Fuel Management Survey Data Collection Standard

May, 2023

These standards apply to all fuel management survey activities under the Wildfire Risk Reduction Program.

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DOCUMENT PURPOSE

The purpose of this document is to standardize data collection for the Crown Land Wildfire Risk Reduction program and ancillary funding streams and to provide the technical background for fuel management projects across British Columbia.

ARTICLE 1: GENERAL STANDARDS

1.1 DEFINITIONS

In this document, the following words shall have the following meanings. Definitions are limited to those that are specific to fuels measurement and fire behaviour. Definitions which are considered common to, and unchanging throughout, the general practice of forestry and surveying (e.g., DBH, sph, etc.) are not re-defined in this standard.

Aspect – The direction towards which a slope faces. For the purposes of wildfire, aspects are categorized as in Table 1.

Table 1. Aspect definitions.

Description	Abbreviation	Approximate Range of Bearings (degrees)
North	N	316 - 45
East	E	46 - 135
South	S	136 - 225
West	W	226 - 315
Flat	F	No identifiable aspect, associated with 0% slope

Categorization – Identification of data collection classes for a certain characteristic to reduce sampling time and cost.

Coarse woody debris (CWD) – Sound and rotting logs, stumps, and coarse roots >20 cm in diameter in all stages of decay, that provide habitat for plants, animals and insects and a source of nutrients for soil structure and development [1].

Crown Base Height (CBH) – Measure of the vertical distance from the ground to the lowest point of the live (or dead, in specific circumstances) crown of an individual tree [2]. Dead components of the crown are measured when they are sufficiently dense to sustain vertical fire propagation. Individual dead limbs should not be considered. Full whorls of, or multiple dead limbs, especially with needles and fine

[1] https://www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/wildlife/wildlife-habitats/wildlife-tree-committee/wildlife-tree-guidance-policies

[2] Scott, J.H.; Reinhardt, E.D. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Res. Pap. RMRS-RP-29. Fort Collins, CO: U.S. Department of Agriculture, Forest Service.

branches or volatile mosses or lichens, should be considered.[3] Crown base height is not necessarily the height at which the branch attaches to the bole (Figure 1). CBH is associated closely with fuel strata gap.

Figure 1. The lowest point of the live crown is the crown base height (right red arrow), not to be confused with where the branch attaches to the bole (left red arrow).[4]

Crown Class – Describes the position of an individual tree relative to the forest canopy. FuelCalcBC uses the terms and definitions, as found in Table 2.

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[3] Ministry of Forests, Lands, Natural Resource Operations, and Rural Development – BC Wildfire Service. 2019. Wildfire Threat Assessment Guide and Worksheets Version 3.

[4] Photo credit: Dana Hicks.

Table 2. Crown class definitions and abbreviations, as cited in FuelCalcBC and FuelCalc. [5, 6]

Crown class	Definition
Dominant	A tree whose crown extends above the general level of the main canopy of even-aged stands or, in uneven-aged stands, above the crowns of the tree's immediate neighbors and receiving full light from above and partial light from the sides (as defined by the Society of American Foresters (SAF) 2008) [7].
Co-dominant	A tree whose crown helps to form the general level of the main canopy in even-aged stands or, in uneven-aged stands, the main canopy of the tree's immediate neighbors and receiving full light from above and comparatively little from the sides (SAF 2008).
Intermediate	A tree whose crown extends into the lower portion of the main canopy of even-aged stands or, in uneven-aged stands, into the lower portion of the canopy formed by the tree's immediate neighbors, but shorter in height than the co-dominants and receiving little direct light from above and none from the sides (SAF 2008).
Emergent	A tree whose crown is completely above the general level of the main canopy, receiving full light from above and from all sides (SAF 2008).
Suppressed	A tree whose crown is completely overtopped by the crowns of one or more neighboring trees. Note that the vigor of overtopped (suppressed) trees varies from high to low depending on individual circumstances (SAF 2008).
None	None or unknown.

[5] Korpela, Ed. 2018. FuelCalcBC User's Guide (version 1.2). Available: www.BCwildfire.ca (within the application's 'Help' menu).

[6] Lutes, Duncan C. 2020. FuelCalc User Guide (version 1.7). Available: https://www.firelab.org/sites/default/files/images/downloads/FuelCalc_1-7_User_Guide.pdf.

[7] Society of American Foresters. The Forestry Dictionary. 2008

Crown Closure – The stand condition, expressed in a percentage, resulting in the crowns of trees touching and effectively blocking sunlight from reaching the forest floor. Crown closure is estimated from a visual observation from aerial photography or as an average of multiple ground-based assessments. Ground based assessments utilize 'speckle diagrams' to assist with calibrating surveyor estimates. At the plot level, crown closure is estimated for each layer (L1 – L4, see definitions) and is estimated to the nearest 10%, as consistent with Forest Analysis and Inventory Branch methods. Diagrams in the FS 660 may be useful as a benchmark for estimation.

Decay – When applied to woody debris sampling using the planar intercept method, decay means visibly punky or able to be kicked apart easily.

Edge effect – The potential introduction of sampling bias from either avoiding polygon edges and / or from sampling technique which results in edge trees being sampled at a lower probability than non-edge trees.

Fine woody debris (FWD) - Woody debris (see definition) with a diameter ≤7 cm. In the case that a piece of woody debris straddles the 7 cm threshold (i.e., one end of the piece >7 cm, while the other end is <7 cm), categorization is determined at the point of measurement (i.e., at the planar intersection). Fine woody debris is further categorized into five diameter classes (Table 3).

Table 3. Category classes defined by diameter for fine woody debris.

Category	Diameter (cm)
1	≤ 0.5 cm
2	0.6 – 1.0
3	1.1 – 3.0
4	3.1 – 5.0
5	5.1 – 7.0

Flammable conifer shrub – Shrub with characteristics of high flammability, such as dry and dead leaves or twigs, dry leathery leaves, high oil or resin, needle-like leaves (e.g., juniper).

Flammable weed – Invasive weed with characteristics of a high flammability, such as dry and dead leaves or twigs, dry leathery leaves, high oil or resin, needle-like leaves (e.g., scotch broom).

Fuel Strata Gap (FSG) - The distance from the top of the surface fuel bed to the lower limit of the canopy fuel layer constituted by live foliage and ladder fuels that can sustain vertical fire propagation (canopy base height).[8] Associated closely with canopy base height and crown base height.

Grid sampling – A systematic sampling method to locate plot centers on a grid from a randomly selected starting point.

[8] Cruz, M.G., Alexander, M.E., Wakimoto, R.H., Modeling the likelihood of crown fire occurrence in conifer forest stands, For. Sci. 50 (2004) 640–658.

Ground Fuel - All combustible materials below the litter layer of the forest floor that normally support smouldering or glowing combustion associated with ground fires (e.g., duff, roots, buried wood, peat). [9]

Ladder Fuels - Fuels that provide vertical continuity between the surface fuels and crown fuels in a forest stand, thus contributing to the ease of torching and crowning (e.g., tall shrubs, small-sized trees, bark flakes, tree lichens).[11]

Large diameter woody debris (LDWD) – Woody debris (see definition) with a diameter >7 cm - 20 cm. In the case that a piece of woody debris straddles the 7 or 20 cm thresholds (i.e., one end of the piece is >7 cm, while the other end is <7 cm), categorization is determined at the point of measurement (i.e., at the planar intersection).

Layer 1 (L1) – Trees with a diameter at breast heigh (DBH) ≥ 12.5 cm. L1 trees may be further categorized based upon DBH.

Layer 2 (L2) – Trees with a DBH ≥ 7.5 cm – 12.49 cm. Also referred to as poles.

Layer 3 (L3) – Trees > 1.3 m in height and with a DBH <7.5 cm. Also referred to as saplings.

Layer 4 (L4) – Trees 0.3 - 1.3 m tall. Also referred to as regeneration.

Masticated fuel bed – A surface fuel bed, or a mixture of surface and ground fuels, of masticated forest fuels.

Mastication – Reduction of forest fuels (usually understorey trees or shrubs) into small pieces by mechanical mulching, grinding, chipping, shredding or chopping.

Microplot - A small, fixed area plot, with a plot multiplier of 10,000. The most used are 1 m x 1 m square or circular with a radius of 0.56 m (1 m^2).

Planar Intercept Sampling – A sampling technique that utilizes sampling planes. Using the planar intercept method, the sampling area is an imaginary plane extending from the ground, vertically from horizontal (not perpendicular to the slope) to an established height above the ground. The sampling plane extends both above and below the transect from the top of the litter layer to the height of the highest surface fuels.

Plot Center – The term plot center is used to refer to the systematically located grid point from which all types of plots (variable radius, fixed area, transect, etc.) are located. One or more types of plots may be located in relation to each plot center in order to collect the data required based upon survey objectives.

Plot Multiplier – The factor used to multiply stand data collected in a fixed area plot to calculate the equivalent data into per hectare numbers. The plot multiplier is equal to the area of a hectare divided by the area of the fixed area plot. The most common plot multipliers are found in Table 4.

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[9] BC Wildfire Service. Wildfire Glossary. https://www2.gov.bc.ca/gov/content/safety/wildfire-status/about-bcws/glossary#F.

Table 4. Plot multipliers for the most used plot radii or plot dimensions.

Plot Radius (m) or Plot Dimension (m)	Plot Area (m^2)	Plot Multiplier
0.56 (or 1 x 1)	1	10,000
2.52	20	500
3.99	50	200
5.64	100	100
7.98	200	50
11.28	400	25

Post-Treatment Surveys - Surveys designed to collect data to assess if the treatment has been implemented to the prescribed specifications and achieved stated post-treatment targets.

Prescription Development Surveys - Surveys to collect fuels characteristics to develop fuel management prescriptions (activities, specifications, post-treatment targets) and to input into associated fire behaviour modeling in the prescription development process.

Sampling Method – Defines how samples are selected from the population of interest (i.e., the treatment unit).

Sampling plane – The imaginary plane extending vertically from horizontal from the top of the litter layer to the height of the highest surface fuels. Sometimes used interchangeably with 'transect', although a transect is a line, whereas a sampling plane extends above and below the transect (see planar intercept sampling definition).

Stand Layers – As defined provincially and agreed upon by the Forest Practices and Investment and Forest Analysis and Inventory Branches of the Ministry of Forests, Lands, Natural Resource Operations, and Rural Development; includes Layer 1, Layer 2, Layer 3, and Layer 4 (see associated definitions).

Surface Fuel - All combustible materials lying above the duff layer between the ground and ladder fuels that are responsible for propagating surface fires.[10]

Treatment Decision Surveys – Surveys used to collect data to drive a binary decision on the next course of action: 1. Leave as-is (do not complete fuel management prescription), 2. Develop a fuel treatment prescription.

[10] BC Wildfire Service. Wildfire Glossary. https://www2.gov.bc.ca/gov/content/safety/wildfire-status/about-bcws/glossary#F.

Tree Status - Tree status (health of the individual tree) is an input for FuelCalcBC and is used to prioritize trees for removal during thinning. The available tree health status categories are detailed in Table 5.

Table 5. Tree status details to describe individual tree health in FuelCalcBC. [11]

Tree Status	Abbreviation	Definition
Healthy	H	Tree with very little biotic or abiotic damage.
Unhealthy	U	Tree with some biotic or abiotic damage and this damage will reduce growth. However, it appears the tree will fully recover from this damage.
Sick	S	Tree with extensive biotic or abiotic damage and this damage will ultimately cause death within the next 5-10 years.
Dead	D	Tree with no observable living tissue.

Wildlife Tree Class (WTC) – A classification system for individual trees based upon the deterioration and decay process. The system is based upon a scale of 1 – 8 for conifer trees and 1 – 5 for broadleaf trees (Figure 2). Wildlife tree classes are used to assess future and current wildlife habitat characteristics.

[11] Korpela Ed. 2018. FuelCalcBC User's Guide (version 1.2). Available: www.BCwildfire.ca (found within the application's 'help' menu).

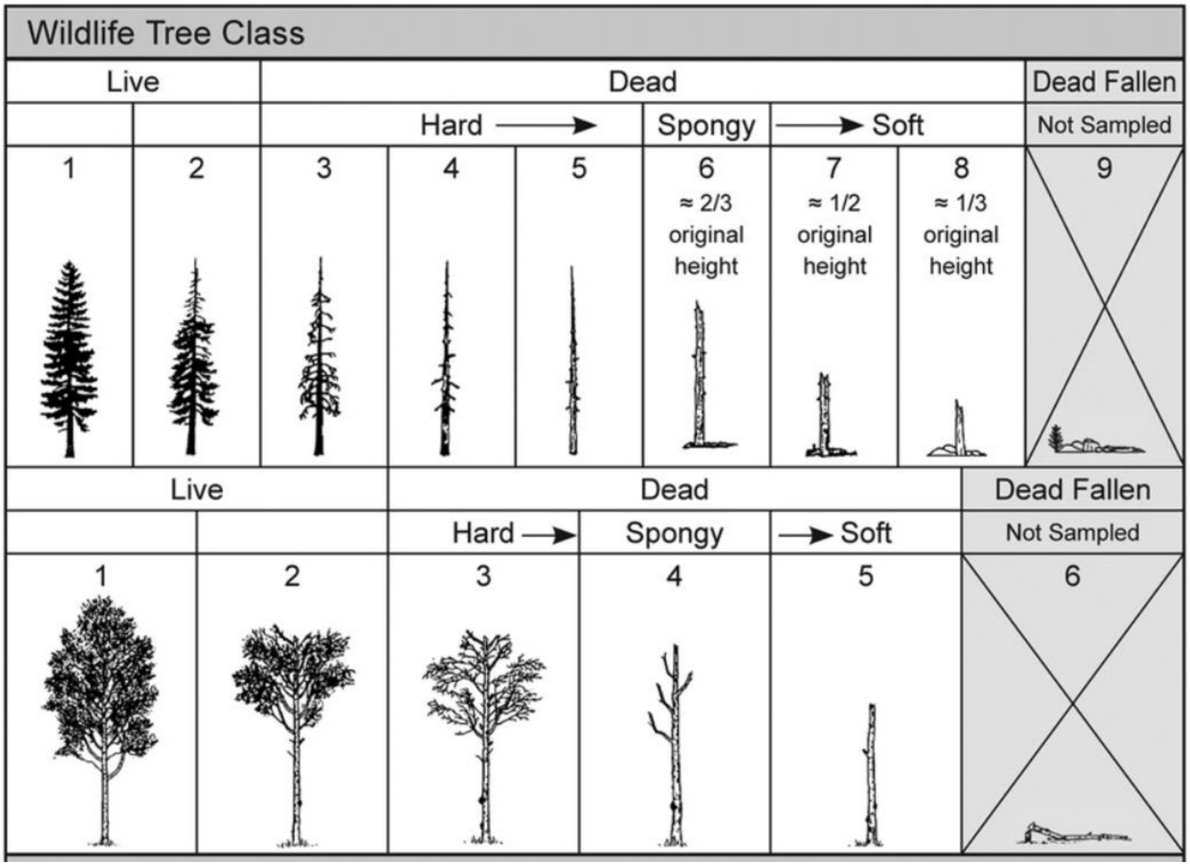

Figure 2. The Wildlife / Danger Tree classification in BC. [12]

Woody Debris – Also referred to as woody surface fuels. Dead and downed woody materials, including twigs, branches, and boles of trees and woody shrubs that have fallen and lie on or above the ground, including dead tree boles leaning greater than 45 degrees from perpendicular. Woody debris can be created through human activity (e.g., logging, fuel management activities) or naturally (e.g., windthrow, self-pruning, mortality). Specific to its impacts on fire behaviour, woody debris is categorized by diameter with two classes: fine woody debris and large diameter woody debris (see definitions).

[12] Wildlife/ Danger Tree assessor's course workbook.

ARTICLE 2: PERSONNEL

2.1 CREW QUALIFICATIONS

Inspector Qualifications

All work should be reviewed and approved by a Registered Professional Forester (RPF), or Registered Forest Technician (RFT) who is experienced in data collection, has an understanding of fire behaviour, and is familiar with the treatment prescription options that are appropriate and considered acceptable for the area(s) and fuel type(s).

Survey Design Qualifications

Stratification, survey designs, sampling method and intensity should be determined by a Silviculture Accredited Surveyor (SAS) or Qualified Forest Professional (RPF or RFT) who has the necessary competencies and experience to ensure accurate and thorough forest measurements, data collection and mapping.

Survey Crew

The Survey Crew must include at least one of the following that is experienced in both forest measurements and fuels data collection, and timber cruising (if applicable) who has been to every polygon surveyed:

1. Qualified Forest Professional (RPF or RFT),
2. Silviculture Accredited Surveyor (SAS),
3. Accredited Timber Evaluator (ATE) or
4. Accredited Timber Cruiser (ATC).

Technical Background

The intent of this document is to provide standards to provincial staff, forest practitioners, and forest industry professionals who, operating in their scope of practice, engage in the planning and implementation of forest fuel management across BC. This document is written for those with experience in surveying, stand and fuels measurement and data collection, and who are collecting data under the supervision of, and for decision-making by, a professional working within their scope of practice. This manual is not written such that it is appropriate for use by individuals without some training and experience in both wildfire and surveying.

> "*Practicing in the field of fire and fuels management requires a specific education and training in subjects such as, but not limited to: fire ecology, fire effects, fire behaviour, fire regimes, conditions classes, fuel types, fuel moisture content, fire suppression, prescribed burning, fire behaviour modelling, and fire weather in addition to forestry subject. Education provided at post-secondary school is insufficient and often additional expertise is obtained through experience*

fighting wildfires or working with a competent forest professional already practicing in the field." [13]

Some of the skills and activities outlined in this document are based upon professional reliance (e.g., visual assessments). For these activities, it is understood that the person undertaking the activity is highly competent in the skill-area and has the expertise to confidently decide based upon their assessment – a decision which other professionals competent in the scope of work would also make under similar circumstances.

Members of the Association of British Columbia Forest Professionals (ABCFP) must ensure that they are practicing within a field only where training and ability make them professionally competent. In 2013 the ABCFP released *Interim Guidelines – Fire and Fuel Management* to provide ABCFP members with information and guidance to be considered when working in the area of fire and fuel management. Members shall stay abreast the aforementioned Interim Guidelines, the related Summary Paper [14], as well as any updates to these guidance papers.

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[13] Ministry of Forests, Lands, Natural Resource Operations, and Rural Development – BC Wildfire Service. 2020. Fuel Management Prescription Guidance.

[14] Association of BC Forest Professionals. 2013. Summary Paper Fire and Fuels Management. https://abcfp.ca/WEB/abcfp/Files/policies/Fire_Fuel_Management-Summary_Paper.pdf

ARTICLE 3: STANDARDS APPLICABLE TO ALL SURVEYS

3.1 GENERAL STANDARDS

The standards of performance in Article 3 apply to every survey.

This standard was written for the following types of surveys:

1. Treatment decision surveys: these surveys are to collect sufficient fuels characteristics to drive a 'treat' or 'no treat' decision.
2. Prescription development surveys: these surveys are to collect fuels characteristics to develop fuel management prescriptions and to input into associated fire behaviour modeling in the prescription development process.
3. Post-treatment surveys: these surveys are designed to collect data to assess if the treatment has been implemented to the prescribed specifications and achieved stated targets.

Technical Background

Objectives

This standard was designed to meet the following objectives and drive the following decision-making, as communicated by BCWS:

1. Pre-treatment stand level data collection to assist in the following decision-making processes:
    a. Treatment decision surveys to drive potential fuel treatment activity recommendations (i.e., treat or no treat); and,
    b. surveys to assess current threat and determine fuel management prescription specifications which will achieve fire behaviour targets (fuel treatment prescription development).
2. Post-treatment stand level data collection to:
    a. assess if the treatment has met fuel management prescription specifications and achieved targets;
    b. feed into fire behaviour models to evaluate post-treatment fire behaviour targets; and
    c. meet RESULTS Information Specification Submission (RISS) for Government Funded Silviculture Activities

In order to meet the aforementioned objectives, this document was written for the following types of surveys:

1. Treatment decision surveys,
2. Prescription development surveys, and
3. Post-treatment surveys.

Completing surveys according to the principles outlined in this manual will demonstrate that the decisions driven by the data are based upon data collected using statistically sound sampling design in a statistically valid manner and is a demonstration of due diligence.

Survey Principles

The survey and data collection principles within this standard are guided by the understanding of:

1. The widely varied range of stand and fuel types for which these surveys must be useful;
2. A professional's ability to determine relevant characteristics based upon survey objectives;
3. The current Fuel Management Prescription Guidance and Specimen (prescription template);
4. Reporting requirements (Community Resiliency Investment (CRI) Program, RISS); and
5. The role of the Registered Forest Professional.

The process of data collection consists of 6 steps:

1. Office review
    a. Preparing for the survey, review of all available information (e.g., higher level plans, ecosystem field guides, resource inventories and assessments, aerial photos, provincial fuel typing, base-map and feature identification, fuel management prescription, wildfire (or other) stocking standards).
2. Pre-stratification
    a. Pre-treatment survey stratification can be based upon potential consequence (e.g., priority zone, distance to values at risk, position relative to values at risk and predominant fire season wind direction), probability (e.g., fuels components, stand structure, areas of low or no fuel), other (e.g., ecology, operational constraints), or a combination of the above.
    b. Pre-stratification will be confirmed / refined in the field
3. Determine a field inspection route / walk-through of each stratum
    a. Route should transect all tentative stratum and traverse the majority of the potential treatment area.
    b. Finalize stratification
        i. Based upon aforementioned considerations.
        ii. Post-treatment stratification may be required based upon
            a) treatment / activity recommendations (e.g., when treatment is determined to not be sufficient / burn not successful, difference in maintenance recommendations)
            b) For payment purposes
            c) Forest cover / inventory label updates / differences
    c. Determine site index method, survey objective(s), survey methods, design, and intensity
4. Data gathering for each stratum
    a. Determine final appropriate survey design, sampling methodology, and intensity.
    b. Collect data based upon above determination for each stratum
    c. Plot photographs
5. Data summary
    a. Summarize the data, calculating statistics where applicable.
    b. Data summarization should result in the data required (e.g., for prescription development, model inputs, RESULTS submissions).
6. Report survey results.

Consistent and accurate data collection, summarization, data analysis, and treatment recommendations are essential.

3.2 FORMAT OF DOCUMENTATION

This standard does not include field forms; it is up to the surveyor to develop a data collection method (paper or digital) which fits with the collection device and method of compilation and that collects all the required data. It is advisable that the Ministry Designated Representative and the survey contractor agree to the chosen method of field data collection, documentation and format for submission prior to commencement of field work.

3.3 FUEL TREATMENT SURVEY PROCEDURAL CHART

Fuel treatment / wildfire risk reduction assessment and survey procedural chart.

The following chart outlines the necessary steps to assess and survey a potential fuel treatment area (pre-treatment, such as treatment decision or prescription development, surveys) or treatment area (post-treatment surveys). The steps outlined below are incorporated within this Standard and are referenced by the corresponding Standard Article numbers.

Step 1 – Treatment Decision Surveys - Article 4

1. Strata clearly not requiring treatment will be separated (stratified) from the Survey area. Visual assessment notes and representative photographs for those areas stratified for not requiring treatment shall be documented.
2. A Treatment Decision Survey will be performed within those areas that 'may require' fuel treatment activities. Treatment Decision Surveys will be performed either by:
    a. using visual assessment if the surveyor has sufficient experience and is confident in defending their professional decision. This process may include subjectively located plots to calibrate the surveyor's decision, but this data is not recorded as it is not statistically defensible.
    b. With a low intensity grid sample to collect data needed to inform the treat/no treat decision.
3. Next course of action recommendation will be made for each stratum, from the following options:
    a. Re-assess, or Leave as is (no further action required),
        i. Move to STEP 3;
    b. Develop a Treatment Prescription
        i. Move to STEP 2.
4. If the Ministry Designated Representative has completed this step and determined the next course of action (i.e., recommendation for treatment is confirmed), move to the relevant next step, as per #3 above.
5. If operational fuel treatment has been completed,
        i. Move to STEP 4 and STEP 5.

Step 2 – Prescription Development Survey - Article 5

1. Sampling intensity will be driven by the degree of variability and complexity found in the stratum.
    a. For all stratum for which a fuel treatment prescription survey will be developed, the following products will be delivered:
        i. Plot data, fuel treatment prescription, prescription map, and a minimum of three photographs per plot clearly labeled with treatment unit and plot number.
        ii. Guidance for fuel treatment prescription is found in the BCWS Fuel Management Prescription Guidance document, accessible through the Tools for Fuel Management webpage. [15]
        iii. Fuel treatment prescription maps shall follow the standards as set out in the BCWS Fuel Management Prescription Guidance document.[15]
2. If operational fuel treatment has been completed,
        i. Move to Step 4 and STEP 5.

Step 3 – Treatment Decision Survey Reports – Article 4

1. Strata for which the next determined course of action is re-assess or Leave as is (no treatment required) trigger submission of a Survey Report Summary.
2. For all stratum within which a treatment decision survey was completed and for which the next determined course of action is re-assess or Leave as is, the following products shall be delivered to the Ministry Designated Representative:
    a. Plot data, field data summary (compilation and / or visual assessment summary), recommendation (and timeline for follow-up, if applicable), survey map, and representative photographs.

Step 4 – Post-Treatment Survey - Article 6

1. Sampling design and intensity will be driven by the degree of variability and complexity found in the stratum.
2. Data shall be collected in formal sample plots consistent with the treatment prescription survey.
3. For all stratum within which a post-treatment survey is completed, the following products shall be delivered to the Ministry Designated Representative:
    a. Plot data, data summary (compilation), recommendation (and timeline for follow-up, if applicable), survey map, and representative photographs.

Step 5 – Submission to RESULTS – Article 7

[15] https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management

1. For all stratum within which operational fuel treatment activity has been completed, a RESULTS submission following the 6th edition of the *RESULTS Information Submission Specifications for Government Funded Silviculture Activities (RISS-gf)* [16] is required.

Technical Background

Prior to embarking on a survey, the surveyor must determine / understand the survey objectives. It is recommended that the surveyor discuss the survey objectives, as well as the implications on additional data collection required, level of statistical rigour, and precision required, based on objectives, with the Ministry Designated Representative.

For example, if the objective is to collect enough information to make a simple 'treat / no treat' decision (i.e., treatment decision survey), then a visual assessment with notes and photographs may be sufficient information on which to base a recommendation. Alternatively, it may be determined that additional formal sample plots are required, potentially at a lower plot intensity.

3.4 SURVEY TIMING

Data collection should be completed in snow-free conditions in order to accurately assess surface fuels (loading, type, arrangement), all layers of the stand (L3, L4 specifically), litter and duff depth. Furthermore, sampling surface fuels (dead and downed woody debris) during times when deciduous shrubs are dormant requires significantly more expertise among the survey crew to identify dead versus dormant trees and shrubs.

If surveys are completed by inexperienced crews when deciduous species are dormant, when ground is snow-covered, or soil is frozen, there may be a need for follow-up data collection and additional surveys to ensure the data collected is accurate and is gathered for all fuels characteristics relevant to the survey objectives.

3.5 STRATIFICATION

A common reason for stratification, from a sampling perspective, is to create more homogeneous strata (sampling areas) to increase sampling precision.

There are several factors to consider during stratification. The initial, most basic level of stratification occurs when determining if a polygon is currently in a state where fuels should be treated, or not (e.g., is the polygon rock, water, deciduous trees or other non-fuel or low-fuel type).

When stratifying areas recommended for treatment, stratification for fuel treatments is done primarily to define areas that have similar characteristics and that will need a specified treatment to reach a prescribed post-treatment state. These characteristics include: stand type (e.g., species composition, vertical structure, spatial distribution of trees and total densities of trees by size classes), surface fuels (e.g., loading), operational considerations (e.g., slope or soil sensitivity), or other variables which factor

[16] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-reporting-results/business-and-policy-documentation

into the specified treatment for a stratum. These reasons for stratification into treatment units will result in more homogenous strata that will also have the added benefit of increasing sampling precision.

Technical Background

Because of the high variability of fuel types within which these surveys will take place, it is not recommended to set minimum triggers for stratification. This practice may lead to over-stratification, if a stratification is triggered by variation in a characteristic which is not of interest for the project objective (e.g., treatment specifications) or under-stratification if one type of stand should be treated using two different methods based upon characteristics which are not included in the list of stratification triggers.

3.6 SURVEY LINES AND PLOTS

Survey lines and plot centers will be established using Global Positioning System (GPS) units (preferred), or if necessary, by manual chaining methods. Survey plot centers will be established utilizing a grid sampling method. To eliminate potential bias, grid sampling will be based upon the selection of a random starting point (P.O.C.) and maintain systematic positioning of plots throughout the survey. Grid sampling may be used with a low or high plot intensity. Square grids are highly recommended.

There is a potential for bias introduced during edge sampling. Methods to correct for edge effect are provided (Appendix B – Sampling to Avoid Edge Effect Bias), should it be determined that the block edges cannot be assumed to be the same as the block interior.

Survey lines and plots must be identified as follows:

1. For both GPS and manual chaining methods:
    a. point of commencement (P.O.C.) must be marked with flagging tape and identifying information recorded in waterproof ink;
    b. Plot centers must be marked on the ground in such a way that they may be re-located for monitoring or auditing purposes. If the ground is frozen or very rocky ground and a shovel or stick cannot be used for a plot center, a comment should be made within the field form indicating what was used for the plot center.
2. If a GPS is being used, plot centre UTM Coordinates must be provided;
3. If a manual chaining method is being used:
    a. survey baseline (if established) and all strip lines must marked with flagging tape showing the baseline and strip line number in waterproof ink;
    b. all plot centre flagging tape must have the bearing and distance to the next plot written in waterproof ink.

Technical Background

Sampling Intensity and Precision

The current BCWS Fuel Management Prescription Guidance document states the following:

> *"In all cases, the stand should be sampled to a level that provides sufficient and accurate data required to determine the desired treatment specifications, measured*

fuel loading, and assist with harvest/treatment planning and valuation (if applicable)."

There are a wide range of stand and fuel types that will be sampled using these protocols. As such it is not possible to specify desired precision or sample size requirements that will be suitable for all situations. Surveys must be completed such that the information collected for the characteristics of interest is precise enough to allow treatment recommendations and prescriptions to be confidently developed. For example, assume that you will treat an area if a stand characteristic of interest is greater than 100 units. If your sample produces a wide confidence interval of 1000 units, +/- 500 (a 50% sampling error), this low precision will be acceptable as your lower confidence limit is well above your threshold of 100 units. If on the other hand your sample produces a confidence interval of 90 +/- 15 then your treatment decision is uncertain and you may decide to establish additional plots. Note that this process is analogous to that described in Section 8.1.1.5 of the silviculture survey manual. The difference in this application is that there are not set standards for fuel treatments (e.g., stocking standards) that we are comparing the confidence intervals to. In this case we are comparing our confidence intervals of a variety of fuel variables to a variety of treatment thresholds. An acceptable confidence interval may be very wide and met with minimal sampling, if the confidence interval clearly does not envelope a threshold for decision-making. Similarly, a very small confidence interval achieved through high sampling intensity may not be acceptable if it includes a threshold which is important for decision-making.

Sample size decisions should also incorporate considerations of costs and available time and project budget. Increasing sample size may result in increased measurement errors if crews are forced to move too quickly to meet time and budget constraints. This also needs to be considered and balanced when choosing sample sizes.

Grid Sampling

The grid sampling method, a type of systematic sampling, is generally the most common method for locating plot center (see definition in glossary). Grid sampling may be used with a low or high plot intensity.

The benefits of using the grid sampling method are:

- Demonstrates that the surveyor has walked over the entirety of the strata reported on;
- Provides accurate, reproducible results;
- Can be used with high or low plot intensity;
- Can be used by surveyor with less experience in surveys or less experience in collecting data on fuels (relies less upon professional experience for decision-making).

A foundation of the grid sampling method is to eliminate potential bias introduced in plot location through the selection of random starting point and maintaining systematic positioning of plots throughout the survey. Square grids are highly recommended, although other grid types are acceptable.

Edge Effects

Technical background for the standard for controlling for bias due to edge effects is found in Appendix B – Sampling to Avoid Edge Effect Bias.

3.7 PLOT INFORMATION

For each formal sample plot established, data will be collected as per Article 8.

3.8 REQUIRED PHOTOGRAPHY

For each plot established, a minimum of 3 photographs shall be taken: one representative of each fuel layer (crown, ladder and surface). Additional photos, one in each cardinal direction, are recommended, particularly in plot locations which will be measured in post-treatment surveys.

3.9 SITE INDEX METHODOLOGY

Site index is determined using the procedural guidelines outlined in Land Management Handbook Field Guide Insert 12 - Selecting a Method to Estimate Site Index, 2006.[17]

3.10 ADDITIONAL FIELD NOTES

The following is a non-exhaustive list of considerations and assessments which may be relevant to the project and field work, depending on site and objective(s). This standard does not provide guidance on additional field notes required, completing the additional assessments, or when such assessments should occur. It is recommended that the surveyor and / or supervising professional consult the appropriate guidance documents and relevant field forms, where available.

- Access
- Soil profile
- Terrain stability
- Windthrow
- Riparian / stream assessments
- Current / available access description (distance, type, width, feasibility, maintenance responsibility)
- Values at Risk (structures or other – distance, direction, location on slope, location in relation the predominant fire season wind direction)
- Archaeological assessments
- Wildlife
- Species or ecosystems at risk

3.11 SURVEY MAPS

Survey maps must show:

1. the type of Survey;
2. land status and tenure overlaps;
3. survey area by stratum (ha);

[17] https://www.for.gov.bc.ca/hfd/pubs/Docs/Fgi/Fgi12.pdf

4. inventory label (if relevant – e.g., post-treatment surveys);
5. point(s) of commencement of the survey;
6. plot centers labeled;
7. survey lines and direction travelled.

3.12 PRESCRIPTION MAPS

Prescription maps will be completed in accordance with Section 4 of the BCWS Fuel Management Prescription Guidance document.[18] Additional requirements may be set by the relevant funding program.

3.13 MERCHANTABLE TIMBER

A professional estimate of the pre-treatment and post-treatment merchantable stand volumes is necessary to ensure the appropriate tenure and pricing are utilized for the fuel management operational treatment. If any merchantable timber will be cut, a professional volume estimate is required and completing a full timber cruise following the procedures in the Timber Cruising Manual[19] should be considered when cutting >50 m^3/ha or >500 m^3 in total. In addition to providing statistically valid data, a full timber cruise also provides the opportunity to utilize a cruise-based cutting authority if applicable and to determine the stumpage rate through a full appraisal if desired. A professional grade profile estimate of the merchantable volume is also required in some circumstances for the utilization of the Interior Concurrent Residual Harvest System (CHRS)[20] which provides an alternative method of scale which is designed to reduce the administrative burden associated with timber delivery to secondary manufacturing facilities.

The merchantable timber sampling method and intensity or if a full timber cruise is required should be determined in collaboration with the Ministry Designated Representative based on the project specifics. Considerations in completing a full cruise should include the total merchantable volume and its value.

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[18] https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management

[19] https://www2.gov.bc.ca/gov/content/industry/forestry/competitive-forest-industry/timber-pricing/timber-cruising/timber-cruising-manual

[20] https://www2.gov.bc.ca/gov/content/industry/forestry/competitive-forest-industry/timber-pricing/timber-scaling/alternate-methods-of-scale

ARTICLE 4 – TREATMENT DECISION SURVEYS STANDARDS

4.1 GENERAL TREATMENT DECISION SURVEY STANDARDS

The standards contained in this article apply to treatment decision surveys, in addition to the standards specified in Article 3. Treatment decision surveys are executed to collect sufficient fuels characteristics to drive a 'treat' or 'no treat' decision. Treatment decision surveys may be completed through visual assessments or formal sample plots.

Visual assessments shall include physically walking through a stratum to visually record information, as described in the standard. Visual assessments are a subjective assessment of a polygon based on ocular estimates, and supported by assessment notes and photographs, and do not involve establishing formal plots or collecting data. Therefore, visual assessments do not result in survey summary compilation and statistical analysis is not required. Relying on visual assessments alone to complete treatment decision standards is acceptable only when: 1) conducted by a skilled surveyor with years of fuels data collection experience, 2) any other qualified surveyor or professional with experience in fuels data collection and fire behaviour would come to the same conclusion, and, 3) discussed with and approved by with the Ministry Designated Representative. In all other cases, formal sample plots shall be established as part of the treatment decision survey.

The treatment decision surveys will be either be executed based upon visual assessment, supported with informal plots to calibrate surveyor eye, or using formal plots on a grid with data gathered in a statistically valid manner. In both cases, the survey includes physically walking through a stratum to record information as defined in this standard.

Technical Background

The sampling method defines how samples are selected from the population of interest (for fuels treatments, the population of interest is typically the treatment unit). Two approaches are presented here: a visual / subjective assessment and systematic (grid) sampling. The first relies solely on expert opinion as data are not collected in a statistically defensible manner. The second provides the recommended option for collecting statistically defensible information.

Ultimately information is collected to make a decision, and professionals need to be able to defend that decision. Part of defending the decision is defending your method for collecting information. Relying on expert opinion may be acceptable, particularly when decisions (e.g., treat / no treat) are obvious and spending time and resources collecting statistically defensible information is not warranted. For example, a treatment decision survey, completed with a visual assessment, results in a clear determination that prescription development is the next recommended course of action. In this case, establishing multiple formal sample plots, which may be re-established during the prescription development survey, would be redundant and may not be an effective use of time or funds. Alternatively, when it is possible that another professional would, given the same information, arrive at a different decision and / or the decision is not obvious, collecting statistically defensible information through systematic grid sampling should be employed.

The credibility of the survey results is only as good as the appropriateness of the sampling method and sampling intensity chosen by the surveyor.

4.2 TREATMENT DECISION SURVEY PROCEDURES

1. Visual assessments, when utilized, shall be completed via a walk-through, or reconnaissance, in which the entire stratum is covered.
2. Pre-stratification is recommended prior to performing the treatment decision survey to identify homogeneous strata for sampling and to delineate non-fuel / no treatment areas which clearly are not to be sampled (e.g., bodies of water, rock, or other low or no-fuel areas). Use of photos, images, maps, and / or use of the aerial overview stratification are recommended in this pre-stratification procedure.
3. Further stratification may be required either in the office or during the field component of the treatment decision survey. For example, there may be strata which clearly meet the criteria for utilizing only the visual assessment method, whereas other areas should be stratified in order to complete formal plots to gather data to help make appropriate recommendations.
4. The areas stratified for formal plot establishment shall be sampled using grid sampling, as detailed in Article 3.
5. Information will be gathered and recorded for all areas on which the treatment decision survey is completed, regardless of recommendation (i.e., areas determined to be not-treatable, through either visual assessments or formal plots, shall have information recorded to help support the aforementioned recommendation).

Technical Background

Technical background on selecting sampling methods is found in Section **4.1 General Treatment Decision Survey Standards**. Background on determining sampling intensity is found in Section **3.6 Survey Lines and Plots**.

4.3 VISUAL ASSESSMENT INFORMATION

1. Visual assessment measurements / observations collected during the treatment decision survey include, but are not limited by:
    a. BEC classification to the site series level
    b. forest health factors/damage agents, including an estimate of severity (percent mortality) (where applicable);
    c. stem density by layer (live and dead/dying);
    d. species composition by layer;
    e. median height by layer;
    f. median crown base height by layer;
    g. basal area (m2) estimates for total live Layer 1 stems (≥12.5 cm DBH) and total live Layer 2 stems (≥7.5 cm DBH and <12.5 cm DBH) using a prism with a Basal Area Factor (BAF);
    h. estimate of woody debris surface fuel loading by fine and large diameter categories;
    i. description of woody debris surface fuel loading (e.g., arrangement, continuity);
    j. duff and litter depth;

k. description of each surface fuel layer (i.e., surface, ladder, and crown), including make-up / composition of fuels, arrangement, and continuity;
l. estimate of crown closure by layer;
m. photographs representing the stand/stratum, specifically surface, ladder, and crown fuel layers.

4.4 PLOT INFORMATION

1. Sample plots shall be established, as per Article 3: located systematically on a grid starting from a randomly selected P.O.C. and maintaining systematic positioning of plots throughout the survey.
2. Sample plots may be completed at a relatively low intensity.
3. Minimum sampling intensity will be determined in collaboration with the Ministry Designated Representative based on the project specifics.

Technical Background

As mentioned in Section **3.6 Survey Lines and Plots**, there are a wide range of stand and fuel types that will be sampled using these protocols. Further to that, there is a variety of survey objectives which may impact the acceptable sampling intensity and precision. As such it is not possible to specify desired precision or sample size requirements (minimum sample size) that will be suitable for all situations. It may be determined to be acceptable precision for treatment decision surveys to sample at a lower intensity, based upon the binary decision and the potential for the area to be surveyed using formal plots again, if the recommended next course of action is prescription development surveys.

4.5 RECOMMENDATIONS

Upon completion of the treatment decision survey, summary of notes, and compilation of data collected, the recommended next course of action will be included in the survey summary. The categories include:

1. Re-assess – Do another treatment decision survey in the future and recommend a date of reassessment.
2. Leave as is – No further treatment or assessment is needed.
3. Develop a treatment prescription - Recommend a full prescription development survey and survey plot intensity.
    a. Alternatively, if formal plots established are at an acceptable intensity, data collection from the treatment decision survey may supplant the need for a prescription development survey.

4.6 REPORTING AND DELIVERABLES

For all stratum within which a treatment decision survey was completed, the following products shall be delivered to the Ministry Designated Representative:

a. Plot data,

b. data summary (compilation),
c. recommendation (and timeline for follow-up, if applicable),
d. survey map, and
e. representative photographs.

ARTICLE 5 - PRESCRIPTION DEVELOPMENT SURVEY

5.1 GENERAL PRESCRIPTION DEVELOPMENT SURVEY

Prescription development surveys are to collect data to develop fuel management prescriptions and to input into associated fire behaviour modeling in the prescription development process.

Prescription development surveys are located plot center on a grid, initiated from a random starting point, and maintain systematic positioning of plots throughout the survey.

5.2 PRESCRIPTION DEVELOPMENT SURVEY PROCEDURES

1. Sample plots shall be established, as per Article 3: located systematically on a grid and maintaining systematic positioning of plots throughout the survey.
2. Sample plots completed on a grid may be completed at a low or high intensity.
3. Minimum sampling intensity will be determined in collaboration with the Ministry Designated Representative based on the project specifics.

Technical Background

As mentioned in Section **3.6 Survey Lines and Plots**, there are a wide range of stand and fuel types that will be sampled using these protocols. Further to that, the survey objective, in this case a survey used to develop a fuel management prescription, will impact the acceptable sampling intensity and precision. As such it is not possible to specify desired precision or sample size requirements (minimum sample size) that will be suitable for all situations.

5.3 REPORTING AND DELIVERABLES

For all stratum within which a prescription development survey is completed, the following products shall be delivered to the Ministry Designated Representative:

a. Plot data,
b. data summary (compilation),
c. fuel treatment prescription
d. prescription map,
e. spatial data, and
f. representative photographs.

Formatting, content, and expectations regarding fuel treatment prescriptions, prescription maps, and spatial data submissions are guided by the BCWS Fuel Management Prescription Guidance. [21] There may be additional standards, depending upon funding or as set in the contract.

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[21] https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/wildfire-status/prevention/fire-fuel-management/fuels-management/2020_fuel_management_prescription_guidance_final.pdf, https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management

ARTICLE 6 – POST-TREATMENT SURVEY

6.1 GENERAL POST-TREATMENT SURVEY

Post-treatment surveys are designed to collect data to assess if the treatment has been implemented to the prescribed specifications and achieved stated targets. Post-treatment surveys shall be executed such that they collect the necessary information for RESULTS Information Specification Submissions (RISS) for Government Funded Silviculture Activities.

6.2 POST-TREATMENT SURVEY PROCEDURES

1. Sample plots shall be established, as per Article 3: located systematically on a grid from a random starting point and maintaining systematic positioning of plots throughout the survey.
2. Sample plots completed on a grid may be completed at a low or high intensity.
3. Minimum sampling intensity will be determined in collaboration with the Ministry Designated Representative based on the project specifics.
4. For post-treatment surveys on areas that have stocking standards associated, surveyors should consult and follow the procedures set out in the Silviculture Survey Procedures Manual to ensure that data collection specific to the stocking standards and relevant RESULTS submission standard is achieved, in addition to the data detailed in Article 7.

Technical Background

As mentioned in Section **3.6 Survey Lines and Plots**, there are a wide range of stand and fuel types that will be sampled using these protocols. Further to that, the survey objective, in this case a survey used to assess if treatments have been implemented to the prescribed specifications and achieved stated targets, will impact the acceptable sampling intensity and precision. As such it is not possible to specify desired precision or sample size requirements (minimum sample size) that will be suitable for all situations.

6.3 REPORTING AND DELIVERABLES

For all stratum within which a post-treatment survey is completed, the following products shall be delivered to the Ministry Designated Representative:

a. Plot data,
b. data summary (compilation),
c. recommendation (and timeline for follow-up, if applicable),
d. survey map, and
e. representative photographs.

Post-treatment surveys trigger a submission into RESULTS. See Article 7 for details.

ARTICLE 7 – SUBMISSION INTO RESULTS

7.1 GENERAL SUBMISSION INTO RESULTS

All Crown land wildfire risk reduction (WRR) projects which include an operational implementation component trigger a submission to RESULTS. For each post-treatment survey completed, a RESULTS submission is required.

7.2 DATA ENTRY STANDARDS

All data must be entered into RESULTS in accordance with the most current version of the *RESULTS Information Submission Specifications for Government Funded Silviculture Activities (RISS-gf)*, and as updated from year to year. The RESULTS business and policy documentation webpage provides the most up-to-date standards including the ***RESULTS Information Submission Specifications for Government Funded Silviculture Activities***. [22]

[22] https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-reporting-results/business-and-policy-documentation

ARTICLE 8 - FIELD DATA COLLECTION

8.1 GENERAL FIELD DATA COLLECTION

This section outlines the standard methodology for data collection. Please see the glossary for additional definitions and details. Any definitions not found within the body of the document and / or the glossary can be assumed to utilize the same definition as applied in the general practice of forestry and defined in the *Silviculture Survey Procedures Manual*.

This standard provides methods to allow data collection for a wide number of fuel characteristics. However, field crews are not required to sample every characteristic represented within this standard. Crews, guided by the Ministry Designated Representative, should only sample the characteristics they are interested in, ensuring that all data to meet the goals and objectives of the program is collected, and also as determined relevant by the goals and objectives of the project. [23] In most cases the data collected from plot to plot will be the same although there are situations when some characteristics may be sampled on a subset of the sampling plots. Table 6 outlines the recommended relative importance of various fuels characteristics, abbreviations for which are used throughout Article 8.

Table 6. Abbreviation and relative importance of each field found in the following sections.

Abbreviation	Description of Importance
H	required to meet legislated requirements, essential component to meet overarching program goals, and / or accuracy is critical
T	desired where it has an effect on treatments being prescribed, or to be collected as per Ministry Designated Representative
L	useful for a complete description of a stratum
B	Best practices

The methodology outlined in the following section describes, where relevant, the minimum level of measurement error and categorization. Depending upon the survey objective, data can be collected to a more precise measurement or collected in more refined categories but should not be collected in a less precise manner or with less categories than outlined.

Technical background

Flexibility Within the Standard

[23] Lutes, Duncan C.; Keane, Robert E.; Caratti, John F.; Key, Carl H.; Benson, Nathan C.; Sutherland, Steve; Gangi, Larry J. 2006. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 1 CD.

Prior to embarking on a survey, the surveyor must clearly understand the survey objectives and project objectives. It is recommended that the surveyor discuss the survey objectives, as well as the implications on additional data collection required, level of statistical rigour, and precision required, based on objectives, with the Ministry Designated Representative. For example, it may not be necessary to collect data on each fuels characteristic outlined within Article 8. This may save time and money for the project, unless an important characteristic is overlooked and then a second trip to the field will be extremely costly.

This document outlines methods for flexibility within the standard. However, field crews guided by the Ministry Designated Representative and the professional responsible for the work, should sample the characteristics they are interested in, while also ensuring that all data to meet the goals and objectives of the program is collected, as determined relevant by the goals and objectives of the project.

Categorization

Several of the stand characteristics measured in these surveys are recorded by categories (e.g., DBH classes / tree layers, fine woody fuel loading categories and large diameter woody fuel categories). Categorization is done to reduce survey time and costs. When deciding on categories the following must be taken into consideration:

1. Available time and budget.
2. Minimum number of categories required for treatment decisions and prescription development.
3. Minimum number of categories required for model inputs.
4. Consistent categorization that may be required if data from multiple surveys is to be combined and analyzed to examine trends and produce summary statistics across projects (e.g., at District, Regional or Provincial level).
    a. It is difficult, and sometimes impossible, to combine data that has been collected with different categories.
    b. If now, or in the future, it is planned to complete comparative analyses of the data between areas and projects, standard categorization (number of categories, as well as set ranges, and absolute start and end points for each category) should be mandated.
5. From an analytical perspective, if a variable can be collected without categorization, this is preferred as it allows for more flexibility in analysis and data processing. It obviously also typically increases survey time and costs so there is a trade-off that needs to be made. It is important to realize that this trade-off is being made when collecting data in categories.
    a. Consider the example of tallying trees by DBH classes. If all trees were measured for DBH, then the data could be summarized by any set of DBH classes required for a particular application of the data.
6. From an analytical perspective, it also follows that if categorization is required to reduce survey time and costs, more categories are better as these can be combined in data processing if required. Again, this comes at an increased cost so the trade-offs must be considered.
    a. E.g., data collected in 1 cm classes can be combined into 2 cm classes. But the reverse is not true.

b. More categories also allow for a more detailed interpretation of the data (see Figure 3).

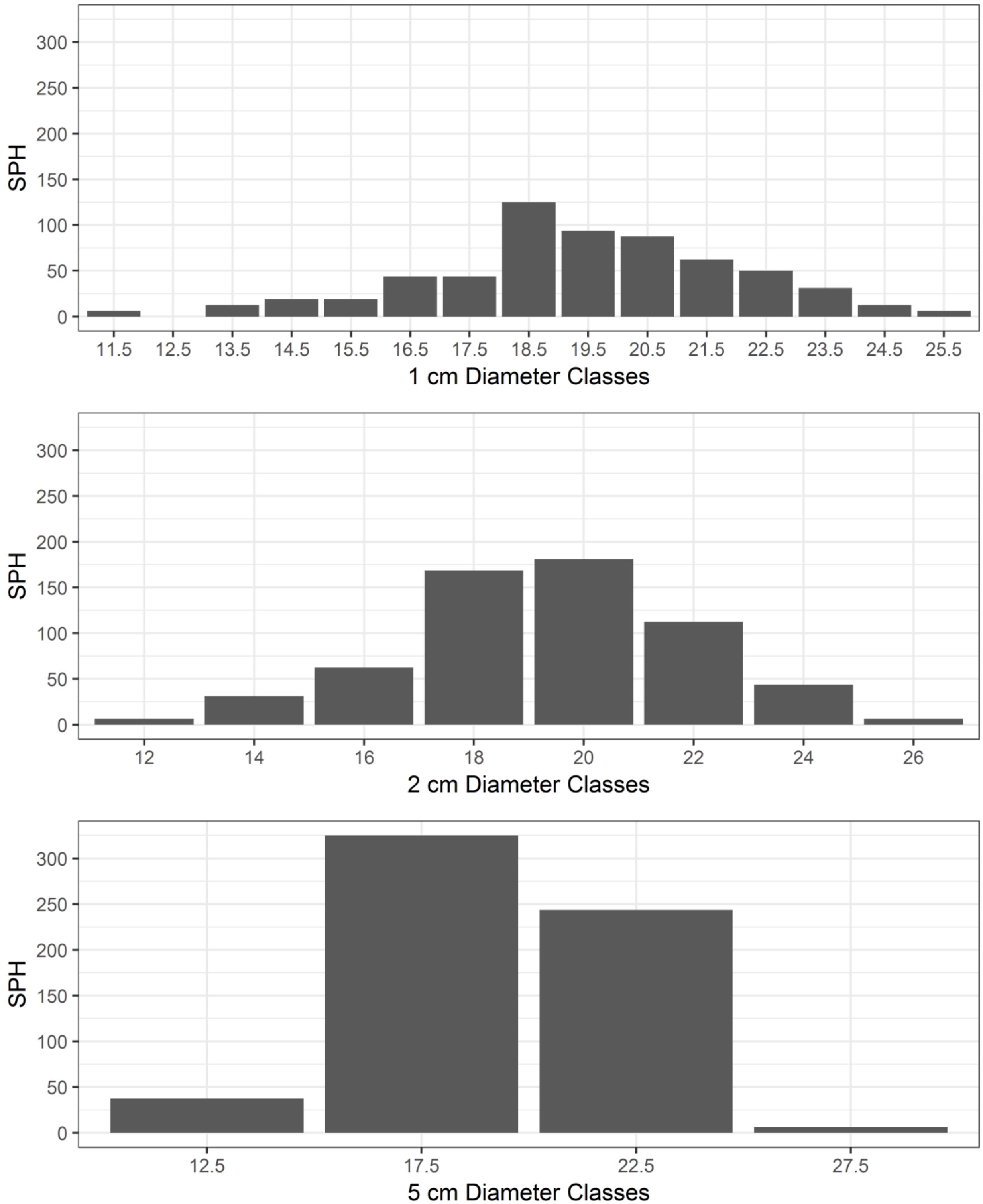

Figure 3. Data from a single survey summarized with different DBH categories. The finer the classes, the more detail is understood about the stand structure.

8.2 ESTABLISHING PLOTS

Formal sample plots shall be established using one or more of five plot types (i.e. data collection / sampling methods): fixed radius circular plot, variable radius circular plot, sampling planes (transects), cross-sectional profile, and fixed area square plot. At one single plot center, multiple plot types listed above may be established, depending upon the project objective. At a minimum, sample plots shall employ fixed radius circular, sampling plane (transect), and cross-sectional profile. Table 7 details acceptable plot type for the data being collected.

Table 7. Details acceptable plot types for the data to be collected.

Data collected	Acceptable sampling method
Large trees (L1 – L2)	Variable radius circular (BAF), fixed radius circular
Small trees (L3 – L4)	Fixed radius circular
Surface fuels (Woody Debris)	Sampling plane (transect)
Surface fuels (grass, shrubs, weed, other)	Fixed area square, fixed radius circular
Surface fuels (litter)	Cross-sectional profile
Ground fuels (duff)	Cross-sectional profile

In this standard, the plot center applies as follows:

- Plot center for fixed radius and variable radius plots, as described in the Silviculture Survey Manual and Cruising Manual.
- Sampling planes (transects), cross-sectional profile, and fixed area square plot are located in relation to, but not centered around, the established plot center.

To reduce bias, the data collection shall adhere to the following:

- Methodology for locating the sampling plane / transect, microplots, and cross-sectional profiles relative to the plot center shall be determined prior to the survey and shall be consistently located throughout the survey. See Figure 4 as an example of how to establish different types of plots relative to one systematically located plot center. Specifically, the following three variables for sampling planes shall be predetermined and remain constant throughout the survey.
    - The starting point of the sampling plane shall be outside the fixed area plot, at a predetermined and consistent distance from plot center, to reduce trampling or disturbing fine fuels prior to measurement (e.g., the fixed plot has a 5.64 m radius; the sampling plane starting point is 6 m from each plot center).
    - The starting point of the sampling plane shall be in a consistent cardinal direction from the plot center (e.g., starting point is always 6 m due north from the plot center).

- The sampling plane shall extend in a predetermined and consistent cardinal direction from the starting point. (e.g., the sampling plane shall extend due north from its starting point).

- Microplots and cross-sectional profiles shall be located at predetermined and consistent locations relative to the sampling plane. To reduce trampling or disturbing surface fuels or duff while collecting data, the microplots and cross sectional profiles shall be at the end of the longest two sampling plane lengths (e.g., 25 m and 30 m).
- Methodology (e.g., plot radius, BAF, sampling plane lengths, etc.), once determined, shall remain constant throughout the survey.

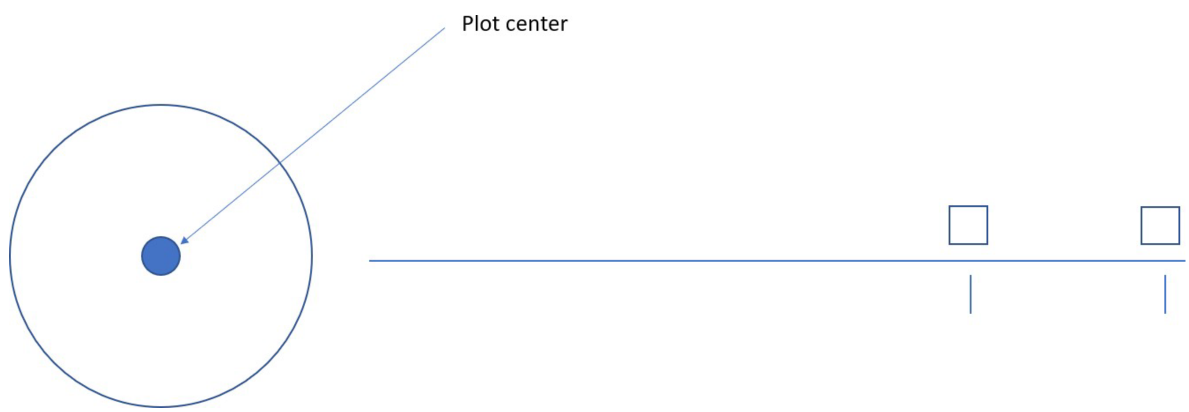

Figure 4. An aerial view example of establishing different types of plots relative to a systematically located plot center. Around the plot center is a fixed radius circular plot. The transect begins outside the fixed area plot, extending away from plot center. Two cross-sectional profiles and two fixed area square microplots fall along the transect at the end of the last two transects.

Fixed Radius Circular Plots

The most common shape and size of plot for stand data collection is 3.99 m radius circular plot. There is no mandatory requirement for any specific plot size; acceptable radii options for circular plots include 2.52 m, 3.99 m, 5.64 m, 7.98 m or 11.28 m. See Table 4 for plot multipliers.[24] A constant plot size should be used for a stratum (i.e., don't change plot sizes within the same stratum). In the case that the data will be compiled to a larger unit (e.g., compiled for multiple strata across the entire treatment area), then the plot size should remain constant for the entire survey.

Fixed radius circular plots are used to collected stand data on smaller trees (L3 – L4) and may be used to collect information on the overstorey / larger trees (L1 – L2), as well. It is important to select an

[24] For more details on, and explanation of plot area and plot multipliers, please consult the *Silviculture Survey Procedures Manual – May 1, 2020*.

appropriate plot size for the survey. Standard errors are generally larger with small plots (i.e., lower precision). [25]

Variable Radius Plots

Variable radius plot sampling (or point sampling) is a method of selecting trees to be tallied based on their size (DBH). In variable radius plots the probability of tree selection is proportional to the size (basal area at breast height) of the tree. Variable plots are generally more efficient to measure than fixed area plots; trees can be assessed for in/out status with an angle gauge (i.e., prism). [26] In fuels data collection, variable radius plots are acceptable to capture data for larger (L1 – L2) trees.

Variable radius sampling is a fast and cost-efficient technique for data collection, but it is important to use the right prism size, or basal area factor (BAF), for the stand type. One risk of using an inappropriate BAF selection is density estimates much higher or lower than actually exists in the stand. Furthermore, a larger BAF, when used in appropriate stand types, may result in lower precision in density. In this case, the mean may still be accurate, but the variability and confidence interval around the mean is much wider than using a lower BAF, more appropriate to the stand type. [27]

The general guidance for variable plots, is that the prism size (basal area factor) should be chosen to capture 5 – 8 ‘in’ trees per plot and that ‘in’ trees should not be more than 12 m from plot center. One BAF should be targeted for use for the entirety of the polygon. In stands with larger trees, a larger BAF is more appropriate; in stands with smaller trees, a smaller BAF will more accurately capture data. If the variation of the stand is high, choose a lower BAF to capture variability at and between sampling locations and to tighten the confidence interval (reduce sampling error).

As L1 and L2 trees may both be measured with BAF, this introduces the potential need for prism plots to accurately capture very high variability. It may be that when determining appropriate BAF size, a small BAF results in the number of ‘in’ trees being unacceptably high or the distance of ‘in’ trees from plot center being unacceptably far. In this case, it is possible to use more than one BAF at one plot center: one smaller BAF used to collect L2 information and a larger BAF used to collect L1 data. As stated in the paragraphs above, the important aspect is to keep sampling methodology constant throughout the stratum. For example, once it has been determined that two BAFs is the appropriate method, then all plots within the stratum should be collected using the same two BAFs. Please note: this approach introduces several potential points for measurement and / or recording errors. For example, it requires keeping the two sets of trees separate so that none fall between the cracks (or are double-counted). This may require the surveyor to measure the DBH of all trees near to the category break-point (i.e., 7

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[25] Iles, K. 2003. *A sampler of inventory topics: a practical discussion for resource samplers, concentrating on forest inventory techniques*. Kim Iles & Associates Ltd. pp 516 – 523.

[26] FLNRORD Cruising Manual 2020.

[27] SilvaTerra Blog Biometrics and Forest Technology. Pond, Nan C. July 22, 2015. https://blog.silviaterra.com/variable-radius-plot-sampling/

cm DBH and 12.5 cm DBH) to determine which BAF is correct. Using a single BAF is more a matter of quality control, as opposed to a technical requirement. [28]

Line of sight and ability for surveyors to see 'in' trees should also be a consideration when deciding upon the use of variable radius plots. For more detailed information on variable plot sampling using a prism, see the most current version of the *Timber Cruising Manual*.

Sampling Planes

Sampling plane, or transect, is a method for measuring downed woody debris. In order to reduce bias, there are two issues to consider: starting point and orientation. Sampling planes should originate from randomly or systematically located points. In this case, the plot centers located on a grid can serve as the systematically located point. Orientation should either be consistent (in the same direction every time) or random (randomly selected orientation for each transect). [29]

For the purposes of data collection specific to fuels management projects, other opportunities to bias the data occur; there is a potential to trample, move, or otherwise disturb woody debris before or during data collection along the sampling plane. It is for this reason that it is recommended to locate the sampling plane starting point outside the fixed area plot. At the same time, the starting point needs to be consistently located relative to the systematically located plot center, in both distance and direction.

Bias introduced through sampling plane orientation can be reduced through random orientation or consistent orientation. Although there are some advantages to random orientation, namely to correct for the non-random orientation of downed woody debris, this method is more difficult to implement, introduces potential opportunity for survey bias, and is more difficult to inspect.

8.3 DATA BY SURVEY

The data collection fields outlined in Table 8 are considered general data which is specific to the survey, or entire polygon / treatment unit. Much of the data included in Table 8 may be populated in the office and prior to heading to the field.

Table 8. Data collected once per survey to be representative of the entire polygon surveyed.

Field Name	Relative Importance	Description
Surveyor	H	Name and accreditation / credentials
District	L	Record the name or abbreviation for the MFLNRORD district.

[28] Iles, K. 2003. *A sampler of inventory topics: a practical discussion for resource samplers, concentrating on forest inventory techniques*. Kim Iles & Associates Ltd. pp 516 – 523.

[29] Iles, K. 2003. *A sampler of inventory topics: a practical discussion for resource samplers, concentrating on forest inventory techniques*. Kim Iles & Associates Ltd. pp 381 – 383.

Field Name	Relative Importance	Description
Project Identification / Contract Number	H	If the survey is being completed under a contract, record the specified project identification number or contract number.
Page	B	Record the page number. The goal is to provide a logically organized package of survey cards to include in the finished report.
Survey Date	H	Record the date in which the survey data was collected in the field.
License	H	Record the license under which the area was treated (if applicable).
Lat/Long	H	Record the center point of the treatment area (or the closest access point)
Treatment Area	H	Record the treatment area name / identifier.
Treatment Unit	H	Record the treatment unit(s) name / identifier.
Treatment Unit Area (Net)	L	Record the net area (ha) of the treatment unit, if applicable.
Survey Type	H	Treatment decision, prescription development, post-treatment
Elevation	L	Record the minimum, maximum and average elevation of the stratum in meters above sea level.
Aspect	H	Record the direction toward which a slope faces for the stratum.
Slope position	L	Record the position for the slope of the stratum. Crest, upper slope, middle slope, lower slope, toe, depression, flat / level.
Surface expression	L	Record the surface expression of the stratum. Plain, undulating, ridges, terraces, cone, depression, fan, hummock, rolling.
Slope %	L	Record the minimum, maximum and average slope percentage of the treatment unit. Slope percent should be measured using a clinometer and measured to the nearest percent.
BGC Zone, Subzone and Variant	L	Record the biogeoclimatic zone, subzone and variant of the stratum. Biogeoclimatic information should be confirmed during the survey.

Field Name	Relative Importance	Description
		Regional ecological classification zone and subzone maps and field guides should be used to confirm the biogeoclimatic zone, subzone, variant.
Site Series	L	The regional field guides for identification and interpretation of ecosystems are used to determine the site series of the stratum. Record the primary site series that covers the majority of the treatment unit, the secondary and tertiary site series if applicable.
Site Series %	L	If there is more than one site series present within the stratum, a percentage should be assigned to each of the different site series. The site series should be rounded to the nearest 10 percent and the combined site series percentages should equal 100 percent.
Edatopic grid	L	The moisture and nutrient co-ordinates of the site can be determined by using the edatopic grid of the corresponding biogeoclimatic zone site series and / or confirmed during the survey.
Plot radius (fixed)	H	Record the plot radius (m) used for fixed radius plots.
Plot multiplier	L	Record the plot multiplier for fixed area plots, based upon the radius.
Basal Area Factor (BAF)	H	Record the prism size used in completing the prism sweeps for variable radius plots.
Sampling plane lengths	H	Record the sampling plane length for the planar intercept methodology for each category of surface fuels. Sampling plane length should be measured in 0.1 m.
Sampling method	H	Record the sampling method being used on this stratum.

8.4 DATA BY PLOT

This section describes the general information which represents, or is applicable at, the plot level. The data for fields in Table 9 should be collected once per plot. Each plot shall be GPS'ed (see Article 3 for details).

Table 9. Fields for plot level data collection to be representative of the circular, fixed radius plot.

Field Name	Relative Importance	Description
Plot name/ number	H	Record the plot name / number / unique identifier.
Deviations to sampling methodology	H	Record any deviations to the sampling methodology and explanation for deviation (if applicable).

8.5 FIXED AND VARIABLE RADIUS CIRCULAR PLOT

This section outlines the standard methodology for collecting stand data using both variable and fixed radius plots, depending on the data to be collected. Data is to be collected on all four layers (L1 – L4).

Table 10. Data to be collected once per plot to be representative of the plot.

Field Name	Relative Importance	Description
Fuel Strata Gap	L	Record the average fuel strata gap for the plot (0.1 m) based upon a visual assessment of the average fuel strata gap.
Crown Closure	H	Record the total crown closure for each layer, representative of the plot. Conifer and deciduous crown closure may also be recorded independently, depending upon survey objectives. Crown closure is estimated from ocular estimates using speckle diagrams to assist with surveyor calibration. Estimate crown closure to the nearest 10%.
Ladder Fuel Horizontal Continuity	L	Record the percent of plot area covered by ladder fuel. Plot area covered should be measured using ocular estimates and speckle diagrams to assist with surveyor calibration. Estimate to the nearest 10%.

L1 - L2 / large trees

Layer 1 (L1) and L2 trees may be measured in fixed or variable radius plots. If any merchantable timber will be cut, refer to Section **3.13 Merchantable Timber** for full timber cruise considerations. The plot type used for L1/ L2 trees shall be determined at the beginning of the survey and remain consistent throughout the survey. Variable radius plots are often preferred, as they are generally more cost-efficient.

The data collected remains the same regardless of the type of plot utilized. Table 11 outlines the data and measurement standards to be collected for each 'in' tree per plot.

Table 11. Fields for data collection for each L1 and L2 'in' tree.

Field Name	Relative Importance	Description
Species	H	Record tree species.
Height	H	Record tree height to the nearest 1.0 m. Minimum one tree per plot shall be measured with a vertex, laser, clinometer and chain, or using an equivalently accurate method. The height of remaining trees may be ocular estimates based upon the height of the measured tree. Additional trees may be measured, as needed, to assist in calibrating surveyor estimates.
Age	H	Record the age of the tallest living tree for the leading and second most abundant species by Layer. The age of remaining species may be estimated ocularly based on the ages of the measured trees. Primary aging method is core sampling with whorl counting for determinant species or destructive sampling as alternatives if the tallest tree is too small for coring.
Diameter	H	Record diameter at breast height to the nearest 1 mm (0.1 cm)
Crown base height (CBH)	H	Record CBH to the nearest 0.5 m. Minimum one tree per plot shall be measured with a vertex, laser, clinometer and chain, measuring tape, or using an equivalently accurate method. CBH of other 'in' trees may be ocular estimates based upon comparison to the CBH of the measured tree. Additional CBHs may be measured, as needed, to assist in calibrating surveyor estimates.
Crown class	T	Record the crown class, as defined and abbreviated by FuelCalcBC. Options are dominant, codominant, intermediate, open grown, emergent, suppressed, none.
Wildlife Tree Class (WTC)	L	Record WTC 1 - 8 (conifer) or 1 - 5 (hardwood), as per the Wildlife Danger Tree diagrams and definitions. [30] [31]
Forest health factor(s)	T, L	Record the applicable pest code(s) of the forest health factor on **each** affected tree. Record all forest health factor(s) determined to impact treatment specifications, targets, or prescription objectives.

L3 – L4 / small trees

[30] Appendix 6. Vegetation Resource Inventory Ground Sampling Procedures. 2002. B.C. Ministry of Sustainable

Resource Management, Terrestrial Information Branch for the Resource Inventory Committee. See http://srmwww.gov.bc.ca/tib/veginv/publications.htm. Or as described in *WorkSafeBC Wildlife/ Danger Tree Assessor's Course Workbook* (various modules).

[31] Equivalent data collection techniques are available, including but not limited to tree status, as defined by FuelCalcBC (see definitions in glossary).

Fixed radius circular plots are recommended for data collection of the small (Layer 3 – Layer 4) trees, but can be equally useful for collecting L1 and L2 data. Data is collected by species and layer. Table 12 outlines the methodology, including minimum precision and categorization, for each data field to be collected. Further refinement in precision or in categorization is possible based upon project objectives (e.g., collecting data by individual stem).

Table 12. Fields for data collection in fixed radius plots.

Field Name	Relative Importance	Description
Tree Density	H	Tally 'in' trees by layer (L3 – L4) and by species. In the case that dead understorey trees are difficult to identify to a species level, a species code of 'dead' is acceptable. (See Table 13 for an example). It is not necessary to tally trees <30 cm in height.
Height	H	Record the plot's median tree height for each layer to the nearest 1.0 m, based upon surveyor's ocular assessment of the median tree. The tree may be measured using a vertex, laser, clinometer and chain, measuring tape, or using an equivalently accurate method or by ocular estimate based upon a comparison with a tree that was measured using a previously measured, and visible, tree.
Age	H	Record the age of the tallest living tree for the leading and second most abundant species by Layer. The age of remaining species may be estimated ocularly based on the ages of the measured trees. Core sampling, whorl counting for determinant species or destructive sampling are all acceptable means of determining age.
Forest health factor(s)	T	Describe any notable forest health factors per layer.

Table 13. Example tally data for small trees (L2 – L4) by layer and species in a 5.64 m radius plot with a plot multiplier of 100.

Layer	Pli	Fd	Py	Dead	Total by Layer (sph)	Average height	Average age	Average CBH	Crown Class	Forest Health Factors
3	IIII	II	II	III	1100	2	4	0.5	S	DMF
4	I		III		400	0.6	2	0.2	S	None
Total by Species (sph)	800	300	500	300	1900					

8.6 SAMPLING PLANE (TRANSECT)

Dead and downed woody surface fuels is be collected using a planar intercept technique based upon the methodology developed by Alexander and McRae (1979)[32] and further adapted in the Prescribed Fire Handbook[33]. Dead and downed woody surface fuels that intersect the sampling plane shall be tallied by size category (see Table 14 for defined categories). Sampling plane lengths vary by debris diameter size category: one sampling plane length is used for each of the six categories. Smaller diameter categories have shorter sampling plane lengths (i.e., at the end of each determined sampling plane length, the smallest size category is 'dropped' and no longer sampled). For example, all size categories are sampled for the first 5 m of the transect after which the smallest size category ceases to be sampled. After 10 m, the next smallest size category is no longer sampled. Figure 5 visually displays an example of sampling plane lengths by size category.

Table 14 details size categories, corresponding sampling plane and category numbers, and outlines general guidance for sampling plane length for each size category, based upon a 30 m default sampling length.

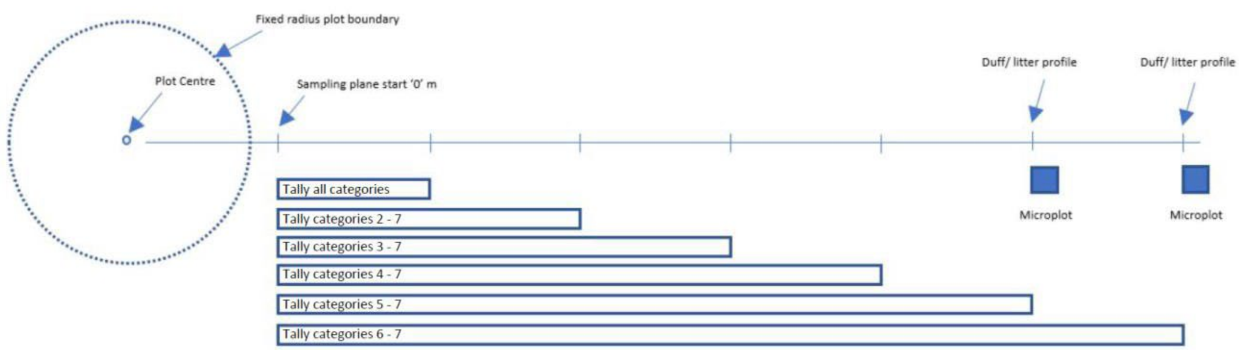

Figure 5. Example of linear sampling plane, microplot, and duff/ litter sampling locations using the planar intercept methodology. [34]

The following recommendations are to avoid or reduce common mistakes or errors during sampling:

1. Complete the surface fuel and ground sampling prior to the stand data collection.
2. Complete the sampling in crews of 2 or 3 to maximize efficiency and reduce travel back and forth over the fuels.

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[32] Alexander and McRae 1974. Measurement and Description of Fuels and Fire Behaviour on Prescribed Burns: A Handbook.

[33] Trowbridge, R., B. Hawkes, A. Macadam, and J. Parminter. 1989. Field Handbook for Prescribed Fire Assessments in British Columbia: Logging Slash Fuels.

[34] Figure adapted from: Lutes, Duncan C.; Keane, Robert E.; Caratti, John F.; Key, Carl H.; Benson, Nathan C.; Sutherland, Steve; Gangi, Larry J. 2006. FIREMON: Fire effects monitoring and inventory system. Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 1 CD.

3. Use a 'go-no-go' gauge [35] to quickly determine size categories for those pieces for which their category is not immediately evident, or for use by inexperienced surveyors.
4. Ensure the measuring tape, which represents the lower portion of the sampling plane, is straight as possible, avoiding kinks or bends.

Measurement rules for planar intercept sampling can be found in Appendix C – Planar Intercept Tally Rules. This standard does not provide all details on implementing planar intercept sampling methodology. For more information and helpful hints, see Appendix A – Tools, Resources, and Links..

Woody debris categories – planar intercept

Woody surface fuels in British Columbia are categorized into 7 diameter classes (see definitions and Table 14) [36].

Table 14. Woody debris size categories and guidance on sampling plane length.

	Diameter category (cm)	Woody debris category No.	Default sampling plane length (m)
Fine Woody Debris (FWD)	≤ 0.5	1	5
	0.6 – 1.0	2	10
	1.1 – 3.0	3	15
	3.1 – 5.0	4	20
	5.1 – 7.0	5	25
Large Diameter Woody Debris (LDWD)	>7.0 – 20.0	6	30
Coarse Woody Debris (CWD)	>20.0	7	30

[35] Go-no-go gauges can be made relatively easily out of sheet aluminium or old plastic cards (credit, grocery, etc.).

[36] Data collection specifics for CWD related to biodiversity values are not included as part of this standard. It is recognized that these logs serve important functions in the ecosystem and provide habitat, biodiversity and other values; it is up to the professional to manage accordingly for the resource values provided by the component of coarse woody debris, including the values provided by pieces greater than 20 cm diameter.

Table 15. Data collection fields for woody surface fuels estimated through planar intercept method.

Field Name	Relative Importance	Description
Slope of sampling plane	H	Record the slope percent of the sampling plane. Slope should be measured using a clinometer and measured to the nearest 1 % percent.
Fine woody debris	H	Tally number (simple counts) of downed and dead woody fuel pieces by size category which intersect the sampling plane.
Species percent breakdown	H	Record estimated percentage of species (round percent to the nearest 10% and ensure that percentages add to 100%).
LDWD\CWD diameter	H	Record diameter of each piece of LDWD\CWD where it intersects the sampling plane. Measure to the nearest mm (0.1 cm).
LDWD \CWD species	H	Record species of each LDWD\CWD piece that intersects the sampling plane.
LDWD \CWD decay class	H	Record if LDWD\CWD is decayed (see definition).

Calculations

A tally line intercept form, a field form and the BCWS-developed *line intersect calculator* are available on the Tools for Fuel Management Webpage[37]. The BCWS-developed *line intersect calculator* is a tool available to assist in calculating total fuel loading estimates based upon the default woody surface fuel categories when collected using the planar intercept technique. In the calculator, sampling plane lengths can be defined, should shorter or longer sampling lengths be desired to meet the desired sampling precision or if / when slope corrections are required.

Technical Background

The length(s) of the sampling plane(s) can be varied to achieve the desired sampling precision. Generally, the less sampling points collected (i.e., fewer surface fuels intersecting the sampling plane), the longer the sampling plane length required. Time and budget, as well as project objectives, should all factor into the determination of an appropriate sampling plane length. It is not uncommon to meet data collection needs and survey objectives with a total sampling plane length shorter than 30 m. Please

[37] https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management

note, sampling plane lengths are horizontal distances (as described in the above paragraph), therefore corrections based upon slope percent may be required.

Similarly, the sampling plane height is undefined; all intersections of dead and down material should be tallied regardless of their height above the ground. General guidance is a sampling plane height of 2 m, although there are certainly sites where a shorter sampling plane height will suffice, or a taller sampling plane height may be required.

8.7 MICROPLOT

The following surface fuels shall be measured in fixed microplots of 1 m^2 (1 m x 1 m or 0.56 m): pinegrass, sagebrush, bunchgrass, flammable weed, pine litter, deciduous shrub, flammable conifer shrub, moss, lichen, and masticated fuel bed. A minimum number will be determined in collaboration with the Ministry Representative. More microplots are acceptable, although as outlined in Section **8.2 Establishing Plots,** the location and number of microplots shall be determined prior to survey start and remain consistent throughout the survey.

Table 16. Data for which collection occurs in fixed 1 m x 1 m microplots.

Field Name	Relative Importance	Description
Surface Fuel Composition	T	Describe the type of the surface fuels for which data is collected. Descriptor options include, but are not limited to: pinegrass, sagebrush, bunchgrass, flammable weed, pine / conifer litter, deciduous shrub, flammable conifer shrub, moss, lichen, masticated fuel bed. It is acceptable to identify more than one type of surface fuel for which data is collected, depending upon the site and survey objectives.
Continuity / coverage	T	Record the surface fuel continuity / coverage of the surface fuel in each microplot by surface fuel composition descriptor (a separate percent cover for each composition descriptor determined relevant). Surface fuel continuity should be measured using ocular estimates and using speckle diagrams to assist with surveyor calibration. Estimate to the nearest 1%.
Fuel bed depth	T	Record the average surface fuel bed depth in each microplot by surface fuel composition descriptor (a separate fuel bed depth for each composition descriptor determined relevant). Average fuel bed depths should be determined using an ocular estimate. Measure to the nearest 1 cm.

Technical Background

Fixed Area Square Plots

Microplots are generally collected in higher sampling intensity than fixed radius plots (i.e., more than one microplot is established per each plot center. The intensity and precision with which microplots are established should follow the same sampling intensity principles as the establishment of other plots.

Fixed area square plots are most commonly established as microplots (e.g., 1 m x 1 m) and are used to collect data on surface fuels. As with all other types of plots, consistent placement of plots relative to a systematically located plot center is key to reducing bias.

8.8 CROSS SECTIONAL PROFILE

Duff and litter depth are measured using a duff / litter profile at established points along the sampling plane. To reduce bias, the goal is to create a vertical cross-section of the litter and duff without compacting, compressing, or disturbing the profile. A minimum of two duff / litter profiles per planar transect shall be used. More cross-sectional profiles are acceptable, although as outlined in Section **8.2 Establishing Plots,** the location and number of cross-sectional profiles shall be determined prior to survey start and remain consistent throughout the survey.

Table 17. Data collection fields for litter and duff depth measured in cross-sectional profiles.

Field Name	Relative Importance	Description
Litter depth	T	Record the litter depth to the nearest 1 cm.
Duff depth	H	Record the duff depth to the nearest 1 cm.

8.9 OTHER ASSESSMENTS AND CONSIDERATIONS

It is expected that to develop a fuel treatment prescription, surveyors / professionals will need to consider additional data collection to manage for other values (e.g., riparian, ungulate winter range, coarse woody debris, etc.).

The following is a non-exhaustive list of considerations and assessments which may be relevant to the project and field work, depending on site and objective(s). This standard does not provide guidance on completing the following assessments or provide guidance regarding when such assessments should occur, as it is outside the scope of this standard. It is recommended that the surveyor and / or supervising professional consult the appropriate guidance documents and relevant field forms, where available.

- Soil profile
- Terrain stability assessment
- Wind throw
- Riparian / stream assessments
- Access (currently existing or planned)
- Values at Risk (structures or other – distance, direction, location on slope, location in relation the predominant fire season wind direction)

- Archaeological assessments
- Wildlife
- Species and ecosystems at risk

ARTICLE 9 CALCULATIONS / STATISTICS

9.1 GENERAL CALCULATIONS AND STATISTICS

For all surveys that result in data collected in a statistically valid manner, statistical analysis / validation should be completed for each characteristic of interest at the stratum level. This will allow surveyors to determine how precisely the survey data describes the stratum, in relation to the characteristic(s) of interest. The characteristics of interest depend upon the survey and project objective and surveyors should confirm the characteristics of interest for the survey, in discussion with the Ministry Designated Representative.

Statistical analysis includes calculation of the sample mean, variance, and sample standard error which is used to determine the confidence intervals for the mean (upper and lower confidence limits). Confidence intervals are calculated at a confidence interval (e.g., 95%). A confidence interval of 95% translates to saying that one can state with 95% confidence that the confidence interval includes the true mean. There is no set level of confidence that must be utilized for the statistical analysis.

Visual assessments do not collect data in a statistically valid manner and therefore statistical analysis is not appropriate.

Technical Background

Statistics enable surveyors and decision-makers to make informed decisions. Estimates of population characteristics are calculated based on the collected data. This typically includes an estimate of the mean and variance. The sample standard error (based on the variance) is used to determine a confidence interval for the mean.

Given the range of variability around the sample mean, as described by the confidence interval at a defined confidence level, the decision maker can consider the following questions:

- Does the decision hinge on a confidence interval that includes an important threshold (i.e., the true mean may be above or below the threshold at the level of precision)?
- Is a greater level of precision required to make a decision?
- What level of confidence is the decision-maker willing to accept?

Statistical calculations are only completed when plots are established (i.e., visual assessments do not result in statistical analysis).

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APPENDIX A – TOOLS, RESOURCES, AND LINKS

Provided below are a list of potentially helpful tools, links, and references for the practitioner and fuels surveyor. These references are not necessarily developed, maintained, or supported by BCWS. It is up to the practitioner and surveyor to verify the quality, accuracy, and currency of the information found within prior to use.

Many of these tools can be accessed through the Tools for Fuel Management webpage: https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management

COMPILATION AND STATISTICS

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CRUISING / PRICING

Ministry of Forests, Lands, Natural Resource Operations and Rural Development – Timber Pricing Branch. *Cruising Manual*. Accessible: https://www2.gov.bc.ca/gov/content/industry/forestry/competitive-forest-industry/timber-pricing/timber-cruising/timber-cruising-manual

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PLANAR INTERCEPT SAMPLING

Measurement And Description of Fuels And Fire Behaviour Alexander & McRae:

https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/wildfire-status/prevention/fire-fuel-management/fuels-management/measurement_of_forest_fuel_mcrae_and_alexander_1979.pdf

Chippewa National Forest Brown's Transect Field Guide. 2004. Accessible: https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/wildfire-status/prevention/fire-fuel-management/cnf_browns_transect_guide.pdf

Line Intersect Calculator (xls). Accessible: https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management

Lutes, Duncan C.; Keane, Robert E.; Caratti, John F.; Key, Carl H.; Benson, Nathan C.; Sutherland, Steve; Gangi, Larry J. 2006. *FIREMON: Fire effects monitoring and inventory system.* Gen. Tech. Rep. RMRS-GTR-164-CD. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 1 CD. Specifically the Fuel Loading section, pages FL-1 – FL-22. Accessible: https://www.fs.fed.us/rm/pubs/rmrs_gtr164.pdf

Tally line intersect form (xls). This is a field form that can be utilized for woody surface fuel data collection. Accessible: https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management

PRESCRIPTION GUIDANCE

BC Wildfire Service *Fuel Management Prescription Guidance*. Accessible: https://www2.gov.bc.ca/gov/content/safety/wildfire-status/prevention/vegetation-and-fuel-management/fire-fuel-management/fuel-management

SURVEYING

Ministry of Forests, Lands, Natural Resources Operations and Rural Development. Silviculture Survey Procedures Manual. Accessible: https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-surveys

APPENDIX B – SAMPLING TO AVOID EDGE EFFECT BIAS

EDGE EFFECTS

Avoidance of block edges when sampling *may* cause a level of bias that is unacceptable for decision making (i.e., could result in the wrong treatment decision being made). The smaller the block is, the higher the proportion of edge area. If you avoid sampling the edges you are making the assumption that the block edges are the same as the interior of the block. If you can defend this assumption, or defend the assumption that avoiding the edges will introduce minimal bias then it may be practical to avoid the edges. However, if you cannot defend this assumption, then you are introducing an unknown bias that may influence your treatment decision and / or prescription. When dealing with estimates of totals per hectare, edge avoidance almost always results in an under-estimate of the totals because trees along the edge are sampled with lower selection probabilities.

Types of edges

In general, one can categorize edges into three types:

Hard Edges – These include a forest next to a clear-cut, lake, swamp, or road (Figure 6).

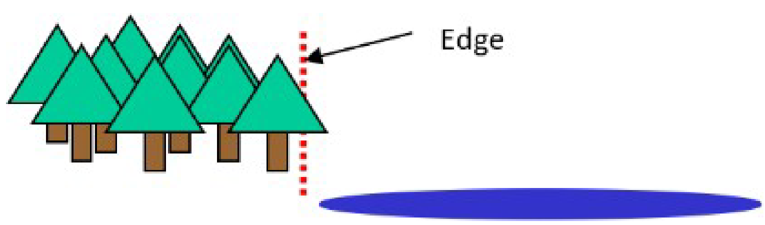


Figure 6. Hard edge

Soft Edges – These include a gradual change in stand differences. These differences could be a result of soil, slope or aspect variation within a forest producing different plant communities (Figure 7).

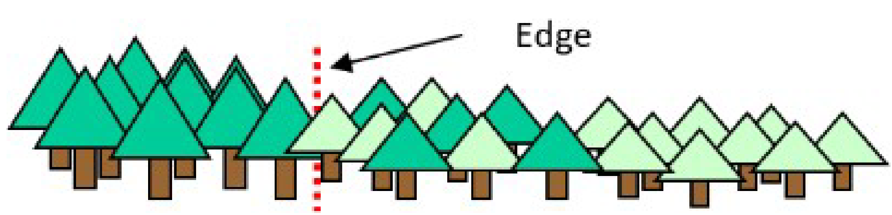


Figure 7. Soft edge

Imaginary Edges – These include legal boundaries, zoning differences or usage differences (Figure 8).

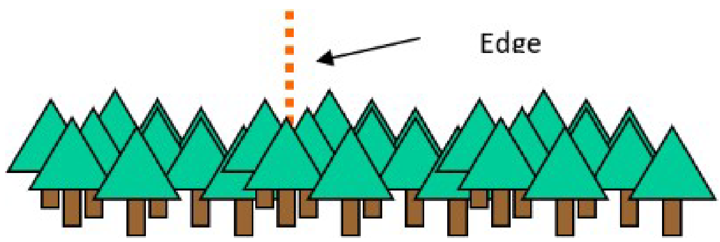


Figure 8. Imaginary edge

Incorrect sampling of edges can lead to significant bias

There are two main sources of bias:

1. Avoidance of the edge – by avoiding the edge you are making the assumption that the edges are the same as the interior of the block. In many cases this is not true.
2. Method caused bias – this is an artifact of the sampling technique that results in edge trees not being sampled with the correct probability.

Significant portions of the target population will be under-sampled if plots are not established due to their proximity to block boundaries (e.g., placing plots with the requirement that the entire plot must fit within the block). The amount excluded depends on the plot size and shape as well as the sampled block sizes and shapes. The smaller the average block size, the larger the bias, as the percentage of area that is under-sampled is higher (Table 18).

Table 18. Percent of area that is undersampled when requiring 11.28 m radius plots to fit fully within the block.

Block Size (ha)	Percent of area undersampled, by block shape		
	Circular (%)	Rectangular (%)	Square (%)
1	64.0	42.8	40.0
2	48.6	31.3	29.4
3	40.8	25.9	24.4
4	36.0	22.7	21.3
5	32.6	20.4	19.2
10	23.7	14.6	13.8
15	19.6	12.0	11.3
20	17.1	10.4	9.8
25	15.4	9.4	8.8

Block Size (ha)	Percent of area undersampled, by block shape		
	Circular (%)	Rectangular (%)	Square (%)
30	14.1	8.6	8.1
35	13.1	7.9	7.5
40	12.2	7.4	7.0
50	11.0	6.7	6.3
60	10.1	6.1	5.7
70	9.3	5.6	5.3
80	8.7	5.3	5.0
90	8.3	5.0	4.7
100	7.8	4.7	4.5
120	7.2	4.3	4.1
140	6.6	4.0	3.8
160	6.2	3.8	3.5
180	5.9	3.5	3.3
200	5.6	3.4	3.2

When using fixed area plots, each tree in the target population must have an equal chance of being selected for the sample to be unbiased. Unless some type of correction is used, trees along the edges have a lower probability of being selected and are therefore under-represented in the sample.

When using variable radius plots, each tree has a selection probability proportional to its size. This selection probability will be reduced for trees along the edges and therefore these trees will be under-represented in the sample unless some type of correction is used.

Design based sampling regimes and estimators rely on known probabilities of selection. Edge avoidance results in reduced selection probabilities for trees along the edge.

The easiest way to understand this is to think of a plot centered on an individual tree. If, for example, we are using 11.28 m radius fixed area plots, then picture an 11.28 m radius plot centered on an individual tree. This tree centered plot is referred to as the tree's inclusion zone. If a sample plot center lands in the tree's inclusion zone the tree will be included in the sample plot. The size of the inclusion zone (equal for all trees with fixed area plots and variable dependent on size with variable radius plots) dictates the weight of that tree in the sample estimators. When a tree's inclusion zone includes area that we do not allow plot centers to land in, then that tree will have a lower probability of being sampled than trees whose entire inclusion zones have a chance of a plot center landing in (Figure 9).

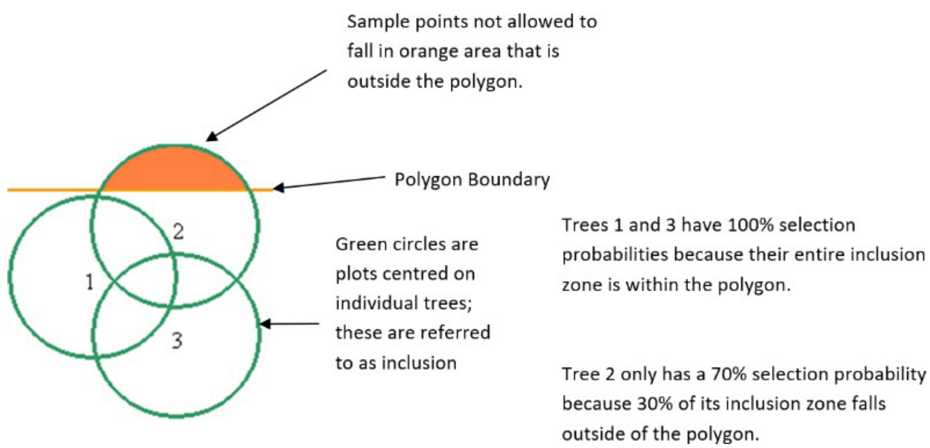


Figure 9. Illustration of trees near an edge having different probabilities of being selected.

Correcting for Edge Effect

Walkthrough Method

The walkthrough method was developed by Ducey *et al.* 2004 [38]. It is described in detail in Iles 2003 [39] and in the Cruising Manual [40].

The walkthrough method is relatively simple to implement in the field. It is a geometric method for implementing a direct correction of the lower selection probabilities of edge trees. Consider tree 2 from Figure 9, which only has a 70% selection probability (30% of the inclusion zone is outside the boundary). Using the walkthrough method, if this tree is selected in the sample, it will be double counted if the sample point lands in the 30% of the inclusion zone that is the mirror image across the tree centre of the 30% that is outside the boundary. The result is a 100% selection probability (40% * 1 + 30% *2 = 100%) (Figure 10).

[38] Ducey, M.J., Gove, J.H. and Valentine, H.T. 2004. A walkthrough solution to the boundary overlap problem. For.Sci. 50(4) 427-435.

[39] Iles, K. 2003. A sampler of inventory topics: a practical discussion for resource samplers, concentrating on forest inventory techniques.

[40] BC Timber Pricing Branch. 2020. Cruising manual.

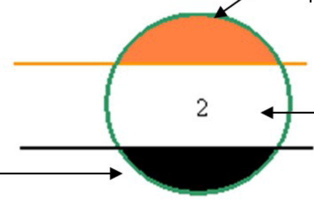


Figure 10. Example of how the walkthrough method increases an individual tree's selection probability to 100%. (Note that the green circle above is a tree centered plot, or the tree's inclusion zone).

In most cases all that is required is a double counting of trees that are closer to the block boundary than to the plot centre when walking a straight line from the plot centre to the tree to the boundary. The point located the same distance and bearing from the tree, as the tree is from the plot centre, is called the "walkthrough point". If the walkthrough point lands outside the block the tree is tallied twice. The following procedure is summarized from Table 1 in Ducey *et al.* 2004.

Step 1: Is it possible the tree is closer to the block boundary than the sample point?

No – tally the tree normally

Yes – proceed to step 2.

Step 2: Measure the direction and distance (x) from the sample point to the tree. Continue in the same direction and measure the distance between the tree and the boundary (y). Is y less than x?

No – tally the tree normally.

Yes – proceed to step 3.

Step 3: If you go the distance x from the tree along the same direction do you end up outside the block? In most cases the answer will be yes if y is less than x, but in some cases with irregular boundaries you may walk outside the block and back inside again.

No – tally the tree normally

Yes – tally the tree twice.

NOTE – the fixed area plot can be entirely within the polygon, and you can still have trees with inclusion zones that overlap the boundary, and which need to be double counted. For this reason, it is important to use the walkthrough method whenever a plot is close to edge, not just when it overlaps the edge.

The "Bounce-back" or Reflection Method for Transects

When a transect encounters the block edge:

- Stop at the boundary, turn around 180 degrees, and follow the original line back into the block.
- Continue along the line in the reverse direction to complete the required sampling distance.
    - For example, if the planned transect is 30 m, and the edge is encountered at 24 m, then the 6 m back into the block is sampled twice.
- Record or tally each piece along the length sampled two times or have a location on the tally sheet to mark it as being counted twice.
- All fixed area square plots or sampling points which are located along the transect shall be 'bounced back' and placed along the transect at the originally planned location.

APPENDIX C – PLANAR INTERCEPT TALLY RULES

All measuring rules and figures are taken or adapted from the Measurement And Description of Fuels And Fire Behaviour Alexander & McRae and the *Field Handbook for Prescribed Fire Assessments in British Columbia: Logging Slash Fuels* (Trowbridge et al, 2002) unless otherwise noted.

Using planar intercept methodology, the plot is a vertical plane extending from the ground to the height of the dead and downed woody debris. For FWD, intersections can be dot tallied by size category. For LDWD and CWD, further data collection is required.

Regardless of diameter class, the following tally rules apply.

- Particles qualifying for tally include twigs, stems, branches, and stems from any trees and shrubs that are dead and downed.
    - Consider a particle downed when it has fallen to the ground or has been severed from its original source of growth.
    - Dead branches attached to boles of standing trees are NOT tallied (they are not downed).
    - Dead woody stems and branches still attached to standing brush or trees are NOT tallied.
    - Litter (cones, bark flakes, needles, leaves, grasses, forbs) is NOT tallied.
    - LDWD and CWD with the decay class of 4-5 will not be tallied (Figure 11).

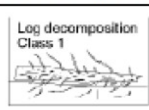
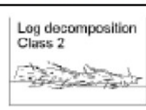
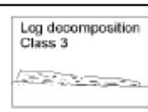
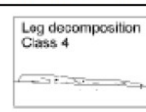
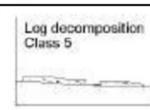
Vegetation Resourse Inventory Ground Sampling Procedures March 1997 Table 8.1					
					
	CLASS 1	**CLASS 2**	**CLASS 3**	**CLASS 4**	**CLASS 5**
WOOD TEXTURE	intact, hard	intact, hard to partly decaying	hard, large pieces, partly decaying	small, blocky pieces	many small pieces, soft portions
Other associated characteristics					
PORTION ON GROUND	elevated on support points	elevated but sagging slightly	sagging near ground, or broken	all of log on ground, sinking	all of log on ground, partly sunken
TWIGS < 3 cm (if originally present)	twigs present	no twigs	no twigs	no twigs	no twigs
BARK	bark intact	intact or partly missing	trace bark	no bark	no bark
SHAPE	round	round	round	round to oval	oval
INVADING ROOTS	none	none	in sapwood	in heartwood	in heartwood

Figure 11. CWD decay classes

- For each piece intersecting the sampling plane, it helps to visualize the central axis (Figure 12).

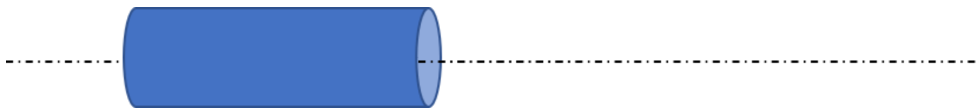


Figure 12. Representation of woody debris and the central axis.

- Intersections are tallied when the central axis lies in, or above the litter. When the central axis of the particle, where the intersection occurs, lies in the duff, the piece is NOT tallied (Figure 13).

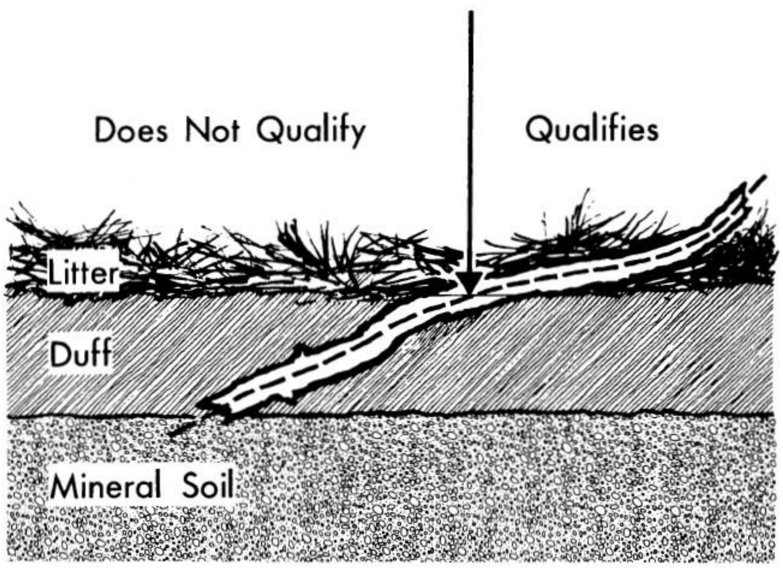


Figure 13. Pieces are tallied only when intersection lies in or above the litter (to the right of the arrow).

- A piece is tallied if the sampling plane intersects the central axis. If the plane exactly intersects the central axis, tally every other such piece.
    - If the sampling plane intersects the end of a piece, the piece must only be counted if the sampling plane intersects the central axis (Figure 14).

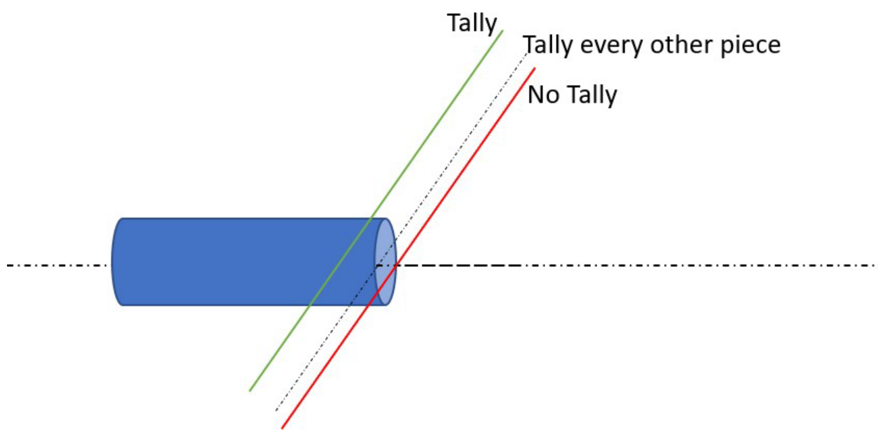


Figure 14. An intersection at the end of a branch or log must include the central axis to be tallied.

- Do NOT tally a piece that has a central axis that coincides exactly with the sampling plane (Figure 15).

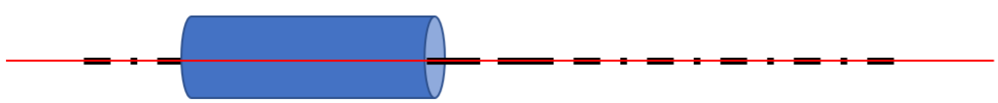


Figure 15. When the sampling plane is exactly the same as the central axis (viewed from above), the piece is not tallied.

- If the sampling plane intersects one curved piece more than once, tally each intersection, assuming all other tally rules are met (Figure 16).

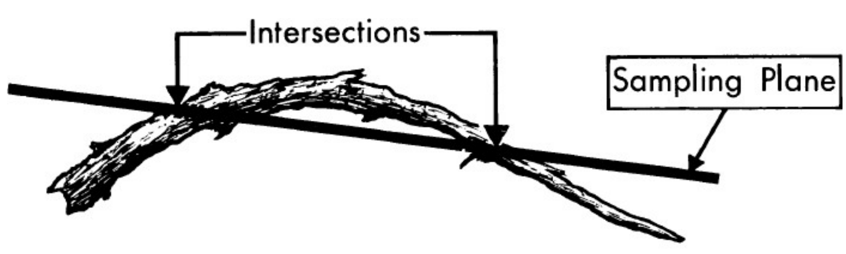


Figure 16. Count all intersections of a curved piece; in this figure there are two.

- Tally wood slivers and chunks left over from logging by visually molding the pieces into a diameter for determining size class or estimating a diameter.

- Tally uprooted stumps and roots that are not encased in dirt. Consider uprooted stumps as either tree stems or individual roots, depending upon where the sampling plane intersects the piece(s).
    - Undisturbed stumps are NOT tallied.
- Be sure to look up from the ground when collecting data; downed material can be at any height. A practical cutoff is 2 m, but in deep slash, 2 m may not be sufficient to collect data on the dead and downed woody debris.
- For areas with very heavy slash loads, modifications may be necessary. Please see the aforementioned references for available options.

Document History

Version	Change Made	Effective Date
1	Add "age" info to tables 12 and 13. Update to Section 3.13 and Appendix C to provide additional clarification. Updated text in red.	May, 2023