided into sound and rotten categories (see Table 3.2).

Category	Size Class	Description
Fine Woody Material	1	0.0 – 0.5 cm
	2	0.5 – 1.0 cm
	3	1.0 – 3.0 cm
	4	3.0 – 5.0 cm
	5	5.0 – 7.0 cm
Coarse Woody Material (<45° angle to the ground)	6S	> 7.0 cm Sound
	6R	> 7.0 cm Rotten

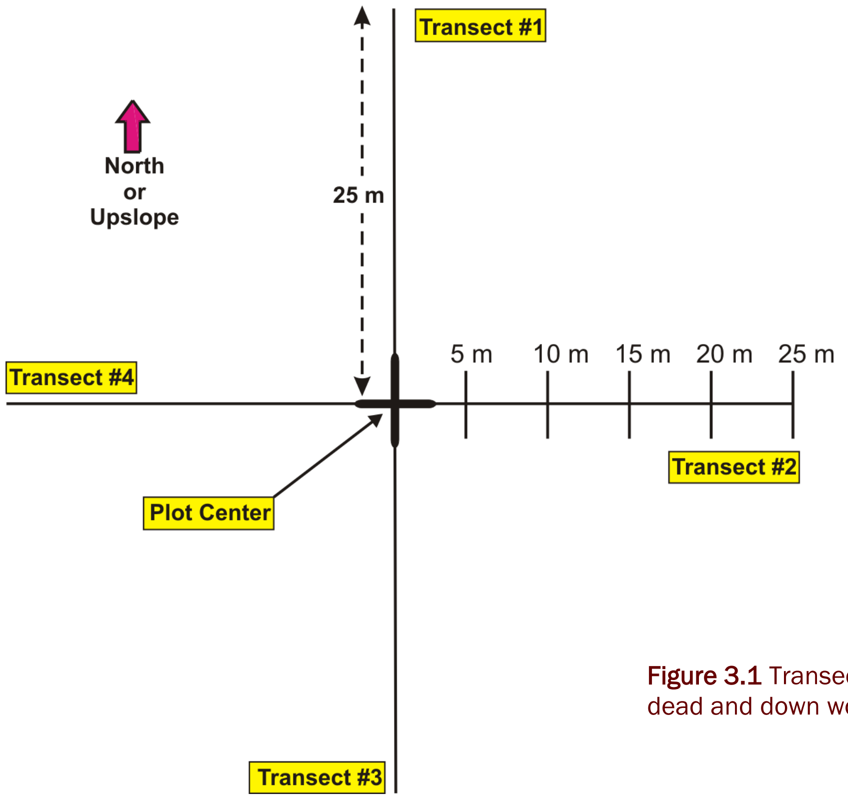

Figure 3.1 Transect layout for measuring dead and down woody materials.

3.2 Sampling Design

Dead and down woody material is sampled along the entire length of all four transects originating from plot center. If the site is flat (slope ≤15%) the four transect lines run north, south, east and west from plot center. If the slope is >15% the four transect lines run up-slope, cross-slope to the right, down-slope and cross-slope to the left from plot center (Alexander 2006). Transect numbers start at the top (North or upslope) and are numbered successively in clockwise direction.

For the sake of clear and succinct data recording, measurements of fine and coarse woody debris are broken up into 5m segments along each transect (ie 0-5m, then 5-10m, then 10-15m, etc). Tallies are later summed for the entire length of the transect.

3.3 Methodology

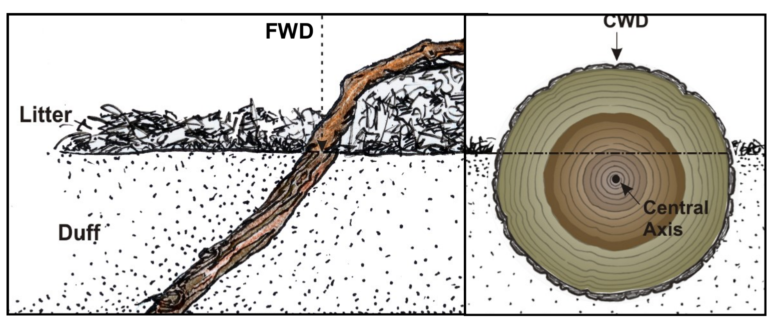

Figure 3.2 Qualifications for down woody material (Browns Transect Guide 2004). If the woody material is submerged in the duff layer it should not be included. If the dead and down material is still attached to a tree or living shrub it should also not be included. If the central axis of a log is below the duff layer, it should not be included.

Dead and down woody material measurements are taken to determine readily available fuels. Only consider woody materials superficial to the duff layer (Fig. 3.2), which are not still attached to a living tree or shrub. If the central axis of the woody material is below the duff layer, do not include it. The diameter of each piece is measured at the point where it crosses the line. Pieces crossing the transect more than once are measured at each intersection with the line. If a stump is uprooted and not covered in dirt it is considered to be part of the down woody material. Measure the stump at the point that it crosses the transect. For CWD, pieces are only included if they are at an angle of 45 degrees or less (in relation to the ground). The only exception to this rule is if the piece is the broken bole of a snag and at least one end is touching the ground and not supported by its own branches or vegetation (Lutes et al. 2005). General overstory species composition should be measured by estimating the top two dominant species along each transect. This can be used should there be no available data on site trees.

3.3.1 Fine Woody Debris

FWD measurements are completed using a "Go-No-Go" gauge (Fig 3.3 and Fig 3.4 A) (Brown 1974). To use a "Go-No-Go" gauge, select the smallest of the five size class slots that the piece will fit into without force. Record the number of pieces that fall into each size class at the end of every five meter section along all four transects. Tally the total number of each size class at the end of each transect.

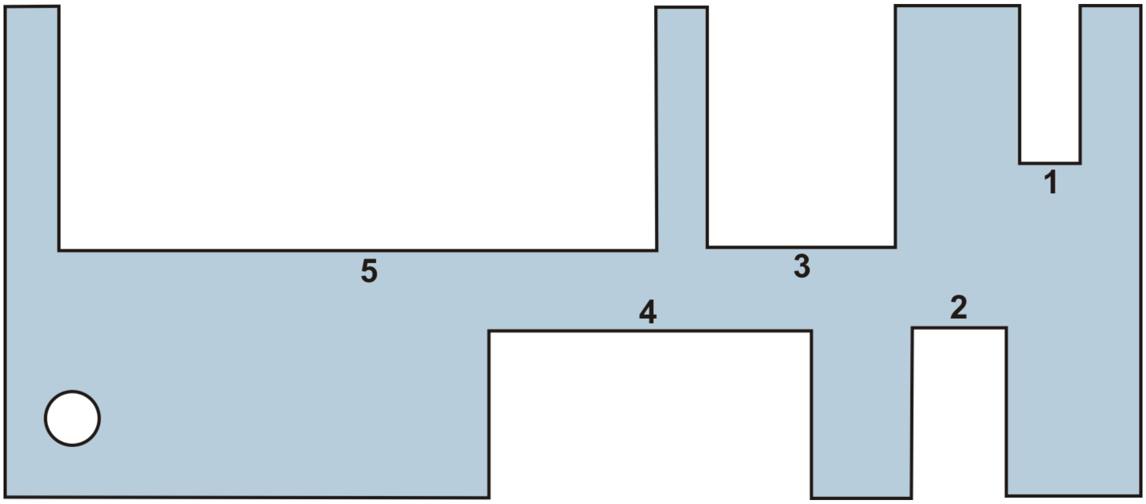

Figure 3.3 The "Go-No-Go" gauge used for determining the 5 size classes of fine woody debris (FWD). Dead and down woody material should be measured by fitting it to the smallest notch possible, without resistance. Size class 1 is 0-0.5cm; size class 2 is 0.6-1cm; size class 3 is 1.1-3cm; size class 4 is 3.1-5cm; size class 5 is 5.1-7cm.

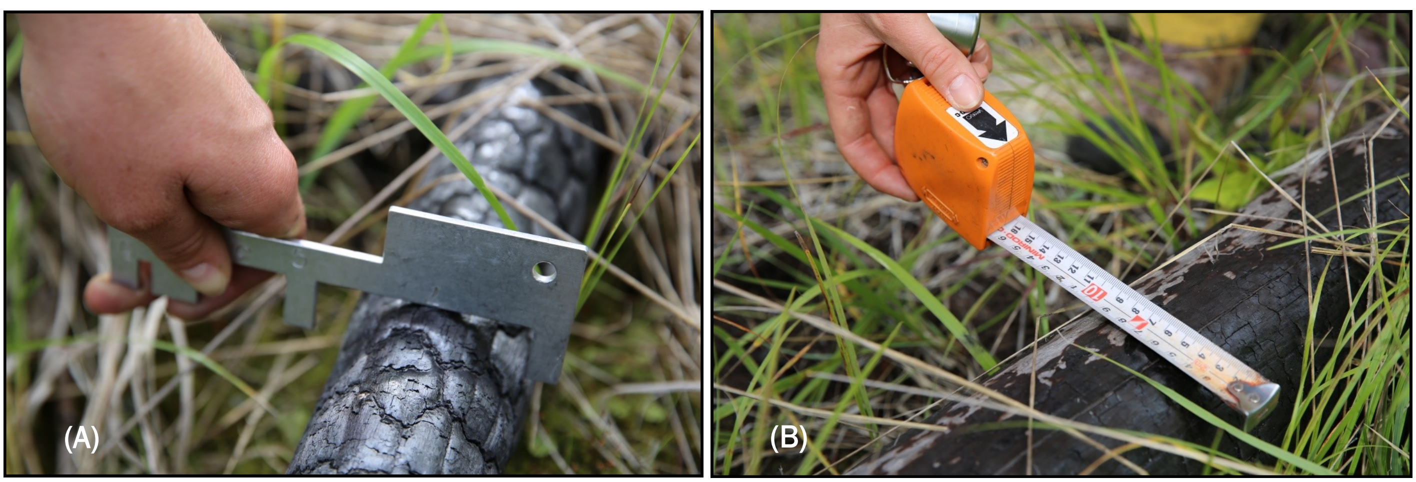

Figure 3.4 Measuring dead and down material using a 'Go-No-Go' gauge and mini-rod measuring tape. In (A), the woody material being sampled is less than 7.0 cm in diameter, thus considered fine woody debris, and falls under a size class 5. In (B), the woody material is greater than 7.0cm in diameter and is therefore considered coarse woody debris. The diameter, species and decay class of the log is then recorded.

3.3.2 Coarse Woody Debris

For each piece of coarse woody debris that intersects the transect, record the **diameter, decay class** and **tree species**. Diameter can be measured using a mini-rod measuring tape (Fig. 3.4 B). The decay class is divided into 7 classes from least decayed (1) to most decayed (5); (6) is Not Assessed and (7) is Burnt. A number of conditions are observed to determine which class the coarse woody debris material falls into (Table 3.2). Decay classes 1-3 are considered 'sound' and 4-5 are 'rotten'. The distinction between sound and rotten is important, as these are the categories used for later calculations. If there is difficulty determining tree species record the most predominant species in the plot as the species.

Table 3.2 Quick reference for decay classes. These classes are divided into 5 categories where decay class 1 is the least decayed and 5 is the most decayed (adapted from Browns Transect Guide 2004).

Class	S/R	Bark	Branches	Twigs	Needles	Texture	Shape	Wood Color	Portion of Log on Ground	Decay	When Kicked
Sound	1	Intact	Present	Present	Present	Intact	Round	Original	None, elevated to supporting points	None	Hard
	2	Intact	Present	Few	Absent	Intact to soft	Round	Original	Parts touch, still elevated slightly	None	Hard
	3	Trace	Absent	Absent	Absent	Hard Large Pieces	Round	Original to Faded	Bole on ground	Little	Hard
Rotten	4	Absent	Absent	Absent	Absent	Soft Blocky Pieces	Round to Oval	Light Brown to Faded Brown	Partially below ground	Sapwood Rotten	Sounds Hollow
	5	Absent	Absent	Absent	Absent	Soft, Powdery	Oval	Faded Light Yellow or Grey	Mostly below ground	Very Rotten	Falls Apart
	6	*Not Assessed*									
	7	*Burnt*									

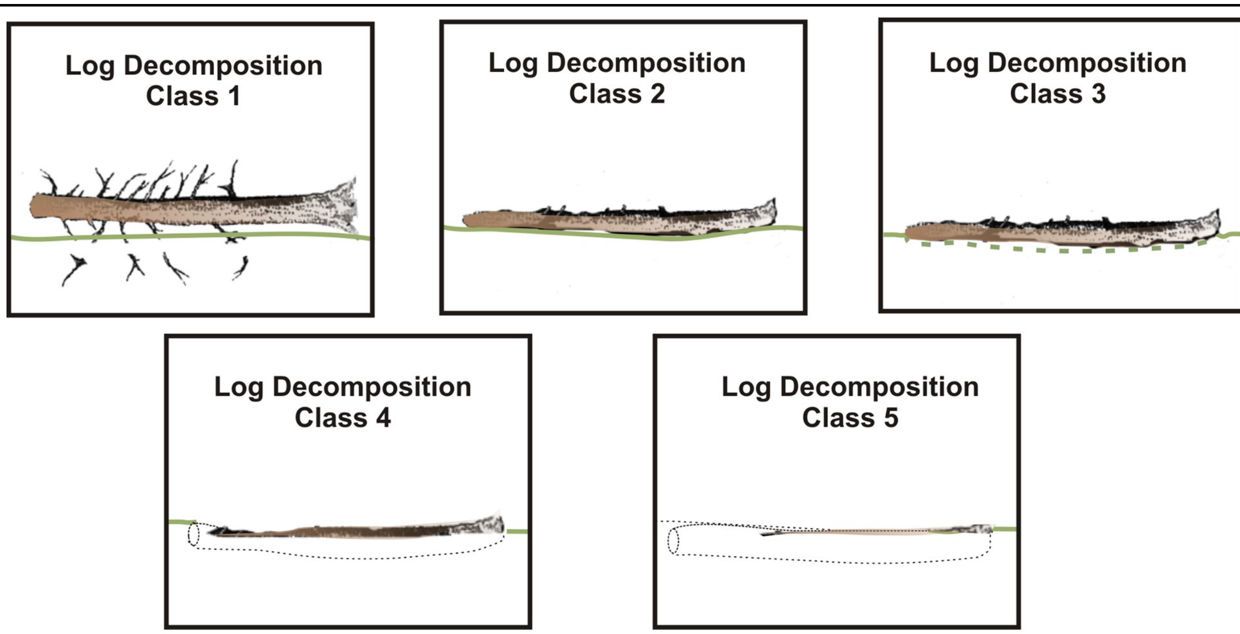

Fig. 3.5 Visual representation of the 5 decay classes. Logs in decay class 1-3 are hard and still have most of their bark, branches and twigs present. Logs in decay classes 4-5 are softer and have transitioned towards rotting, with most of their bark, branches and twigs absent.

3.4 Precision Standards

Record stem tally of fine woody debris to the nearest 1 stem.
Record diameter of coarse woody debris to the nearest 0.1 cm.

3.5 Calculations

3.5.1 Fine Woody Material:

Equation 1. The fine woody debris (FWD) fuel load equation is used for size classes 1 to 5. It is calculated separately on each transect. Multipliers (M) are used for the two most prevalent species from each transect (Spp = species) and are conditional on the type of down woody material (natural or slash). A correction factor is applied for the slope of each transect as well.

$$W_{FWD} = \frac{n * S_1 * M_{Spp1} * c}{L} + \frac{n * S_2 * M_{Spp2} * c}{L}$$

This equation can be simplified as follows:

$$W_{FWD} = \frac{(n * c)}{L} * [(S_1 * M_{Spp1}) + (S_2 * M_{Spp2})]$$

List of symbols & abbreviations:

W, mass per unit area or fuel load (Kg/ ha or t/ha)
n, number of intercepts over length of transect
d, diameter (cm)
S, Species composition of down woody material (1st, 2nd) = %
c, correction factor for slope = $\sqrt{[1 + (\% \text{ ground slope}/100)^2]}$
L, Length of transect (m)
M, Multiplier coefficient. M values are conditional on the "type" of down woody material (natural or slash).*

EXAMPLE 1:

Calculate the fuel load of size class 1 FWD on transect 1 using the simplified equation above. The multiplier coefficients used were conditional on the "natural"
(M-1) type of down woody material.

Table 3.3 Tree species composition of an example plot. The top two dominant species and their relative percent composition are observed and recorded in the field for each transect.

Transect	Species 1	Percent Composition (%)	Species 2	Percent Composition (%)
1	ABBI	70	PIEN	30
2	ABBI	50	PIEN	50
3	POTR	30	PIEN	70
4	ABBI	40	PIEN	60

Transect 1					
Slope (%)	Size Class Counts				
	1	2	3	4	5
56	474	22	13	3	1

$$W_{FWD1} = \frac{(n * c)}{L} * [(S_{ABBI} * M\text{-}1_{ABBI}) + (S_{PIEN} * M\text{-}1_{PIEN})]$$

$$W_{FWD1} = \frac{(474 * \sqrt{[1 + (56/100)^2]})}{25} * [(70/100*0.04454) + (30/100*0.0388)]$$

$$W_{FWD1} = (21.728) * [0.0312 + 0.0116]$$

$$W_{FWD1} = 0.930 \text{ t/ha}$$

The total fuel load of size class 1 for transect 1 is 0.930 t/ha.

*Multiplier coefficients extracted from Nalder et al 1999, Delisle 1986 and Bessie & Johnson 1995.

3.5.2 Coarse Woody Material:

Equation 2. The coarse woody debris (CWD) fuel load equation is used for size class 6 on each transect. The multiplier (M) used in this formula will depend on the type of down woody material (natural or slash), and the decay class (sound or rotten). Decay classes 1,2,3 = Sound (6S) and classes 4,5 = Rotten (6R). Σd^2 is also conditional on decay class and tree species, i.e. only sum squared diameters if the coarse woody material belongs to the same decay class and tree species. Note: The tree species for coarse woody material may be entered as unknown (UNKN) in the database. Whenever this is encountered the multiplier (M) for the tree species with the highest composition should be used.

$$W_{CWD} = \frac{\Sigma d^2 * M_{Spp1} * c}{L} + \frac{\Sigma d^2 * M_{Spp2} * c}{L} + \frac{\Sigma d^2 * M_{Spp3} * c}{L} + ...$$

This equation can also be simplified as follows:

$$W_{CWD} = \frac{c}{L} * [(\Sigma d^2 * M_{Spp1}) + (\Sigma d^2 * M_{Spp2}) + (\Sigma d^2 * M_{Spp3}) + ...]$$

EXAMPLE 2:

Calculate the fuel load for sound coarse woody debris (6S) on transect 1 using the simplified equation above. The multiplier coefficients used are conditional on the "natural" type of down woody material. *Note - this formula would need to be repeated for rotten coarse woody material.*

$$W_{6S} = \frac{c}{L} * [(\Sigma d^2 * M\text{-}6S_{ABBI}) + (\Sigma d^2 * M\text{-}6S_{PIEN})]$$

$$W_{6S} = \frac{\sqrt{[1 + (56/100)^2]}}{25} * [(\Sigma(8.3^2\ 26.0^2, 27.6^2, 14.2^2) * 0.4441)$$

$$+ (\Sigma(35.4^2, 24.0^2)* 0.5675)]$$

$$W_{6S} = (0.0458) * [758.7066 + 1038.0520]$$

$$W_{6S} = 82.372 \text{ t/ha}$$

The fuel load for sound coarse woody debris on transect 1 is 82.4 t/ha.

Table 3.4 CWD findings on an example transect line.

Transect 1 CWD			
Slope (%)	Species	Decay Class	Diameter (cm)
56	PIEN	2	24.0
	ABBI	1	8.3
	PIEN	2	35.4
	ABBI	2	26.0
	ABBI	1	27.6
	PIEN	5	21.2
	PIEN	3	15.1
	ABBI	1	14.2
	ABBI	5	10.0

3.5.3 Fuel Load Outputs

Fuel loads should be reported at the plot level. Plot-level fuel loads are calculated by averaging transect-level fuel loads for each respective size class. Plot-level fuel loads should be reported for each of the size classes listed in Table 3.1.

3.6 References

Alexander, M.E. 2006. *Alberta Prescribed Burn Fuel Sampling Handbook.* Wildland Fire Operations Research Group. Forest Engineering Research Institute of Canada – Western Division. Hinton, Alberta.

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Nalder, I.A., Wein, R.W., Alexander, M.E., de Groot, W.J. 1999. *Physical Properties of Dead and Downed Round-wood Fuels in the Boreal Forests of Western and Northern Canada.* International Journal of Wildland Fire 9(2):85-99.

Chapter 4 — Shrubs

4.1 Introduction

Shrubs are defined as woody perennial plants which differ from trees in their shorter stature and multi-stemmed base (Natural Regions Committee 2006). Shrubs are considered to be light, flashy fuels due to the fact that they ignite easily and burn rapidly. Consequently, this can affect the rate of spread for a fire (Cotton 2003). For the purpose of the Alberta Wildland Fuels Inventory Program (AWFIP), shrubs are measured using the line intercept method. With this method the shrub coverage **length** and average **height** along each 5 meter interval on the transect is recorded for every species that intersects it. Species intercept lengths are then summed and later divided by the total transect length to determine the percent cover for that species (Lutes et al. 2005).

Equipment Checklist			
	Four 25-meter Loggers tapes		One mini-rod measuring tape (2m)
	Shrub Data Sheet		Pencil
	Book: *Plants of the Rocky Mountains*		Clipboard
	Book: *Plants of the Western Boreal Forest and Aspen Parkland*		

4.2 Sampling Design

The shrub plot measurements are performed along all four transects originating from plot center (Figure 4.1). If the site is flat (slope ≤ 15%) the four transect lines run north, south, east and west from plot center. If the slope is >15% the four transect lines run up-slope, cross-slope to the right, down-slope and cross-slope to the left from plot center (Alexander 2006). Transect numbers start at the top (north or upslope) and are numbered successively in clockwise direction.

When laying out the transect lines it is important to keep them as straight as possible. Follow the compass bearing from plot center to ensure transects are laid out at 90˚ angles to each other. If obstacles are located along the transect go under or over them rather then zigzagging around them. If you must go around an obstacle, keep the transect line as close to the object as possible until around it then continue in the original trajectory. Straight transect lines help to ensure that the same vegetation is sampled each time the plot is revisited (Lutes et al. 2005). Shrub measurements are taken along all four 25 meter transects.

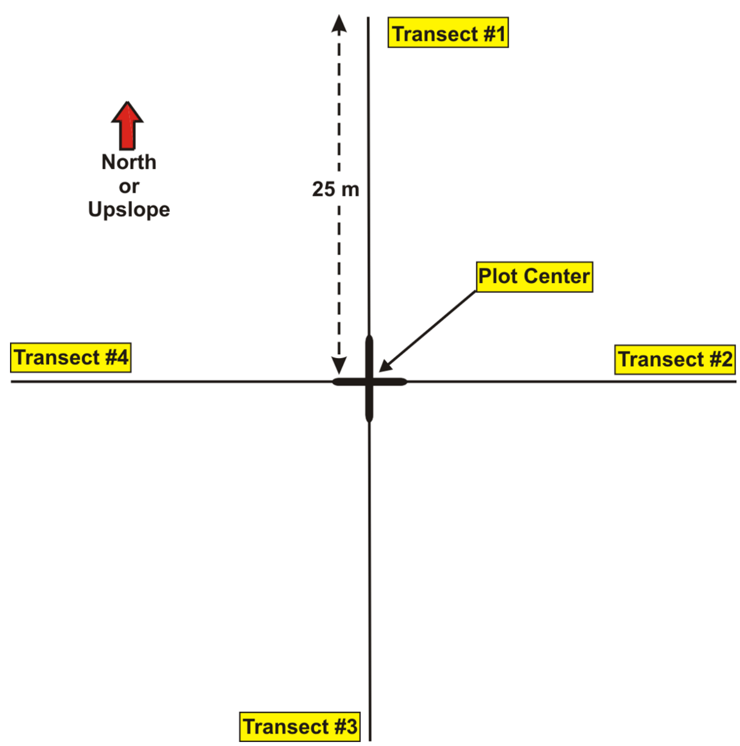
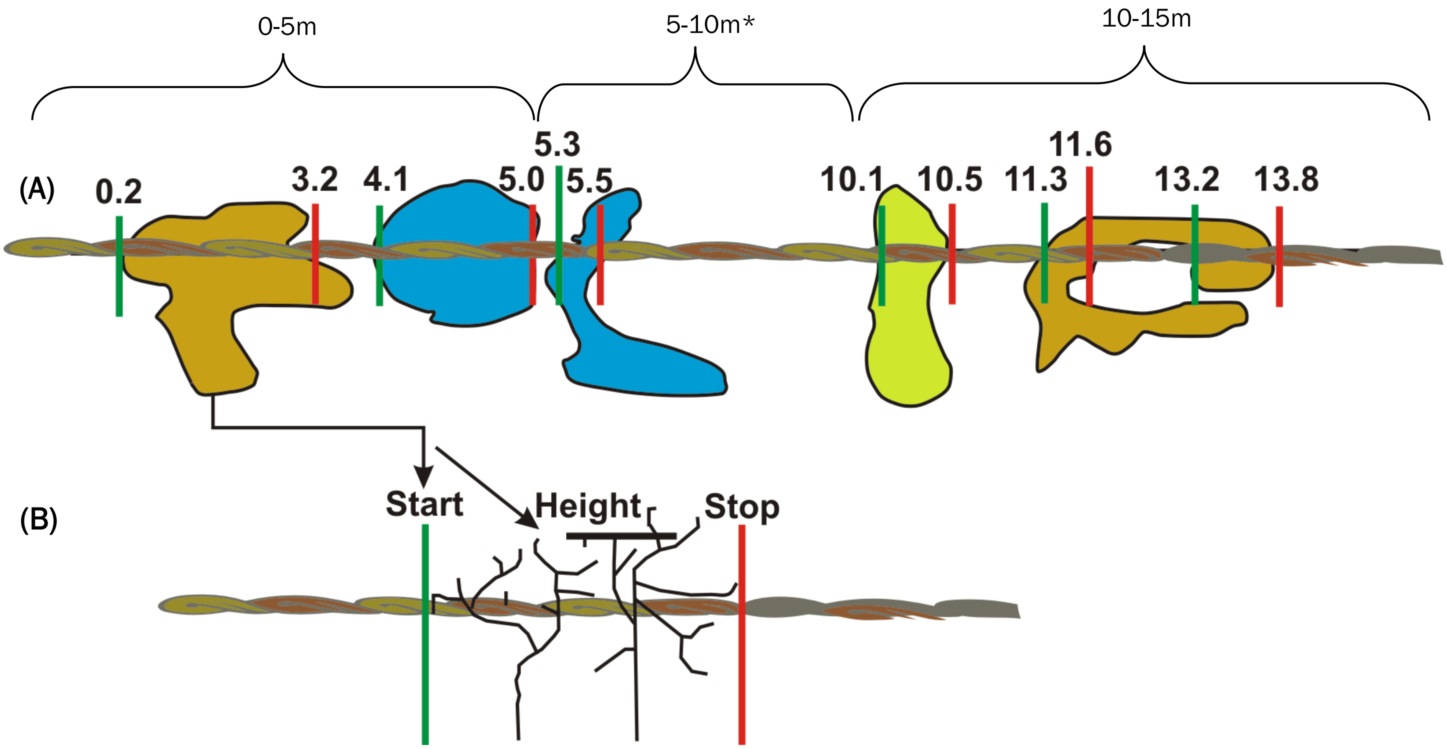


Figure 4.1 Shrub plot layout.

4.3 Methodology

Shrub cover is measured using the line intercept method (Fig 4.2). Shrub specimens are identified to species using plant identification field guides. A four letter species code is used to record the species present along each transect. The item code is comprised of the first two letters of the genus followed by the first two letters of the species of a shrub (e.g. *Alnus crispa* has an item code of ALCR; *Lonicera involucrata* has an item code of LOIN). A code table for AWFIP's most commonly found shrub species in the Alberta Forest Protection Area is provided at the end of this chapter.

The shrub frequency and coverage along each transect as well as the average height will determine the percent cover and the bulk density for a given species. Shrub status is categorized as live or dead. To be considered dead a shrub must have no living tissue visible on the plant; never assume a shrub is dead because it does not have leaves on it, especially in early spring. Status is a deterministic call which does not qualify the health of the shrub but rather identifies if water is flowing through the plant.



(C)

Transect 1	Species (Spp)	Status (L/D)	Length on Transect (m)	Average Height (m)	Σ Length
0 - 5m	Orange	L	3.0	1.3	3.0
	Blue	L	0.9	1.1	0.9
5 - 10m	Blue	L	0.2	0.8	0.2
10 - 15m	Green	L	0.4	1.8	0.4
	Orange	L	0.3, 0.5	1.5	0.8

Figure 4.2 Measuring shrub cover along 15m of the transect*. (A) Overhead view of shrub placement and their length along each segment. (B) Side profile view for recording average height of each shrub species (C) Table containing status, length and average height of each species.
*Transect lengths not to scale.

Shrub coverage is measured as the total distance along each transect that is covered by that shrub, measured in meters. For example, if a shrub first crosses the transect at 1.2m, and continues to 2.5m, the shrub occupies 1.3m of distance. This distance should be recorded for each species over each 5m interval along the transect (See Fig 4.3). Shrubs often grow in a patchy arrangement; record a closed shrub canopy unless there is a gap for that species that is greater than 10 cm along the transect. Shrubs also do not grow in perfect circles and often one specimen may cross the line more than once. Record this as two different measurements, unless the distance between the two patches is 10cm or less. If two shrubs of the same species overlap along the transect line, count both shrubs as one plant (Fig 5.3).

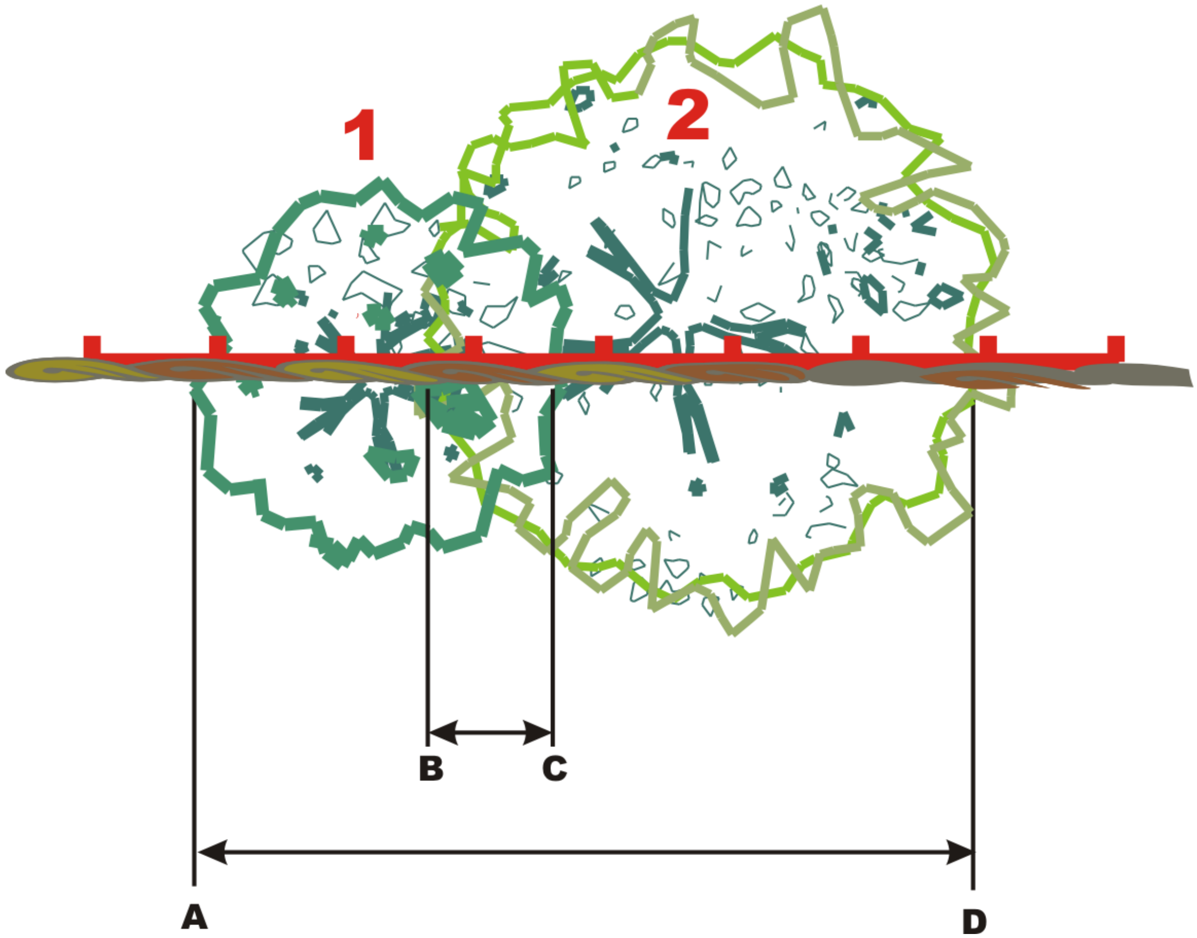


Figure 543. Measuring shrubs if two plants of the same species overlap each other (Lutes et al. 2005).

To measure shrub height pick a sample that is representative for the coverage interval (5 meters). The height of a shrub may not necessarily be the highest point as there may be outlying branches that do not give a sound representation of the height. When measuring height, choose a part of the shrub that represents the average height for the sample. In some cases, it may be necessary to take two or more measurements in order to determine the average height.

4.4 Precision Standards

Record shrub coverage to the nearest 0.01m
Record shrub height to the nearest 0.01m

4.5 Calculations

Percent Cover (%) = ($\sum$ All distances for a species (m) ÷ total transect length (m))*100

Average Height (m) = $\sum$ Average height per species (m) along each transect ÷ 4 transects

4.6 References

Alexander, M.E. 2006. *Alberta Prescribed Burn Fuel Sampling Handbook*. Wildland Fire Operations Research Group. Forest Engineering Research Institute of Canada – Western Division. Hinton, Alberta.

Cotton, K.R. 2003. *Fire in the wildland-urban interface: understanding fire behaviour*. School of Forest Resources and Conservation, Institute of Food and Agricultural Sciences, University of Florida, Gainesville.

Lutes, D.C., Keane, R.E., Caratti, J.F., Key, C.H., Benson, N.C., Sutherland, S., Gangi, L.J. 2005. *FIREMON: Fire Effects Monitoring and Inventory System*. Gen. Tech. Rep. RMRS-GTR-XXX-CD. Ogden UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Natural Regions Committee. 2006. *Natural Regions and Subregions of Alberta*. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. I/005.

Chapter 5 — Ground Cover

5.1 Introduction

Ground cover includes forbs, mosses, lichens, grasses and ferns as well as litter, wood, ash, bare ground, bedrock, boulders, charred material, cobbles, gravel, sand, stones and water. AWFIP measures both basal ground cover and foliar cover. The point intercept method is used to measure ground cover by assessing changes in cover type and cover height over time (Lutes et al. 2005). This method uses a small diameter pole to determine “hits” for each ground cover class along a transect line. Total “hits” for each cover class can later be divided by the total number of sampled points along the transect line to determine % cover (Lutes et al. 2005).

Herbaceous ground cover consists of non-woody vascular plants on the forest floor (Natural Regions Committee 2006). Herbaceous cover is sampled by clipping all non-woody vascular plants within a 1x1 meter sample plot (forbs and graminoids). Vegetation samples are then weighed, oven-dried and weighed again to determine fuel load (kg/m^2).

Equipment Checklist			
	Four 25-meter Loggers tapes		Mini-rod measuring tape (2m)
	Small diameter pole (e.g. a twig or mini-rod)		4 or 5m length of cord
	Pair of sharp scissors		8 lunch size paper bags (for forb and grass samples)
	1 sharpie marker		Clipboard
	Pencil		Ground Cover Data Sheet

5.2 Sampling Design

Ground cover features are sampled along all four transects originating from plot center (Fig 6.1). If the site is flat (slope ≤ 15%) the four transect lines run north, south, east and west from plot center. If the slope is >15% the four transect lines run up-slope, cross-slope to the right, down-slope and cross-slope to the left from plot center (Alexander 2006). Transect numbers start at the top (North or upslope) and are numbered successively in clockwise direction.

Measurements are taken every 0.5 meters along all 4 transects (50 measurements per transect and 200 measurements per plot). Measurements are taken directly on the transect line.

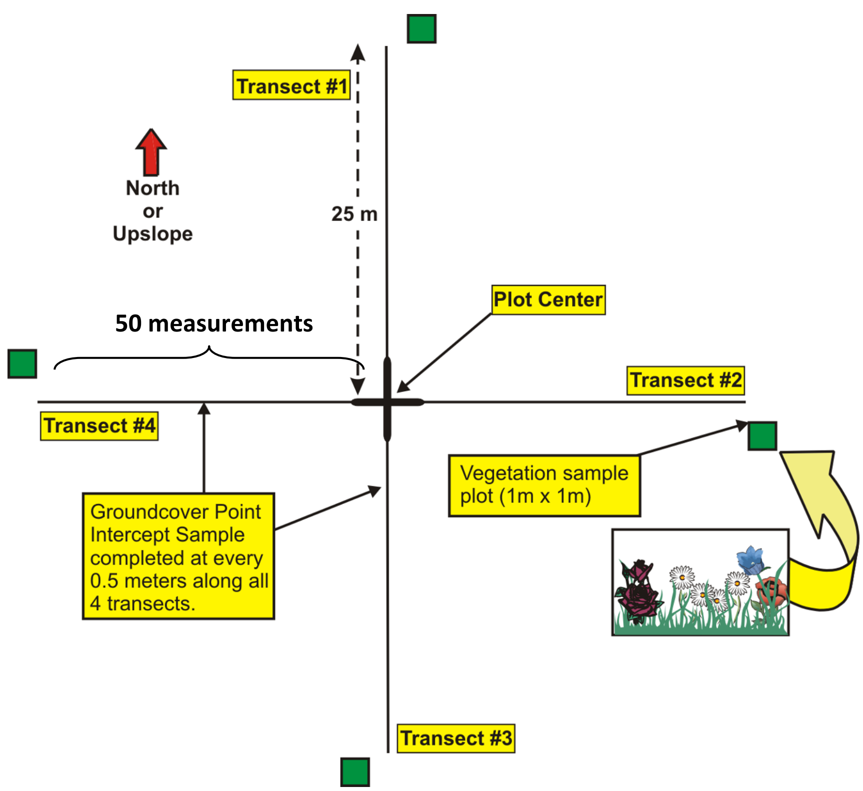


Figure 5.1.
Ground cover plot layout, including herbaceous vegetation 1x1m plots. Using the point-intercept method, 50 points are sampled along each transect. Plot center is not included. In the 1x1m plots, grasses and forbs are clipped and collected, separately.

5.3 Methodology

5.3.1 Ground Cover by Point Intercept Method

Ground cover measurements are performed by holding a pole perpendicular to the transect line at every 0.5 meters and tallying all items that come into contact with the pole. It is recommended that the sampling pole be approximately 0.65 cm (0.25 inches) in diameter, as larger poles can result in an overestimation of cover (Lutes et al. 2005). Using the mini-rod tape is a practical alternative in the field (Fig. 5.2). Position the pole as straight as possible in an upright position with the tip on the ground at the transect point. At each point, measurements will be tallied as a "hit" for each category that the pole comes into contact with. Only tally items once at each sample point, for example a cluster of grass may touch the pole numerous times but only receives one tally per measurement location.

Figure 5.2 Using a mini-rod measuring tape as a small diameter pole. Here, the tape is touching moss, dead grass and live grass (GRAM). The tape can then conveniently be used to measure average heights.

Herbaceous classes are divided into "dead" and "live." If only a few leaves on the plant are dead, consider the plant to still be alive. "Hits" are then calculated into a percent cover by dividing the total number of "hits" for each class by the total number of sample points for that transect. Fore example if the transect has 50 sample points and an item had 20 "hits" then that item covers 40%. A maximum of 100% cover can be achieved for each item. However, the total percent cover (all categories) for each transect or plot can exceed 100%.

The categories used for this type of sampling are chosen based on the level of sample intensity desired. For the purpose of the AWFIP, sample intensity will remain at a moderate level where item codes are divided into general categories (e.g. moss and lichen). If sampling needs dictate a higher level of sample intensity then it is possible to classify items into more specific categories (i.e. feather mosses vs. sphagnum mosses). Sedges shall be considered graminoids (live and dead GRAM) for the sake of simplicity in our sampling. Also note that tree lichen (i.e. Old Man's Beard) is not considered lichen/LICH in our sampling.

If you come across something that is not included on the datasheet, there is room at the bottom to include a new code. Each code is comprised of four letters. If the category is described by one word then the code is just the first four letters of that word (i.e. water = WATE). If the category is described by two words then the code consists of the first two letters of the first word followed by the first two letters of the second word (i.e. Horsetail = HOTA). When a new item code is added it is important to ensure that it is also added into the database. Record the new code in the comments section and consistently use the code throughout the sampling program. Refer to the code table in Appendix 3 for code definitions. Use a dot tally (Figure 5.3) to record the number of "hits" for each category, then sum up the total number of "hits" for the entire transect.

Note: When measuring ground cover at a post-burn site, consider char (i.e. CHAR) as indistinguishable material that has been completely burned.

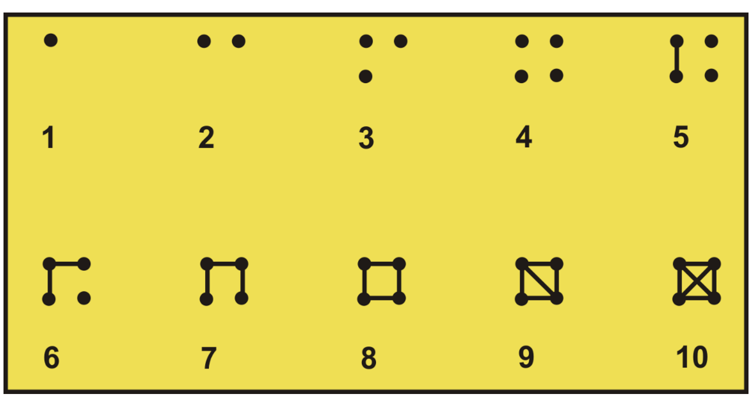


Figure 5.3. Dot tally used for tallying herbaceous cover (Lutes et al. 2005).

Sphagnum vs. Feather Mosses

Sphagnum moss, or peat moss, includes species of the *Sphagnum* genus and has low fire behaviour potential. **Feather moss** includes *Hylocomium splendens, Pleurozium schreberi* and *Ptilium crista-castrensis* and has greater fire behaviour potential.

Upon encountering mulch along the transect, there are two categories present on the datasheet for it to fall under. Use the following guidelines for categorizing mulch as ground cover:

Table 5.1 Mulch piece sizes

Category	Code	Average Length	Average Diameter
Fine	MULF	-	≤ 3 cm
Coarse	MULC	-	> 3 cm

Furthermore, sand, cobble, gravel, stone and boulders can similarly be categorized by size range (Canadian System of Soil Classification 1998):

Table 5.2 Rock fragment sizes

Category	Code	Size range
Sand	SAND	0.005 - 0.2cm
Gravel	GRAV	0.2 - 8 cm
Cobble	CBBL	8 - 25 cm
Stone	STON	25—60cm
Boulder	BOUL	>60c m

Average heights are recorded for each category along each transect for each 5m interval. When measuring average height, choose a couple sample pieces that best represent that category for the entire transect and average them. For items that occur on the ground level (i.e. moss) measure the average depth of that item. For items that are at the ground height (i.e. bare soil) record zero for the height. If cover is suspended, (i.e. a propped up log) record the height of the log from the ground up, including air space. If an item is drooping or leaning, do not attempt to straighten the item when measuring height, unless it was trampled during sampling. Remember, we want to obtain an accurate picture of what the plot was like before we got there.

5.3.2 Herbaceous Plots

Destructive vegetation sampling is done at the end of each transect within a 1.0 x 1.0 meter plot. The plot is located 1 meter to the right and 1 meter past the end of the transect (Figure 6.1). Use a 4 meter length of cord to mark out the sides of the plot. Use four depth of burn pins to mark out the corners of the plot (do not leave these markers). Within each of these plots, all of the herbaceous vegetation (forbs and grasses) will be clipped to ground level and collected in a properly labelled paper bag. Collect both dead and live vegetation. Do not include mosses, lichens or shrubs with these samples. Labels should include the Plot ID number as well as the transect number and identified as either grass or forb. Be sure to record on the Soils data sheet the presence or absence of forbs and grasses in each 1mx1m plot. Samples should be stored with the soil core samples until they are weighed and oven dried to determine fuel load (kg/m^2).

Tip: In the field it is often most efficient for the crew member conducting the soil sampling to complete the vegetation plots because they tend to move more quickly than the crew members working on dead and down, ground cover and shrubs.

5.4 Precision Standards

Record ground cover heights to the nearest 0.5 cm.

5.5 Calculations

Percent Cover (%) = (Number of “hits” for each category ÷ total number of “hits”) * 100 (Lutes et al. 2005)

Average Height (m) = Average height of each category “hit” ÷ number of “hits” for that category.

5.6 References

Alexander, M.E. 2006. *Alberta Prescribed Burn Fuel Sampling Handbook*. Wildland Fire Operations Research Group. Forest Engineering Research Institute of Canada – Western Division. Hinton, Alberta.

Lutes, D.C., Keane, R.E., Caratti, J.F., Key, C.H., Benson, N.C., Sutherland, S., Gangi, L.J. 2005. *FIREMON: Fire Effects Monitoring and Inventory System*. Gen. Tech. Rep. RMRS-GTR-XXX-CD. Ogden UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Natural Regions Committee. 2006. *Natural Regions and Subregions of Alberta*. Compiled by D.J. Downing and W.W. Pettapiece. Government of Alberta. Pub. No. I/005.

Soil Classification Working Group. 1998. *The Canadian System of Soil Classification, 3rd Edition*. Agriculture and Agri-Food Canada Publication 1646, 187 pp.

Figure 5.4 Assessing ground cover along a 25m transect.

Chapter 6 — Small Trees

6.1 Introduction

Small trees compose the understory layer of the forest and consequently the ladder fuels in a forest stand. For the purposes of the Alberta Wildland Fuels Inventory Program (AWFIP), small trees are all trees having a diameter at breast height (DBH) less than 9.0 cm (Canadian Forest Inventory Committee, 2004, Alberta Sustainable Resource Development, 2005). Small trees are measured within a circular plot located around the plot center. The radius of the sampling plot is determined by tree density. The objective is to use the smallest of the two radii such that a minimum of 20 small trees fall within the sampling area. Small trees are divided into two separate classes: seedlings and saplings. Saplings are all trees within the sampling radius that have a DBH less than 9.0 cm and a height greater than or equal to 1.3 meters. Seedlings are trees with a DBH less than 9.0 cm and a height less than 1.3 meters.

Equipment Checklist			
	One 25-meter Loggers tape		1 can of orange/pink spray paint
	1 counter		1 set of 15cm calipers
	Mini-Rod measuring tape (2m)		DBH tape
	Clipboard		Laser Hypsometer and/or Clinometer
	Small Tree Data Sheet		Pencil
	Book: *Plants of the Rocky Mountains*		Book: *Plants of the Western Boreal Forest and Aspen Parkland*

6.2 Sampling Design

Understory information is gathered from either a 3.57m radius (0.004 ha) or a 5.64m radius (0.01 ha) plot, located around plot center (Fig 6.1). The size (radius) of the sampling plot is determined by tree density. The objective is to use the smallest of two radii such that a minimum of 20 small trees fall within the sampling area. If it is still not possible to measure 20 trees within the largest plot size, it is not necessary to increase the plot size any further. Seedlings are recorded as a tally per height class. For saplings, record the species, status (L/D), height, LCBH and DBH (cm). A laser hypsometer can be used to quickly determine the boundaries of your circle plot. Have one person stand at plot center and hold the transponder (puck) at the same height as the person finding the plot edge with the hypsometer.

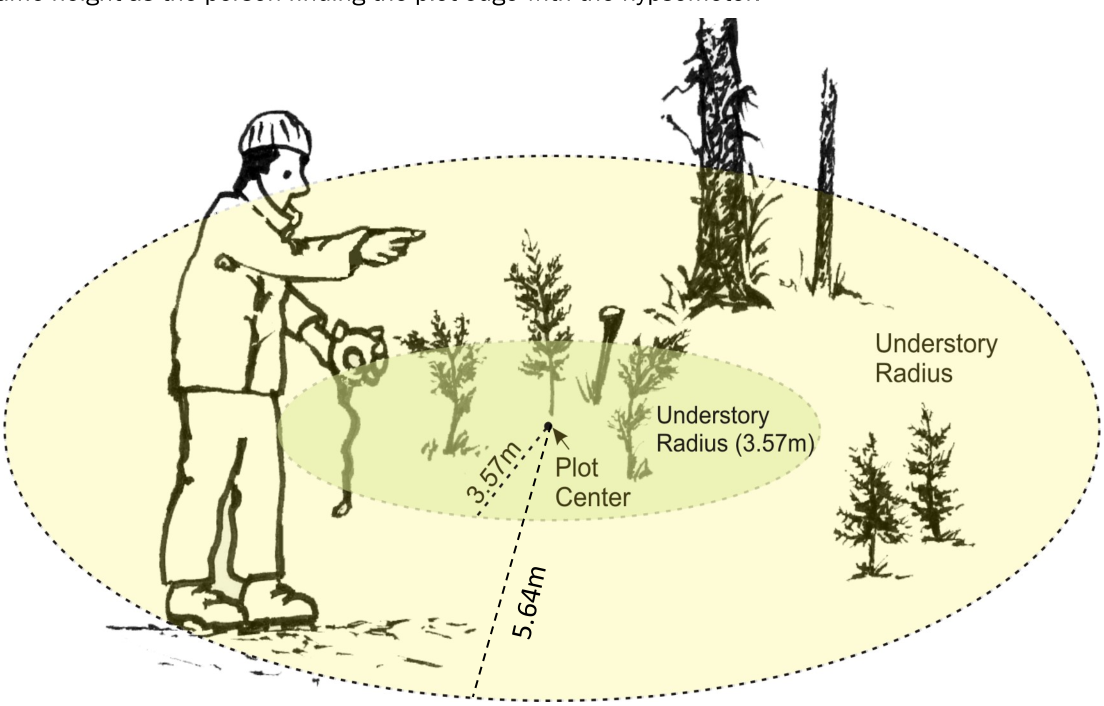


Figure 6.1. Small plot layout (adapted from Lutes et al. 2005). Plot boundary can be found using a laser hypsometer.

6.3 Methodology

6.3.1 Seedling Measurements

Seedlings, sometimes informally referred to as regen, are small trees less than 1.3m in height. With seedlings, a stem tally is recorded by species and status (live/dead). Species codes follow the scientific naming convention. These consists of 4 letter codes determined by combining he first two letters of the genus name with the first two letters of the species name. For example, Lodgepole Pine (***Pi**nus **co**ntorta*) would be recorded as **PICO**. Seedlings are then tallied and categorized into one of four height classes:

Table 6.1 Height categories for the four height classes used for sampling seedlings.

Height Class	Height (meters)
Class 1	Less than 0.1
Class 2	0.1 - 0.5
Class 3	0.5 - 1.0
Class 4	1.0 - 1.3

Figure 6.2 Determining height class for a PICO seedling using a mini-rod tape. Because the seedling is roughly 20cm high, it is categorized as a height class 2.

Use a 2 meter mini-rod measuring tape to measure seedling heights (Fig. 6.2). If a tree is bent or leaning do not straighten it for measurement but rather measure from the base of the tree to the highest point.

Tree status is characterized as live or dead. Dead trees must have no living tissue visible on the plant to be classified as dead. Never assume that a tree is dead because it does not have leaves or needles on it. Status is a deterministic call which does not qualify the health of the tree but rather identifies if water is flowing through the plant.

6.3.2 Sapling Measurements

Saplings are small trees greater than 1.3m tall and having a DBH less than 9.0cm. The species, status, DBH (cm), live crown base height (m) and height (m) is recorded for each tree. Use the tree descriptions in *Plants of the Rocky Mountains* and *Plants of the Western Boreal Forest and Aspen Parkland* to aid in determining tree species if you are unsure. DBH is measured using a DBH tape or calipers and should be recorded to the nearest 0.1 cm from breast height. Seedling height is measured using either a 2.0 meter mini-rod measuring tape or if the tree is greater than 2.0 meters tall, a laser hypsometer. Status is recorded as either live or dead.

For both seedling and sapling sampling it is recommended to work in one direction (ie clockwise) from one quadrant to the next in order to avoid missing any small trees.

Figure 6.3 Measuring sapling DBH using a small pair of calipers at breast height.

6.4 Precision Standards

Record sapling height to the nearest 0.1m.
Record sapling live crown base height to the nearest 0.1m.
Record sapling DBH to the nearest 0.1m.

6.5 Calculations

Seedling Stem Density

When calculating the number of stems per hectare consider both the density for individual species within the plot as well as all seedlings combined. The calculation used is as follows:

Stems/Hectare = Number of stems ÷ ((π(Plot Radius)^2) ÷ 10 000).

Sapling Average Height and Average Live Crown Base Height

To calculate the average height or LCBH for individual species sum the individual heights or LCBHs of each species and divide by the total number of that species.

Average Height (m) = Sum of heights (m) ÷ number of stems

Sapling Stem Density

When calculating the number of stems per hectare for saplings consider the density for both individual species and for all saplings combined. The following calculation is used:

Stems/Hectare = Number of stems ÷ ((π(Plot Radius)^2) ÷ 10000).

Note: When individual sapling heights are equal to or greater than the plot Large Tree mean LCBH + 3m, then those are considered part of the overstory and those sapling's LCBH values are used in overstory calculations.

6.6 References

Alberta Sustainable Resource Development. 2005. *Permanent Sample Plot (PSP) Field Procedures Manual*. Public Lands and Forests Division, Forest Management Branch, Edmonton, AB.

Canadian Forest Inventory Committee (CFIC). 2004. *Canada's National Forest Inventory Ground Sampling Guidelines*. The Climate Change Action Fund and the National Forest Inventory.

Lutes, D.C., Keane, R.E., Caratti, J.F., Key, C.H., Benson, N.C., Sutherland, S., Gangi, L.J. 2005. *FIREMON: Fire Effects Monitor ing and Inventory System*. Gen. Tech. Rep. RMRS-GTR-XXX-CD. Ogden UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Chapter 7 — Large Trees

7.1 Introduction

For the purposes of the Alberta Wildland Fuel Inventory Program (AWFIP), large trees are single stemmed woody plants that have a DBH greater than 9.0 cm (Alberta Sustainable Resource Development, 2005). Large trees form the upper canopy layer, or overstory, within a forest stand. When assessing wildfire potential or activity, crown structure can play an important role. The measurements laid out in this chapter help to determine the overall height of the canopy, continuity of canopy fuels and vertical fuel continuity between the forest floor and the canopy. Additionally these measurements assess the overall age, health and history of the stand.

Equipment Checklist			
	Compass		Code tables
	Vertex hypsometer and/or clinometer		25 meter loggers tape
	DBH tape		20 - 30 numbered metal tree tags
	Orange spray paint		Increment borer
	Sharpie marker		Clipboard
	Pencil		Large Tree Data Sheets

7.2 Sampling Design

The large trees are measured with a fixed radius plot located around plot center (Fig 7.1). The radius of the sampling plot is determined by tree density. The objective is to use the smallest of three radii such that a minimum of 20 trees fall within the sampling area. For example, if there are 20 trees that can be sampled within a radius of 5.64m, then that radius should be used. If there are only 15 trees that can be sampled in that area then the next largest radius, 7.98, should be used. If in the 7.98 there are say, 28 trees that fall in that area, all 28 trees must be sampled, not just the first 20. This method of using a breakpoint radius to sample > 20 trees should be used for all of our plots, as opposed to the National Forest Inventory method which uses a standardized 11.28 meter plot size regardless of tree density. This is one means of achieving time management objectives in the field. There are three plot areas used with the breakpoint radius method:

Table 7.1 Large tree plot radii and their equivalent areas

Plot Radius (m)	Plot Size (ha)	Area (m^2)
5.64	0.01	100
7.98	0.02	200
11.28	0.04	400

11.28 meters is the maximum plot size, if it is still not possible to measure 20 trees within this plot size, then it is not necessary to increase the plot size any further.

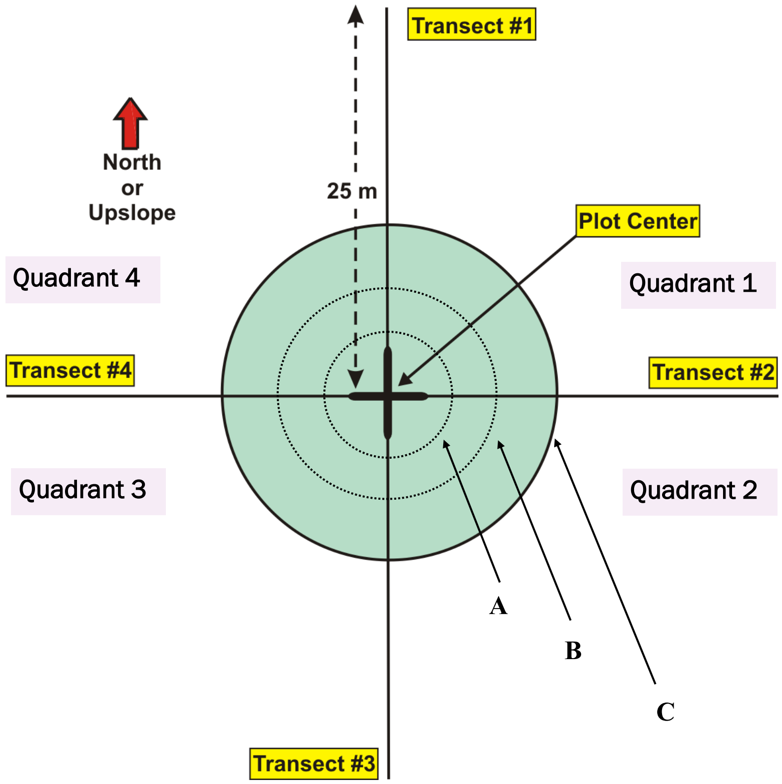


Figure 7.1. Large tree plot layout. There are three radii to choose from: (A) 5.64m, (B) 7.98m, and (C) 11.28m.

In order to easily identify the plot radius, use a measuring tape to measure the radius distance from plot center and use tree paint to mark at least 4 distances on the ground (1 per quadrant). This can also be done quickly and efficiently with the *Vertex* hypsometer, placing the transponder (puck) at plot center. Be sure to calibrate the hypsometer each day prior to taking any measurements.

Trees are numbered by quadrant starting with the tree that is closest to plot center in quadrant one and moving in a clockwise direction through the quadrants. Tree numbers should face plot center and be painted as high up on the tree as possible. Numbered metal tags should also be nailed to each tree in order to properly identify sample trees in future sampling (especially after fire). Tree number should correspond with the numbered metal tag attached to each tree. The **azimuth** and **distance** from plot center to each tree will be measured and recorded to further aid in identifying each tree during post-treatment sampling.

7.3 Methodology

Large trees are all trees (live or dead) within the plot having a DBH greater than 9.0 cm. These trees are assessed for:

- Species
- Tree status
- Diameter at breast height (DBH)
- Height
- Live crown base height (LCBH)
- Dead crown base height (DCBH)
- Crown widths
- Damage/mortality
- Age

Note: For prescribed burns, char height (up and down slope or high and low scorch) and the percent crown scorched will also be assessed during the post-treatment assessment (refer to Lutes et al 2005). For these measurements, high char height should be the highest height on the tree that is burned to char (black), low char height should be the lowest height on the tree that is burned to char (black), and scorch height is the highest area that is head affected (brown needles and leaves).

Species is recorded using a 4 letter species code derived from the scientific (Latin) name. It is determined by combining the first two letters of the genus with the first two letters of the species. For example Lodgepole pine (***Pi**nus **co**ntorta*) would be PICO.

The status of the tree is categorized as either live or dead. For a tree to be considered dead it must have no living tissue visible on the plant, never assume that a tree is dead because it does not have leaves on it. There are many reasons for this other than seasonal variation (i.e. browsing). Status is a qualitative call that does not reveal the health of the tree but rather identifies if there is water flowing through the plant.

Figure 7.2 Measuring DBH on a large tree using a DBH tape. Ensure the tape is snug around the circumference of the tree.

Diameter Breast Height (DBH) measurements are taken at **1.3 meters** from the ground. If there are deformities or branches at the 1.3 meter mark then offset the measurement by 5 cm increments until the measurement is located in a representative spot. In the case where two stems are joined together at the base follow these rules:

⇒ If the point of separation is ***higher*** than DBH then count as one stem and take one measurement below both stems.

⇒ If the point of separation is ***lower*** than DBH then count the tree as two separate stems and take two separate measurements at DBH.

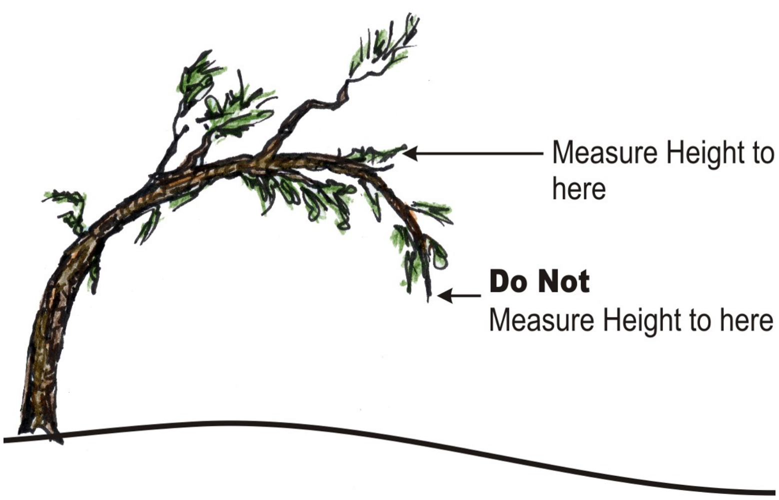


Figure 7.3. Measuring tree height on a sweeping tree. It is helpful to have one crew member stand below the highest point on the swept tree with the transponder (puck) at breast height while another crew member stands at least 15m away.

Tree height is the height to the highest point on the tree. In most cases, this will be to the tip of the tree, but in some cases, this will be to the highest point of the bole (Fig 7.3). For the purpose of this program we want to investigate where the top of the crown is, as that is where the available fuel is. When measuring with the *Vertex* hypsometer, attach the transponder (puck) at breast height to the tree trunk and stand at a distance approximately the height of the tree away (or at least 15m away).

Reminder

Bole refers to the trunk of a tree.

Figure 7.4 Example of dead crown on white spruce in a mixed wood stand.

Dead crown base height (DCBH) is the height to which dead crown fuels extends to. This includes dead branches, twigs, foliage and needles, usually found below the live crown (Fig 7.4). It can also include the dead sections that contain mistletoe infections and lichens. Often dead crown extends right to the forest floor. This measurement should contain the average elevation above the ground where the dead crown base height begins.

Figure 7.5. Measuring live crown base height.

Live crown base height (LCBH) is the height of available fuels in a continuous arrangement (Fig 7.5). Live crown fuels are defined as: the standing and supported forest combustibles not in direct contact with the ground that are generally only consumed in crown fires (i.e. foliage, twigs, branches, cone) (Canadian Interagency Forest Fire Centre). Live crown base height is measured as the height above ground where most of the branches and twigs above that point are alive, continuous and have the ability to move fire higher into the tree (Lutes et al. 2005). Live crown is to be measured from the tip of the leaves/live branch, not the trunks of the branches (Alberta Sustainable Resource Development 2005). Do not include whorls that are not part of the main crown (Lutes et al. 2005). If the live branches are distributed asymmetrically along the tree trunk, take the average live crown base height.

Table 7.1 Damage/mortality codes for live and dead large trees.

Code	Damage Agent
F	Fire
W	Wind
M	Mechanical
A	Animals
E	Other Environmental Factors
ID	Insects and Disease

Mortality/damage codes are assessed on standing dead trees or any tree showing visible signs of damage from an identifiable source. When looking at a tree look for scars, pitch flow and foliage damage. If you are unable to determine the cause of the damage, take pictures and descriptive notes so that your supervisor can asses the cause of the damage. If you think you may know the specific insect or disease that is present, then make note of it in the comment section. If you are performing a re-measurement survey and you are unable to find a tree, note it as missing. Table 7.1 outlines mortality/damage codes used by the AWFIP.

The purpose of measuring crown widths is to determine the percent ground cover of all the trees within the plot combined. These measurements generally require two people and are done by measuring the x and y axis of the tree canopy, where the x axis runs East-West and the y axis runs North-south (Fig 7.6). Measure the average width of the crown as seen from the ground in both the x and y directions. Should branches extend significantly beyond the overall width of the crown, do not measure to the tip of these branches but rather to the average width of the entire canopy.

Note: If a tree has no crown (i.e. a dead pole) record "0" for crown width.

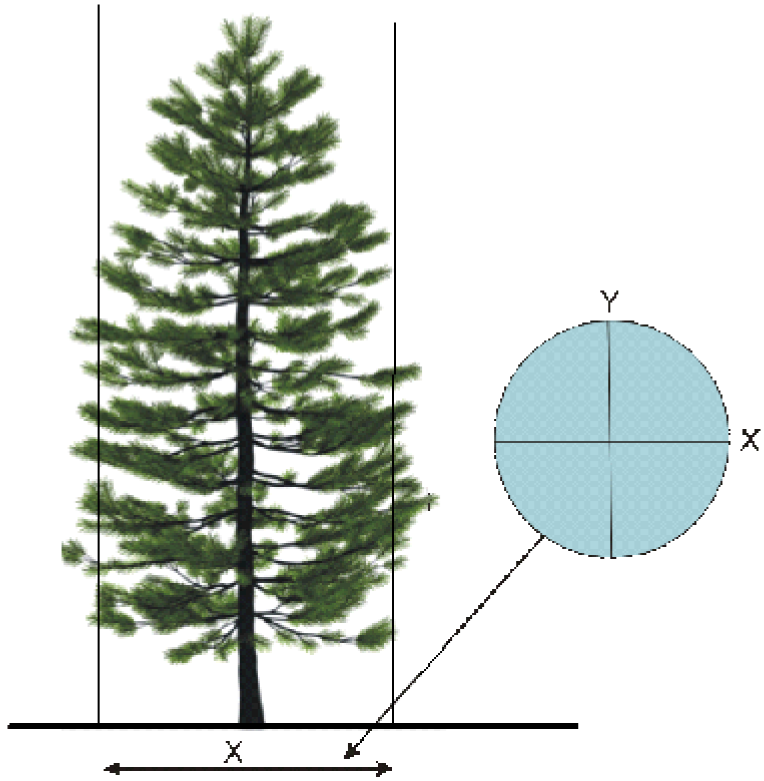


Figure 7.6 Measuring crown widths along the east-west and north-south axis.

Tree age is measured using an increment borer. Two sample cores should be taken from each tree species represented in the plot. A minimum of four cores per plot is required—if only one species is present in the stand then all four cores will be taken from that species. Only sample live trees.

Cores should be retrieved from as close to the base of the tree as feasible—barring factors such as root flares, ground interference, etc. Record the height at which the core was taken.

7.4 Precision Standards

Record DBH to the nearest 0.1 cm
Record height to the nearest 0.1 m
Record crown fuel base height to the nearest 0.1 m
Record age to the nearest 1 year

7.5 Calculations

Crown Height (m) = Tree Height (m) - Live Crown Base Height (m)
Crown Density (trees/ha) = Total number of trees/area of circle plot used (ha)
Crown Fuel Load (kg/m^2) = $\sum$ Crown Weights[1] per plot (kg) / Plot area (m^2)
Canopy Bulk Density (CBD) (kg/m^3) = Crown Fuel Load (kg/m^2) * Crown Height (m)
Species % = Number of species "x"/total number of trees (n) (Relative Density)
Average LCBH = $\sum$Tree LCBH/n
Average DBH = $\sum$DBH/n
Overall Stand Density = n trees/(π*Plot r^2(m^2)*0.0001(ha/m^2))
Species Density = Stand Density * Relative Density

[1]Crown weights (kg) are obtained using allometric equations specific to each tree species based off of DBH measurements.

7.6 References

Alberta Sustainable Resource Development. 2005. *Permanent Sample Plot (PSP) Field Procedures Manual*. Public Lands and Forests Division, Forest Management Branch, Edmonton, AB.

Lutes, D.C., Keane, R.E., Caratti, J.F., Key, C.H., Benson, N.C., Sutherland, S., Gangi, L.J. 2005. *FIREMON: Fire Effects Monitoring and Inventory System.* Gen. Tech. Rep. RMRS-GTR-XXX-CD. Ogden UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Chapter 8 — Mulch

8.1 Introduction

Mulching treatments are one of several preventative measures employed by the FireSmart program in an effort to reduce wildfire threat to Albertans and their communities while balancing the benefits of wildfire on the landscape (wildfire.alberta.ca, 2014). Mulch treatments can be implemented in various forms, at different intensities, and by different pieces of machinery (Hvenegaard 2014). Mulching can reduce tree density and canopy bulk density, and increase canopy base height, potentially lowering active crown fire risk (Kreye 2011). The Alberta Wildland Fuels Inventory Program (AWFIP) has come up with a protocol for collecting mulch samples from treated sites in order to obtain a representation of an area's mulch component of the fuel load. In doing so, we are contributing to a database of knowledge for the beginnings of understanding mulching effects as a FireSmart tool on the landscape.

Equipment Checklist			
	One 25-meter Loggers tape		1 can of orange/pink spray paint
	1 quadrat square (30cm x 30cm)		Ruler
	4 Duff pins		Camera
	Clipboard		Brown paper bags
	Mulch and Soils Data Sheet		Sharpie
	Hand/power/chain saw		Calculator

8.2 Sampling Design

Mulch samples are taken along the four transect lines running north, south, east and west from plot center. If the slope is >15% the four transect lines run up-slope, cross-slope to the right, down-slope and cross-slope to the left from plot center (Alexander 2006). Transect numbers start at the top (North or upslope) and are numbered successively in clockwise direction.

The number and location of mulch samples will depend on the type of mulch treatment, in accordance with the project objectives (Fig. 8.1). Two or three 30x30cm quadrat samples of mulch are collected from each transect.

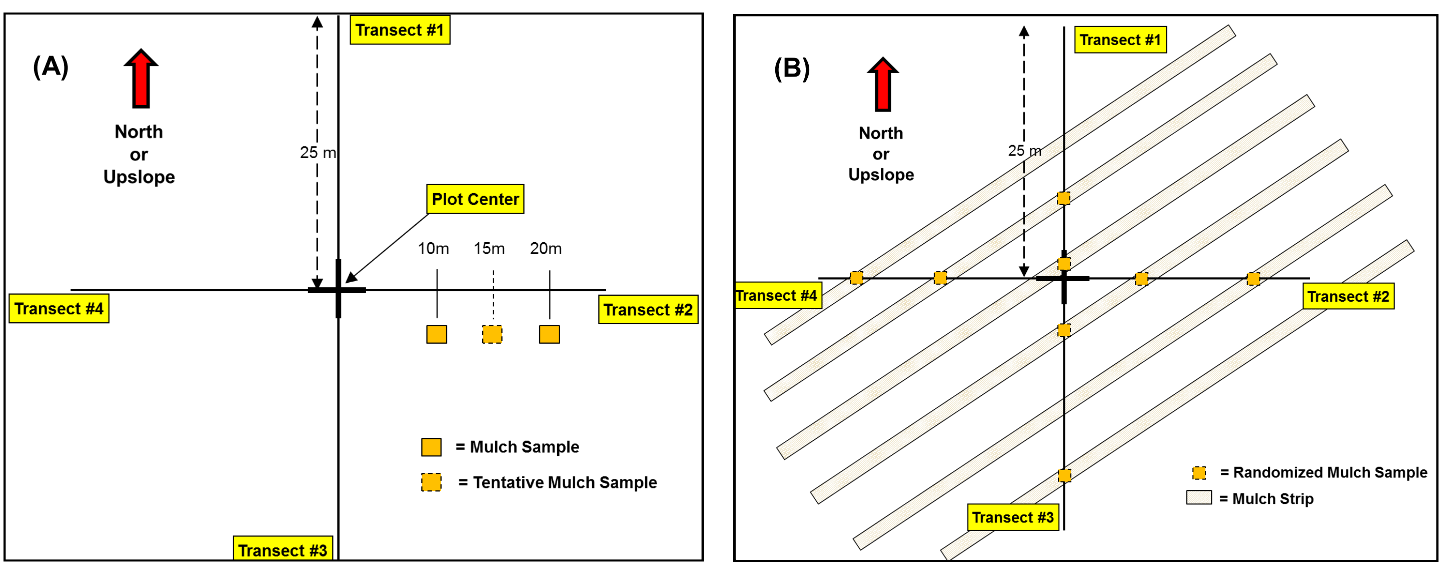


Figure 8.1 Mulch sampling layout in two different treatment types. (A) represents an inter-tree spacing treatment where two 30 x 30cm samples are collected on each transect, one at 10m and one at 20m. Depending on treatment intensity, a third sample may be required at 15m. (B) represents a strip mulch treatment where samples are collected on two randomly chosen strips per transect.

8.3 Methodology

8.3.1 Mulch

Mulch samples are taken using a 30cm x 30cm square quadrat. At least two of the these quadrats are sampled on every transect. Treatment type and intensity will determine the set up of the sampling (Fig 8.1). For sites that have undergone high intensity mulching we will collect samples from three quadrats—one at 10m, one at 15m and one at 20m (Fig 8.1A). If the treatment was of lower intensity, only two will be collected, at 10m and 20m.

For sites that have undergone strip mulching, two samples per transect will be taken (Fig 8.1B). If more than two strips cross a transect, two will be selected at random to sample from. In order to determine *where* on the strip to sample, the width of the strip must first be measured, then divided by five and subsequently one of those five locations must be randomly selected to sample at. Make certain to record the distance on the transect that was selected for the sampling.

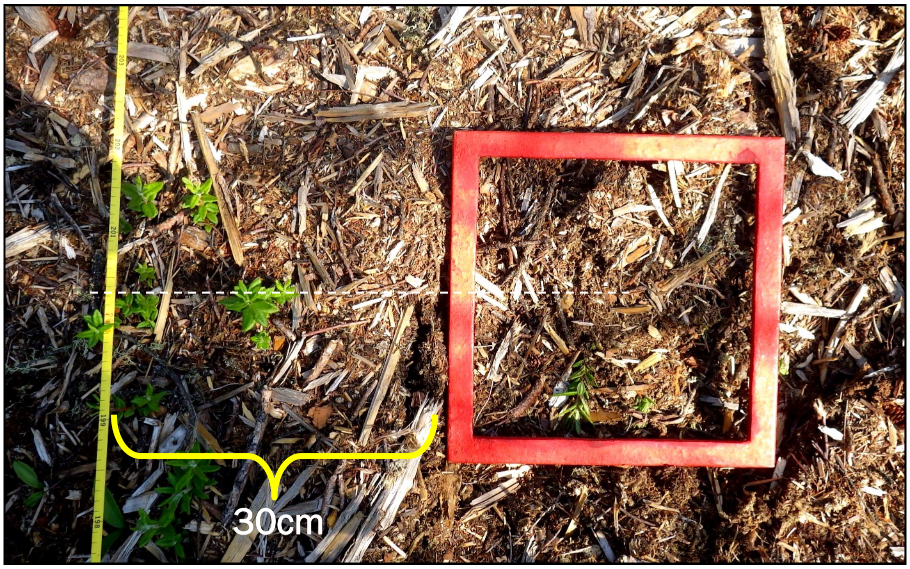


Figure 8.2 Correct orientation and placement of quadrat along transect tape. The square should be 30cm away from the tape and the center in line with the distance you are sampling at.

All sampling should take place on the right side of the transect tape. The center of the quadrat should be placed in line with the distance you are sampling at, and approximately 30cm away from the transect tape (Fig 8.2). Each of the four corners are marked with a duff pin, with the cross bars sitting just on top of the mulch. A measurement of mulch depth at the center of the quadrat should be taken prior to sampling, and recorded. The inside of the square can be spray painted to aid in maintaining the quadrat outline should it get bumped or displaced.

Collect all mulch within the perimeters of the quadrat, all the way down to the litter or duff layer below (Fig. 8.3). Anything that has been mechanically altered or churned is considered mulch. This means that foliage or duff that is mixed into the mulch complex is now considered mulch and this should all be collected as one sample (i.e. do not attempt to separate the two). Litter that has fallen on the ground after mulching has occurred should not be collected with the mulch sample—this is classified as litter. In cases where treatment sites are starting to re-vegetate, do not include live vegetation in the sample (Fig 8.3C). Pieces of mulch that straddle the perimeter should be cut and only the sections inside the quadrat are to be collected. Larger pieces of mulch will need to be hand or power sawed (Fig. 8.3A) and trunks that have fallen as a result of mulching will need to be chain sawed (Fig. 8.3B).

Figure 8.3 Examples of mulch quadrats. (A) Quadrat square with mulch removed, except for a large piece which needs to be hand sawed. Note the duff pins in the corners. (B) Some quadrats will land on tree trunks. Collect all loose mulch first and proceed to chainsaw the log after. (C) Some locations will have a large amount of re-growth. Do not collect live vegetation.

After all the mulch has been collected, measure the depths from the duff or litter to the top of the cross bars of the duff pins in all four corners,. Record these depths on the data sheet. The percent cover of mulch at each quadrat also needs to be estimated and classified as either low (0-25%), medium (25-50%) or high (50+%).
Note: If you are collecting mulch samples shortly after treatment and the original litter layer (marking the end of the mulch sample) has not yet turned to duff, still count it as duff and not as litter. Once mulching has occurred, litter should only be considered what has happened since mulching treatment. The exception is if mulch has been lightly scattered on an otherwise undisturbed piece of land and all original litter is still available to actively burn in a fire.

The program has found that the best way to collect samples is with brown paper bags in a variety of sizes. If moisture content of the mulch is relatively low, medium sized grocery paper bags are ideal, but are rendered useless if they are exposed to any significant amount of moisture. Large yard waste paper bags (ie 110L) are handy for sites with heavy and/or deep mulch. Paper bags with plastic linings or biodegradable linings can be useful for wetter conditions, however it is important to ensure these samples are well aerated while being stored in the truck, otherwise mold will set in quickly. The best method is to keep a variety of these paper bags on hand and use discretion on the day of as to what will work best. Write down the plot ID, transect number and distance at which the sample was taken on each bag.

8.3.2 Dead and Down Material

At sites where there is widespread mulching and few trees remaining, no dead and down woody material needs measuring. Any dead and downed material remaining will be assumed to be mixed in with mulch and accounted for with those samples. In locations where there is strip mulching, only collect dead and down measurement on the 'natural' strips, not on the mulched strips. Take measurements of all five size classes of fine woody debris (FWD) for every 'natural' strip. Record the placements of each 'natural' strip on the transect (ie 5.4m to 9.6m and 10.4m to16.6m) and sum these widths for a total "natural' length along each transect. For example, if 'natural' strips on transect 2 occurred at 5.4 - 9.6m, 10.4- 16.6m and 20.4- 23.5m, you would write this down and record the sum of these widths (4.2m + 6.2m + 3.1m) as 13.2m. Easy right?

8.3.3 Soils

Done in combination, soils and mulch can be completed quite effectively. Collecting mulch first leaves a perfectly cleared square for the soil core to sample from. So ideally we take our 10 and 20m mulch and soil samples from the same location on inter-tree mulched sites. On strip mulch plots however, soil samples remain at 10 and 20m, whereas mulch samples will only be taken where the mulch strips cross the transect.

8.4 Precision Standards

Record mulch strip widths to the nearest 0.1m
Record mulch depths to 0.1cm

8.5 Calculations

Bulk Density (Kg/m^3) = Oven dried Weight (kg) ÷ Volume (m^3)
Volume (cm^3)= 30cm x 30cm x Average Depth of Sample per Plot (cm)

Average Mulch Depth by plot (cm) = Sum of all depths (measured AND sampled) ÷ 20

Fuel Load (kg/m^2) = Bulk Density (kg/m^3) x Average Mulch Depth per Plot (m)

8.6 References

Hvenegaard, S; Hsieh, R. 2014. *Project Report: Summary of mulch treatments and equipment productivity at the Slave Lake Mulch Research Area*. FP Innovations Wildfire Operations Research. Retrieved from: http:// wildfire.fpinnovations.ca/119/ Slave%20Lake%20Summary_v5.pdf

Kreye, JK; Varner, JM; Knapp, EE. 2011. *Effects of particle fracturing and moisture content on fire behaviour in masticated fuel beds burned in a laboratory*. International Journal of Wildland Fire 20:308–317.

http://www.wildfire.alberta.ca/fire-smart/default.aspx. 2014.

Appendix 1 — Canadian Forest Fire Behaviour Prediction (FBP) System Fuel Types Descriptions

C1: Spruce–Lichen Woodland

This fuel type is characterized by open, parklike black spruce (*Picea mariana* (Mill.) B.S.P.) stands occupying well-drained uplands in the subarctic zone of western and northern Canada. Jack pine (*Pinus banksiana* Lamb.) and white birch (*Betula papyrifera* Marsh.) are minor associates in the overstory. Forest cover occurs as widely spaced individuals and dense clumps. Tree heights vary considerably, but bole branches (live and dead) uniformly extend to the forest floor and layering development is extensive. Accumulation of woody surface fuel is very light and scattered. Shrub cover is exceedingly sparse. The ground surface is fully exposed to the sun and covered by a nearly continuous mat of reindeer lichens (*Cladina* spp.), averaging 3-4 cm in depth above mineral soil.

C2: Boreal Spruce

This fuel type is characterized by pure, moderately well-stocked black spruce (*Picea mariana* (Mill.) B.S.P.) stands on lowland (excluding *Sphagnum* bogs) and upland sites. Tree crowns extend to or near the ground, and dead branches are typically draped with bearded lichens (*Usnea* spp.). The flaky nature of the bark on the lower portion of stem boles is pronounced. Low to moderate volumes of down woody material are present. Labrador tea (*Ledum groenlandicum* Oeder) is often the major shrub component. The forest floor is dominated by a carpet of feather mosses and/or ground-dwelling lichens (chiefly *Cladina*). *Sphagnum* mosses may occasionally be present, but they are of little hindrance to surface fire spread. A compacted organic layer commonly exceeds a depth of 20–30 cm.

C3: Mature Jack or Lodgepole Pine

This fuel type is characterized by pure, fully stocked (1000–2000 stems/ha) jack pine (*Pinus banksiana* Lamb.) or lodgepole pine (*Pinus contorta* Dougl. ex Loud.) stands that have matured at least to the stage of complete crown closure. The base of live crown is well above the ground. Dead surface fuels are light and scattered. Ground cover is feather moss (*Pleurozium schreberi*) over a moderately deep (approximately 10 cm), compacted organic layer. A sparse conifer understory may be present.

C4: Immature Jack or Lodgepole Pine

This fuel type is characterized by pure, dense jack pine (*Pinus banksiana* Lamb.) or lodgepole pine (*Pinus contorta* Dougl. ex Loud.) stands (10 000–30 000 stems/ha) in which natural thinning mortality results in a large quantity of standing dead stems and dead downed woody fuel. Vertical and horizontal fuel continuity is characteristic of this fuel type. Surface fuel loadings are greater than in fuel type C3, and organic layers are shallower and less compact. Ground cover is mainly needle litter suspended within a low shrub layer (*Vaccinium* spp.).

C5: Red and White Pine

This fuel type is characterized by mature stands of red pine (*Pinus resinosa* Ait.) and eastern white pine (*Pinus strobus* L.) in various proportions, sometimes with small components of white spruce (*Picea glauca* (Moench) Voss) and old white birch (*Betula papyrifera* Marsh.) or aspen (*Populus* spp.). The understory is of moderate density, usually red maple (*Acer rubrum* L.) or balsam fir (*Abies balsamea* (L.) Mill.). A shrub layer, usually beaked hazelnut (*Corylus cornuta* Marsh.), may be present in moderate proportions. The ground surface cover is a combination of herbs and pine litter. The organic layer is usually 5–10 cm deep.

C6: Conifer Plantation

This fuel type is characterized by pure, fully stocked conifer plantations with closed crowns and no understory or shrub layer. The forest floor is covered by needle litter with an underlying duff layer up to 10 cm deep. The crown base height is taken into account in predicting fire spread rate and crowning.

C7: Ponderosa Pine – Douglas-Fir

This fuel type is characterized by uneven-aged stands of ponderosa pine (*Pinus ponderosa* Laws.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in various proportions. Western larch (*Larix occidentalis* Nutt.) and lodgepole pine (*Pinus contorta* Dougl. ex Loud.) may be significant stand components on some sites and at some elevations. Stands are open, with occasional clumpy thickets of multiaged Douglas-fir and/or larch as a discontinuous understory. Canopy closure is less than 50% overall, although thickets are closed and often dense. Woody surface fuel accumulations are light and scattered. Except within Douglas-fir thickets, the forest floor is dominated by perennial grasses, herbs, and scattered shrubs. Within tree thickets, needle litter is the predominant surface fuel. Duff layers are nonexistent to shallow (<3 cm).

D1: Leafless Aspen / D2: Green Aspen

This fuel type is characterized by pure, semimature trembling aspen (*Populus tremuloides* Michx.) stands before bud break in the spring or following leaf fall and curing of the lesser vegetation in the autumn. A conifer understory is noticeably absent, but a well-developed medium to tall shrub layer is typically present. Dead and down roundwood fuels are a minor component of the fuel complex. The principal fire-carrying surface fuel consists chiefly of deciduous leaf litter and cured herbaceous material that is directly exposed to wind and solar radiation. In the spring the duff mantle (F and H horizons) seldom contributes to the available combustion fuel because of its high moisture content.

M1: Boreal Mixedwood—Leafless / M2: Boreal Mixedwood Green

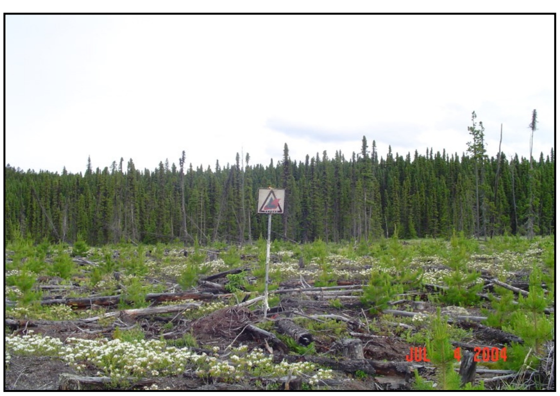
This fuel type (and its "green" counterpart, M2) is characterized by stand mixtures consisting of the following coniferous and deciduous tree species in varying proportions: black spruce (*Picea mariana* , white spruce (*Picea glauca*, balsam fir (*Abies balsamea*, subalpine fir (*Abies lasiocarpa*, trembling aspen (*Populus tremuloides,* and white birch (*Betula papyrifera*. On any specific site, individual species can be present or absent from the mixture. In addition to the diversity in species composition, stands exhibit wide variability in structure and development, but are generally confined to moderately well-drained upland sites. M1, the first phase of seasonal variation in flammability, occurs during the spring and fall. The rate of spread is weighted according to the proportion (expressed as a percentage) of softwood and hardwood components.

O1: Grass

This fuel type is characterized by continuous grass cover, with no more than occasional trees or shrub clumps that do not appreciably affect fire behavior. Two subtype designations are available for grasslands; one for the matted grass condition common after snowmelt or in the spring (O1-a) and the other for standing dead grass common in late summer to early fall (O1-b). The proportion of cured or dead material in grasslands has a pronounced effect on fire spread there and must be estimated with care.

S1: Jack or Lodgepole Pine Slash

This fuel type is characterized by slash resulting from tractor or skidder clear-cut logging of mature jack pine (*Pinus banksiana* Lamb.) or lodgepole pine (*Pinus contorta* Dougl. ex Loud.) stands. The slash is typically one or two seasons old, retaining up to 50% of the foliage, particularly on branches closest to the ground. No postlogging treatment has been applied, and slash fuels are continuous. Tops and branches left on site result in moderate fuel loads and depths. Ground cover is continuous feather moss mixed with discontinuous fallen needle litter. Organic layers are moderately deep and fairly compact.



S2: White Spruce – Balsam Slash

This fuel type is characterized by slash resulting from tractor or skidder clear-cut logging of mature to overmature stands of white spruce (*Picea glauca* (Moench) Voss) and alpine fir (*Abies lasiocarpa* (Hook.) Nutt.) or balsam fir (*Abies balsamea* (L.) Mill.). Slash is typically one or two seasons old, retaining from 10% to 50% of the foliage on the branches. No postlogging treatment has been applied. Fuel continuity may be broken by skid trails unless the site was logged in winter. Tops have been left on site, and most branch fuels have broken off during skidding of logs to landings, which results in moderate fuel loads and depths. Quantities of shattered large and rotten woody fuels may be significant. Ground cover is feather moss with considerable needle litter fallen from the slash. Organic layers are moderately deep and compact.

Appendix 2 — Alberta Wildland Fuels Inventory Program Code Tables

Alberta Tree Codes		
Code	**Scientific Name**	**Common Name**
ABBA	Abies balsamea	Balsam Fir
ABBI	Abies bifolia	SubAlpine Fir
ACGL	Acer glabrum	Mountain Maple
ACNE	Acer negundo	Manitoba Maple
BEPA	Betula papyrifera	White Birch
LALA	Larix laricina	Tamarack Larch
LALY	Larix lyallii	SubAlpine Larch
LAOC	Larix occidentalis	Western Larch
PIAL	Pinus albicualus	White-bark Pine
PIBA	Pinus banksiana	Jack Pine
PICO	Pinus contorta	Lodgepole Pine
PIEN	Picea engelmannii	Engelmann Spruce
PIFL	Pinus flexillis	Limber Pine
PIGL	Picea glauca	White Spruce
PIMA	Picea mariana	Black Spruce
POAN	Populus angustifolia	Narrow-leaf Cottonwood
POBA	Populus balsamifera	Balsam Poplar
PODE	Populus deltoides	Plains Cottonwood
POTR	Populus tremuloides	Trembling Aspen
PSME	Pseudotsuga menziesii	Douglas Fir
UNKN	Unknown	Unknown

Common Shrub Codes		
Code	**Common Name**	**Scientific Name**
ALCR	Green Alder	*Alnus crispa*
ALTE	River Alder	*Alnus tenuifolia*
AMAL	Saskatoon	*Amelanchier alnifolia*
ARUV	Kinnikinnick	*Arctostaphylos uva-ursi*
BEGL	Bog Birch	*Betula glandulosa*
BEPU	Dwarf Birch	*Betula pumila var. gladulifera*
CHCA	Leatherleaf	*Chamaedaphne calyculata*
CHUM	Prince's Pine	*Chimaphila umbellata*
COST	Red-Osier Dogwood	*Cornus stolonifera*
ELCO	Wolfwillow	*Elaeagnus commutata*
EMNI	Crowberry	*Empetrum nigrum*
GAHI	Creeping Snowberry	*Gaultheria hispidula*
JUCO	Common Juniper	*Juniperus communis*
JUHO	Creeping Juniper	*Juniperus horizontalis*
KAPO	Northern Bog-Laurel	*Kalmia polifolia*
LEGR	Labrador Tea	*Ledum groenlandicum*
LIBO	Twin Flower	*Linnaea borealis*
LODI	Twining Honeysuckle	*Lonicera dioica*
LOIN	Bracted Honeysuckle	*Lonicera involucrata*
OXMI	Small Bog Cranberry	*Oxycoccus microcarpus*
MARE	Creeping Oregon-Grape	*Mahonia repens*
MEFE	False-Azalea	*Menziesia ferruginea*
POFR	Shrubby Cinquefoil	*Potentilla fruiticosa*
PRVI	Choke Cherry	*Prunus virginiana*
RIGL	Skunk Currant	*Ribes glandulosum*
RIHU	Northern Black Currant	*Ribes hudsonianum*
RILA	Black Gooseberry	*Ribes lacustre*
RIOX	Northern Gooseberry	*Ribes oxyacanthoides*
RITR	Red Swamp Currant	*Ribes triste*
ROAC	Prickly Rose	*Rosa acicularis*
ROWO	Common Wild Rose	*Rosa woodsii*
RUID	Wild Red Raspberry	*Rubus idaeus*
SASP	Willow	*Salix spp*
SHCA	Buffaloberry	*Shepherdia canadensis*
SPBE	Birch-Leaved Spiraea	*Spiraea betulifolia*

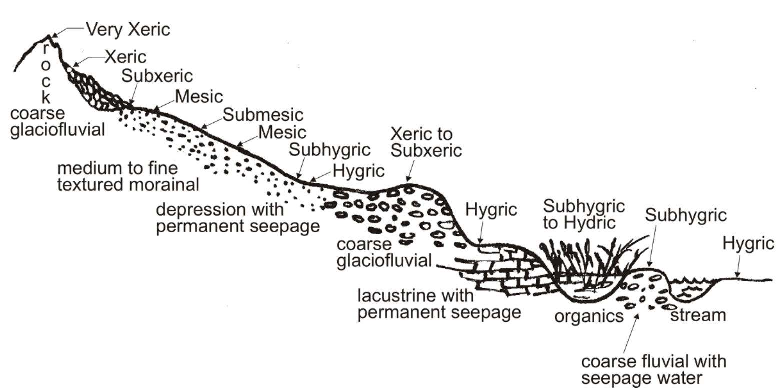
Ground Cover Codes	
Code	**Ground Cover**
FORB	Forb (basal and standing)
FERN	Ferns & allies
GRAM	Graminoid (grass)
LICH	Lichen
SMOSS	Sphagnum Moss
FMOSS	Feather Moss
OMOSS	Other Moss
HOTA	Horsetail
CLMO	Club moss
LITT	Litter (needles & leaves)
WOOD	Woody debris (dead & down)
MULF	Fine mulch (≤3 cm diameter)
MULC	Coarse mulch (>3 cm diameter)
ASH	Ash (organic, from fire)
BARE	Bare soil
BEDR	Bedrock
BOUL	Boulders (>60 cm diameter)
CBBL	Cobble (8-25 cm diameter)
CHAR	Char
GRAV	Gravel (0.2 - 8 cm diameter)
SAND	Sand (0.005-0.2 cm diameter)
STON	Stone (25-60 cm diamter)
WATE	Water
UNKN	Unknown

Soil Color Codes	
Code	**Soil Color Description**
D	Dark, brown, or black
M	Medium, intermediate color
L	Light, very pale soil
No Soil	No Soil

Common Shrub Codes Continued		
Code	**Common Name**	**Scientific Name**
SYAL	Common Snowberry	*Symphoricarpus albus*
SYOC	Western Snowberry	*Symphoricarpus occidentalis*
VAMY	Velvet-Leaved Blueberry	*Vaccinium myrtilloies*
VACE	Dward Bilberry	*Vaccinium cespitosum*
VASC	Grouseberry	*Vaccinium scoparium*
VAVI	Bog Cranberry	*Vaccinium vitis-idaea*
VIED	LowBush Cranberry	*Viburnum edule*
VIOP	HighBush Cranberry	*Viburnum opulus*

Damage Codes	
Code	**Damage Agent**
A	Animals
F	Fire
W	Wind
E	Other Environmental Factors
ID	Insects & Disease
M	Mechanical

Alternative Tree Codes		
AWFIP	**Common Name**	**Ecosite**
ABBA	Balsam Fir	Fb
ABBI	Subalpine Fir	Fa
BEPA	White Birch	Bw
LALA	Tamarack	Lt
LALY	Alpine Larch	La
PIAL	Whitebark Pine	Pw
PICO	Lodgepole Pine	Pl
PIEN	Engelmann Spruce	Se
PIFL	Limber Pine	Pf
PIGL	White Spurce	Ws
PIMA	Black Spruce	Sb
PIBA	Jack Pine	Pj
POBA	Balsam Poplar	Pb
POTR	Trembling Aspen	Aw
PSME	Douglas Fir	Fd



Appendix 3 — Plot Re-visit Protocols

When returning to a site for either a post-treatment assessment, or for a second pre-treatment assessment, there are a few things to keep in mind. Remember the plot has already been visited and much of the essential basic plot information has already been collected. This includes most of the plot description on the first data sheet and a large portion of the tree data. Use the chart below as a reference for what details should be kept the same (copied) from the original datasheets, what should be verified/confirmed and what will need to be recorded or re-sampled (changed):

Re-visiting Checklist ☑			
Data Sheet:	**Copy from primary visit:**	**Verify:**	**Change:**
Plot Description	☑ All Plot Description boxes, except those listed to the right		☑ Sampling Event ☑ Date ☑ GPS Accuracy ☑ Erosion Severity ☑ Possibly Ecosite ☑ Plot Access (if applicable)
Soils		☑ Soil type ☑ Soil texture ☑ Soil color	☑ All measurements
Dead and Down			☑ Overstory composition ☑ Dead and DownType[1]
Ground Cover			☑ All measurements
Shrubs			☑ All measurements
Small Trees			☑ All measurements
Large Trees	☑ Tree #[2] ☑ Tag #[3] ☑ Azimuth ☑ Distance ☑ Species ☑ Age[5]	☑ Tree Species	☑ DBH ☑ Height ☑ LCBH ☑ DCBH ☑ Damage Codes[4] ☑ Crown Widths ☑ High and Low Scorch (if applicable)
Mulch			☑ All measurements

[1] Usually remains Natural, unless it's been converted to a cutblock. See Chapter 3 — Dead and Down Material.
[2] If tree is gone, do not copy it from datasheet, simply record the next remaining tree number.
[3] If tag missing from tree, replace with a new tag and record this new number.
[4] Especially look for mechanical damage in post-treatment mulch sites.
[5] No re-assessment of tree age necessary during re-visits.

Finding Plot Center

Re-locating a plot center pin can be tricky, especially when the original center pin is nowhere to be found. In such circumstances using Large Tree information we have from the previous visit can help us come very close to finding where the center pin should have been.
You will use:

- (3) Tree Distances
- (3) Duff Pins
- Hypsometer
- Compass

For example, let's say you choose tree #1, #8 and #15. Starting with the first tree, stand at approximately where you think plot center should be and then use the hypsometer + transponder (puck) to arrive at tree #1's previously recorded distance from plot center. Then using your compass and tree #1's previously recorded azimuth you can determine where exactly around the tree you should be standing (Fig 9.1).

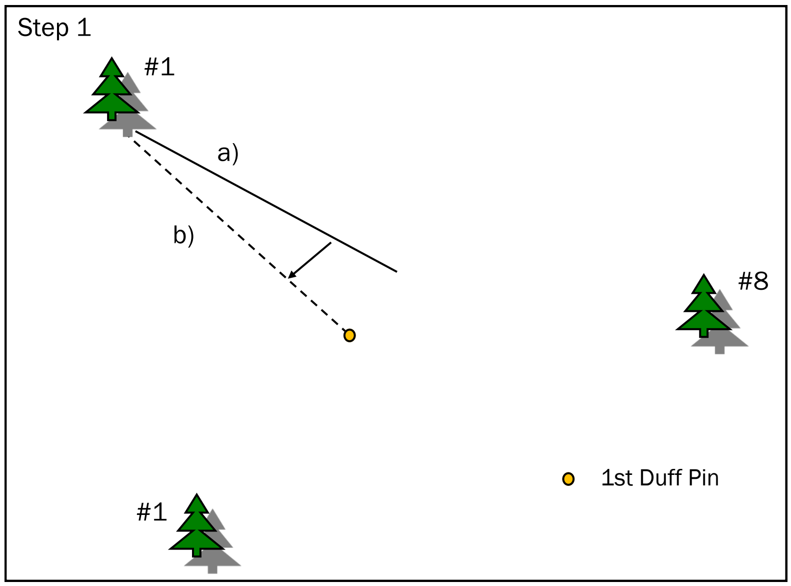


Figure 9.1: a) First find the original distance away from plot center. b) Adjust angle according to the tree's original recorded azimuth. Mark the spot with a duff pin.

Repeat this process for the other two trees, #15 and #8:

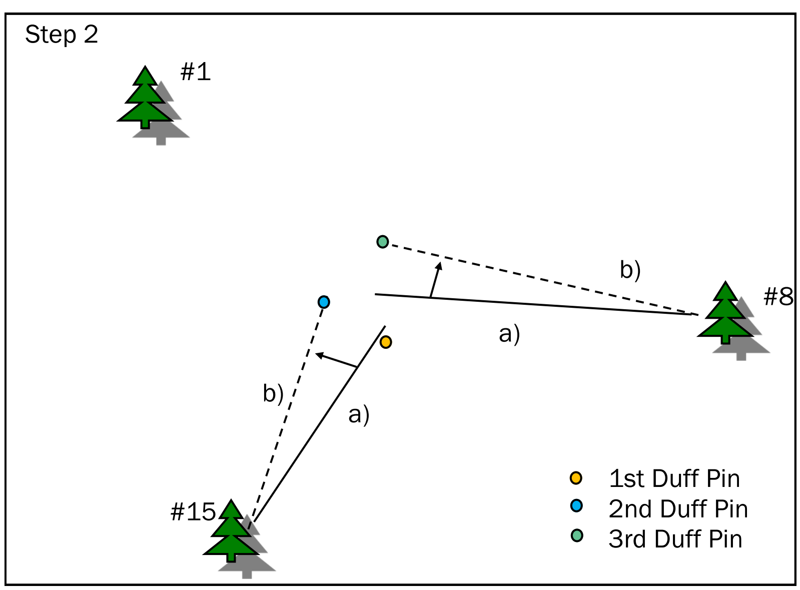
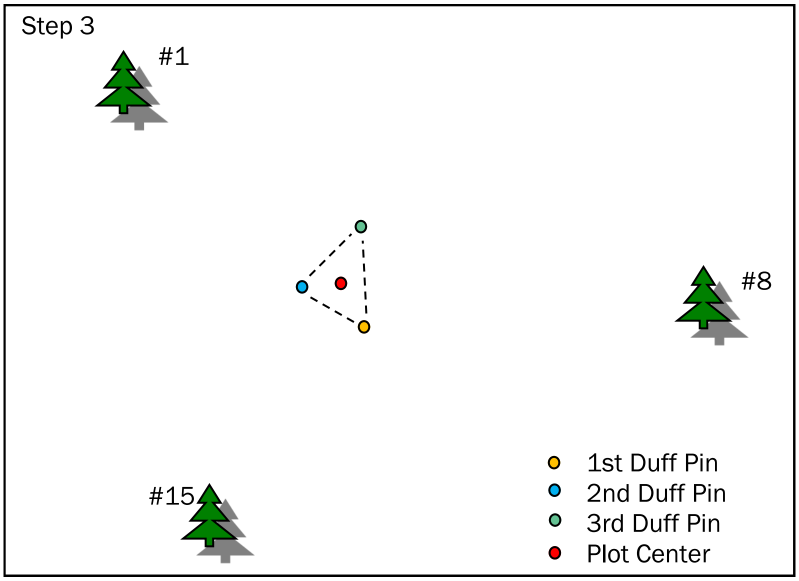


Figure 9.2: Finding distance a) and azimuth b) for tree # 15 and tree # 8.



You have now created a triangle using three duff pins. The center of the triangle marks plot center. Place a center pin there and remove the duff pins. Sometimes the triangle formed in the end can appear quite irregular—but do your best to find the middle and use that spot.

Appendix 4 — Fire Behaviour Documentation

1.0 Depth of Burn

- Use depth of burn pins to measure duff consumption at each AWFIP plot location.
- Install depth of burn pins the week of the burn along the four transect lines. Install three pins per transect line at 5, 15 and 25 meters. Depth of burn pins must be checked and reinstalled if the burn does not occur within one week.
- Insert pin so that cross bar is flush with the top of the duff layer. Make sure to avoid disturbing the litter layer overtop of the cross bar.
- Return to each burned plot within one week and measure the vertical distance between the remaining duff and the pin's cross bar. Record depth of duff consumption (cm) for each depth of burn pin.
- Best efforts should be made to complete post-burn measurements within one week of the burn. If this is not possible due to safety concerns, post-burn measurements should be made no later than one month from burn.

2.0 Rate of Spread

- Use wildfire temperature loggers to measure rate of spread at each AWFIP plot location based on Simard et al. (1984).
- Install one logger at end of the four transect lines at each AWFIP plot location.
- Set the loggers pre-fire sampling rate to the maximum interval (254 seconds). Set the logger's threshold temperature 10 °C higher than the maximum daytime temperature expected for the deployment period. Set the loggers post-fire sampling rate to one second.
- Ensure all loggers are protected from the fire by putting the loggers in fire-proof containers or burying the loggers underneath ≥ 5 cm of mineral soil in a water proof bag/container.
- Loggers have sufficient battery life and memory to be installed up to two weeks prior to the burn. This assumes that new batteries are installed in a logger and its memory is cleared at the time of deployment.
- Loggers can be retrieved whenever it is safe to re-enter the burn unit. No data will be lost if the loggers use up their memory and/or battery life. Temperature data is saved to non-volatile memory.

3.0 Fuel Moisture

- Ground-truth the nearest weather station's FWI moisture codes by sampling litter (FFMC), shallow duff (DMC), and deep duff (DC) in a location that is representative of the burn unit.
- Elevation, slope, aspect and fuel type should all be considered when selecting a representative sampling site. Multiple sample locations are recommended if the burn unit is characterized by a variety of elevation, slope, aspect and fuel type combinations.
- Prescribed Fire Behaviour Documentation Procedure 2 Sampling fuel moisture at the bottom, mid-slope, and top of a burn unit is recommended if there is an elevation change ≥ 500 meters within the unit.
- If time permits, determine the foliar moisture content (FMC) of the predominant conifer tree species. Otherwise, FMC can be estimated for each plot location using the equations provided in STX-3 (Forestry Canada 1992). Latitude, longitude, elevation and Julian date are required inputs for these equations.
- Use one of the following methods to determine the gravimetric moisture content of litter, duff and foliage samples.
    - ◊ DMM600 moisture meter – duff only
    - ◊ NeoSystem moisture meter – litter, duff, and foliage
    - ◊ Drying Oven and Scale – litter, duff, and foliage

4.0 Fire Weather

- Install an on-site automatic weather station according to Lawson and Armitage (2008). Make sure to record clearly diameter and mast height (meters).
- If possible, multiple weather stations/kestrels should be deployed for burn units located in mountainous terrain. Locate the weather stations at different elevations.
- Save hourly weather data (temperature, RH, windspeed, wind direction, precipitation, and FWI) electronically for the duration of prescribed burn activities including one day prior to burn operations. Sub-hourly weather data would be beneficial for research purposes.
- Use data from wildfire temperature loggers to determine the exact time the fire reached each plot location. Retrieve fire weather data for the time the fire reached each plot.

5.0 Ignitions

- Use GPS tracker to save the spatial location of ignitions. Ideally, GPS track-logs are time-stamped (otherwise, efforts should be made to record ignition times).
- Fire ignitions should be sketched on maps if a GPS tracker is not available.

6.0 Photo Documentation

- Photographs can be used to capture many additional fire behaviour attributes.
- Ensure all photos are date and time stamped.
- If landmarks are not visible in the camera's view field, record latitude and longitude coordinates and compass azimuth from where the photograph was taken.
- Hall (2002a and 2002b) provides a procedure for photo point documentation and analysis.

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