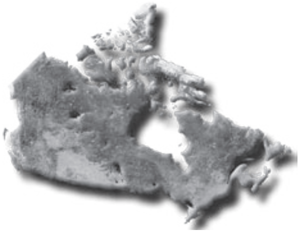

Sample plan to measure tree characteristics related to the shelf life of mountain pine beetle-killed lodgepole pine trees in British Columbia

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Mountain Pine Beetle Initiative
Working Paper 2005-1

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2004

Abstract
The main effect of a mountain pine beetle infestation is pine mortality in mature stands being disproportionately greater in the larger diameter classes. Concerns with regards to economic operability, resource management costs and future timber supply, include the rate of deterioration of killed trees, the structure and growth of the residual stands, and the establishment and quality of natural regeneration. In addition, the changes in stand structure, species composition, the amount of coarse woody debris following infestations and the resulting changes in stand microclimate, have potentially important implications for ecological succession, biomass accumulation and forest-fire interactions. All of these concerns are heightened by the occurrence of mountain pine beetle epidemics at the landscape scale (as evidenced by the current epidemic in central British Columbia) and the relatively large variation in tree mortality as affected by tree, stand, site and climatic factors. The objective of the studies is to establish baseline information on the economic and ecological characteristics of beetle damaged stands within a selection of biogeoclimatic regions of British Columbia.

Résumé
La principale conséquence d'une infestation de dendroctones du pin ponderosa, c'est que la mortalité des arbres de gros diamètre est exagérément grande dans les peuplements de pins mûrs. Le taux de détérioration des arbres tués, la structure et la croissance des peuplements résiduels ainsi que l'établissement et la qualité de la régénération naturelle représentent autant de préoccupations en regard de la capacité d'exploitation de la ressource, sur le plan économique, des coûts de gestion des ressources et de l'approvisionnement futur en bois. De plus, à la suite d'une infestation, des changements surviennent dans la structure des peuplements, dans la composition en essences, et des débris ligneux grossiers jonchent les lieux. Il en résulte un changement de microclimat des peuplements. Et tout cela a des répercussions potentiellement importantes sur la succession écologique, l'accumulation de la biomasse et les interactions entre les incendies et la forêt. Les épidémies de dendroctones du pin ponderosa à l'échelle du paysage (comme en témoigne l'actuelle épidémie dans le centre de la Colombie-Britannique) et la variation relativement grande dans la mortalité des arbres dépendant des essences, des peuplements, des conditions prévalant sur les lieux et des facteurs climatiques accroissent toutes ces préoccupations. L'objectif des études est d'avoir des données de base sur les caractéristiques économiques et écologiques des peuplements endommagés par les scolytes dans des régions biogéoclimatiques déterminées de la Colombie-Britannique.

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1. INTRODUCTION

1.1 TERMS OF REFERENCE

This project was completed by J.S. Thrower & Associates Ltd. for the Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia. The Canadian Forest Service contact was Dave Harrison, RPF. The J.S. Thrower team that prepared this plan and reviewed the document included Jim Thrower, PhD, RPF, Rod Willis, RPF, Rene de Jong, RPF, Dave Gilbert, RPF, and Hamish Robertson, RPF.

1.2 BACKGROUND

In October 2002, the Government of Canada initiated a five-year, $40-million Mountain Pine Beetle Initiative to be implemented by the Canadian Forest Service. The program aims to improve research on mountain pine beetle (MPB) outbreaks and the rehabilitation of federal and private forestlands impacted by the current epidemic outbreak in British Columbia. The Mountain Pine Beetle Initiative Epidemic Risk Reduction Research & Development (R&D) component of this program will focus on development, demonstration, and dissemination of forest management options to reduce the risk of future MPB epidemics.[1]

Enhanced R&D under the program will concentrate on epidemic dynamics (detection, mapping, and prediction), forest ecology (response and impact), and management options at the landscape and stand level. The program will also include R&D on product and market options, timber supply, and economic modeling to enhance community and manufacturing stability within sustainable forest resource management. The sample plan presented in this document is one of several projects that will be undertaken at the Pacific Forestry Centre as part of the Mountain Pine Beetle Initiative.

1.3 PROJECT GOALS

The overall goal of the Canadian Forest Service project is to develop mathematical models to predict, from a reasonable range of variables, the utility of manufacturing MPB-killed lodgepole pine into a range of products, as a function of time since attack and other covariates.

The goal of this project is to develop the sample design to guide the Canadian Forest Service in collecting the data to build those models. These data will include information on tree, log, and wood characteristics related to the shelf life of beetle-killed lodgepole pine trees in British Columbia. The specific objectives to achieve this goal were to:

1. Work with Canadian Forest Service staff to ensure the design meets their R&D needs and link with other forest service projects where possible.
2. Develop the sample design while considering Canadian Forest Service timelines, budgets, and the potential use of the data.
3. Document the sample design and the plan for pilot testing and eventual application.

This project is the first of several major steps required to achieve the Canadian Forest Service objectives of collecting and analyzing data, and building and applying shelf life information and models (Figure 1).

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[1] The Canadian Forest Service website for this program is: http://mpb.cfs.nrcan.gc.ca/initiative_e.html.

This project provides the sample design and sampling plan for the shelf life project. The next two phases are an interactive process of data collection and sampling plan re-evaluation, with the final phase being data analysis, modeling, and application of the information. Related projects are listed in Appendix 1.

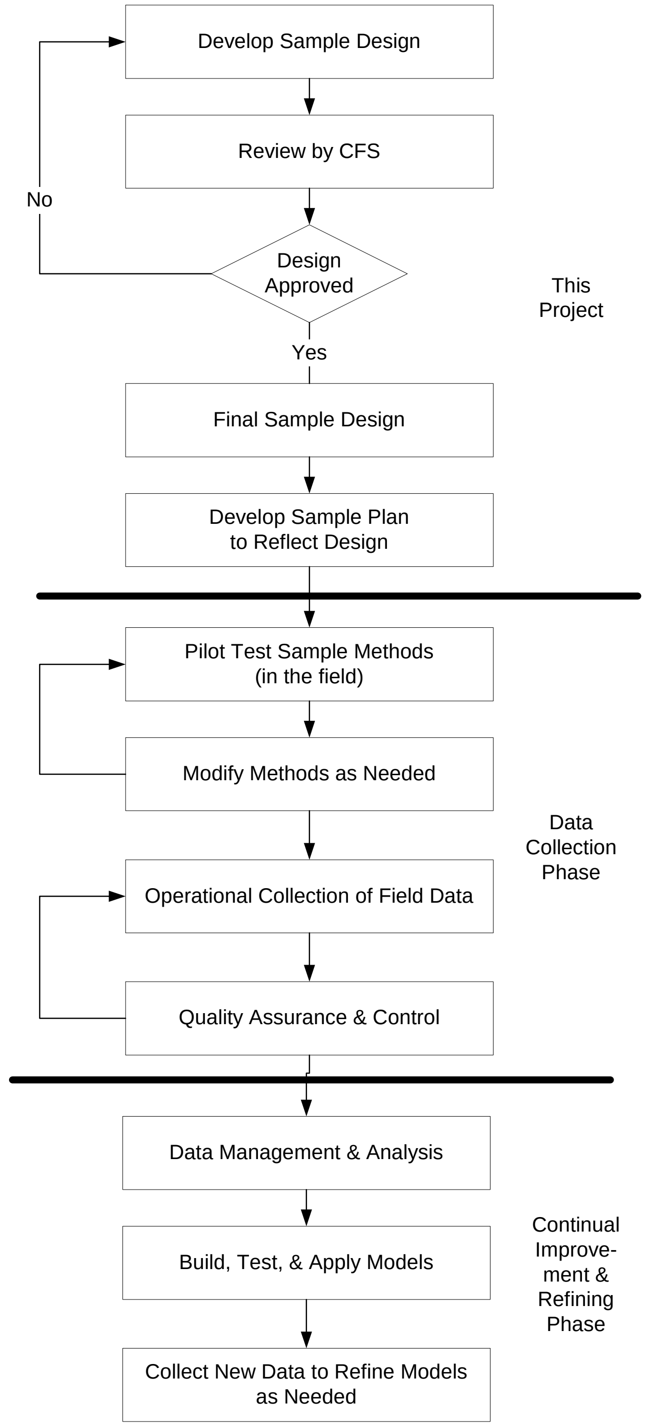

Figure 1. Conceptual flow of project.

1.4 DEFINITIONS

Terms commonly used in this document that require clarification include:

Shelf Life – The term *shelf life* is most often used in reference to a food or product that degrades over time, to a point where it is no longer salable, consumable, or suitable for its intended purpose. In this document, our definition of shelf life is the time that MPB-killed lodgepole pine wood is suitable for a specific use. Therefore, the shelf life of the wood is inextricably linked to the product of interest. For example, the shelf life of beetle-killed wood is different for conversion into peelers, sawlogs, J-grade lumber, domestic lumber, and oriented strand board.

Sample Design – A sample design describes fundamental elements of a sampling scheme such as defining the target population, sample population (or sample frame), how the sample will be selected, and the intended use of the data.

Sample Plan – A sample plan describes the details of how the design is implemented and how data are collected.

2. SAMPLE DESIGN

2.1 OVERVIEW

The sample design is to purposively select and measure lodgepole pine trees from a range of time since death (by MPB attack), geographic area, ecological conditions, and tree size. The focus of the sample is to collect information to build mathematical models to predict key attributes related to the shelf life of beetle-killed trees as they relate to different end uses, and to compare differences in these attributes over geographic areas, ecological conditions, and tree sizes.

2.2 SAMPLING OBJECTIVES

The objective of the sample is to measure a variety of characteristics related to the deterioration of wood over time in beetle-killed lodgepole pine trees over a range of conditions throughout British Columbia.

2.3 ANTICIPATED USE OF THE DATA

We anticipate the primary use of the data will be to build models to predict log and tree characteristics related to the shelf life of beetle-killed trees. Anticipated secondary uses will be to test hypotheses about these characteristics and to provide information for other research.

Build models – to predict the characteristics of individual trees and logs related to the shelf life of MPB-killed wood. These models could be applied at the stand level by compiling the estimates for the individual trees. The predicted characteristics, and subsequent analyses, will support tactical and strategic planning on how to maximize the use and value of beetle-killed wood. The models could also be used to schedule harvesting of individual stands and for strategic fibre planning for large areas.

We anticipate that the primary analytical method will be multiple linear regression to predict the level of different response variables using the predictor variables. For example, the model to predict the number of checks in the butt log of an beetle-killed lodgepole pine tree could be:

$$Y = b_0 + b_1 \textit{(yrs since death)} + b_2 \textit{(DBH)} + b_3 \textit{(moisture regime)} + b_4 \textit{(BGC unit)} + e$$

where *Y* is a specific attribute (e.g., number of checks) for a single tree or portion (log) of tree and b_i are parameters of the model to estimate using regression methods. Preliminary analysis may show that one or more of the predictor variables are not significant and thus would not be included in the final predictor equation. Likewise, analyses may show that some other variable collected in sampling, but not specifically included in the sample matrix (e.g., aspect, stand structure elements, etc.), may be significantly related to some elements of shelf life for some products.

Test hypotheses – about how some characteristics related to shelf life vary across geographic, ecological, and tree-size gradients. The results of these tests will help further develop the general understanding of shelf life and predictive models. This knowledge will help design further R&D in this area. The tests can be done comparing means and variances (t-tests and analysis of variance [ANOVA]; requiring assumptions of randomness, etc.).

Provide information for other research – the goal is to share information and create efficiencies and synergies where possible. The information from this project will be of interest to other researchers. For example, we expect that the relationship between external and internal characteristics of the MPB-killed trees can be used by the British Columbia Ministry of Forests to develop guidelines for call-grading and valuation in the province's interior. The utility of these data for use by other researchers will be encouraged by communicating these plans to other groups completing research for the Canadian Forest Service as part of the larger initiative (Appendix 1).

2.4 Target Population

The target population is all existing and future MPB-killed lodgepole pine trees in British Columbia. This is the area where the models built from the data will ultimately be applied.

2.5 Sample Population

The sample population is all existing MPB-killed lodgepole pine trees in British Columbia within the range of the attributes included in the sample matrix (discussed below).

2.6 Sample Matrix (Predictor Variables)

Samples will be taken from a response surface including the covariates of:

1. Time since death:
    a) Red attack – no needle loss (1 year since death).
    b) Red attack – some to almost all needles lost (2–4 years since death).
    c) Grey attack – all needles lost, some fine branches lost, some trees starting to fall (5–7 years since death).
    d) Grey attack – all fine branches lost, many trees starting to fall (8+ years since death).
2. Soil moisture regime (SMR) (relative to the biogeoclimatic (BGC) unit):
    a) Wet.
    b) Mesic.
    c) Dry.
3. Tree diameter (at breast height [1.3 m]; DBH):
    a) 12.5–22.5 cm.
    b) 22.6–32.5 cm.
    c) 32.6+ cm.
4. BGC unit:
    a) SBS (northern interior).
    b) SBPS (Chilcotin).
    c) MS and IDF (southern interior).

This distribution gives a target sample matrix of 4 x 3 x 3 x 3 = 108 strata where samples are targeted. These will be the covariates used as predictor variables in equations developed from the sample data.

Location of sample sites within the three geographic areas should also consider geographic distribution within that larger target area, and a range of aspects. This is not a specific part of the sample matrix, but is an important part of the distribution of samples across a range of conditions.

2.7 Sample Size

The goal is to sample 10 trees from as many of the 108 sample matrix cells as possible. The total 1,080 trees will not be achieved because some combinations of the matrix variables do not exist or will be difficult to locate.

2.8 Sampling Unit

The sampling unit is individual trees with measurements taken from stem analysis discs cut from the entire length of the stem.

2.9 Variables of Interest

The following variables of interest will be collected for each stem analysis disc (taken at each 2.5 m section of the bole):

Checks:

1. Number of checks.
2. Depth of checks.
3. Width of check.
4. Azimuth (orientation) of checks.

Spiral checking:

5. Presence or absence.
6. Degree of twist.

Blue stain:

7. Depth of stain.
8. Severity of stain.

Decay:

9. Location of decay.
10. Type of decay.
11. Extent of decay.

Moisture Content:

12. Moisture content.

2.10 Inference

The scope of inference is the target population, which is all MPB-killed lodgepole pine trees in British Columbia. The target population changes each year as the infestation expands, thus the ultimate target population will not exist until the infestation has subsided. Therefore, applying models developed from these data assumes that the relationship between predictor and response variables is the same in the areas that were sampled (from the sample population) as those in the area that could not be sampled (the areas where the beetle will expand into over the next few years). We believe this is a reasonable assumption, but do not know with certainty. We therefore suggest that this assumption is tested at a later date after the equations are developed and the spread of the beetle population has slowed or stopped.

2.11 Link with Existing Programs

We are not aware of any existing data collection programs that could be used in this initiative. The major problem is that sampling for shelf life in this study requires destructive sampling of trees, which should not be done in the Government of British Columbia's Vegetation Resources Inventory (VRI), Change Monitoring Inventory (CMI), Permanent Sample Plot (PSP), or the Government of Canada's National Forest Inventory (NFI) plots.

2.12 Linkage with Future Programs

This sampling program focuses on a core purpose. The sample will be extensive, but not exhaustive. However, the resulting data may be of use for other applications and research initiatives that were not directly addressed by this project.

3.

3. SAMPLE PLAN

3.1 Overview

The general steps to sample MPB-killed lodgepole pine trees from each geographic (BGC unit) area is:

1. Locate general sample areas.
2. Locate sample trees and plots within those areas.
3. Complete stand measurements in the sample plots and around the sample trees.
4. Complete external measurements on the sample trees.
5. Fall sample trees and remove stem analysis discs.
6. Complete detailed measurements of discs and section bolts.

3.2 Locate General Sample Areas

The first step is to locate MPB-killed stands across the widest geographic range as possible to fill the sample matrix. This will be done by repeating the entire sample matrix in each of three different geographic areas, and attempting to distribute sample locations within those areas where possible. Individual trees will then be felled and measured from the sample areas (discussed in the next section).

We expect the sample matrix will be filled with varying success in the different geographic areas, and that locating sample areas will become increasingly difficult as the sample matrix is filled with the most common stand types. The success in filling the matrix will not be known until after some analyses are complete, such as the number trees in the different age classes since death (which will not be known for many samples until lab analyses and dendrochronology are completed to more precisely estimate time since death).

There are several ways to locate stands potentially suitable for sampling. There is considerable work that can be done in the office to help identify candidate areas but, ultimately, stand suitability must be assessed in the field. It is logical to start by identifying areas with the oldest attack, as they will be hardest to find and hardest for which to ascertain time since death. Some older attack areas were not salvaged and these can be identified with the help of local practitioners in various places throughout the province. Some of these areas are in parks, protected areas, riparian zones, or adjacent to salvaged areas.

Potential sources to locate beetle-attacked tree and stands include:

1. Local British Columbia Ministry of Forests practitioners.
   Many staff with the Ministry of Forests have history and experience working in MPB detection, salvage, and treatment. These include forest health technicians, other district staff, and regional pathologists. A good source of information might be trees marked for fall-and-burn by district staff that were not treated. Some green attack trees around the province were identified for

fall-and-burn, but were not treated. The locations of these trees were often mapped, trees measured for diameter, and marked in the field (e.g., with flagging tape and paint). Neighboring older attacked trees were also sometimes marked and information recorded that may help estimate time since death. These trees may provide the best information for this study, as their time since attack (death) may be known with a high degree of certainty.

2. Local industry practitioners.
   Many industry staff also have history and experience working in MPB detection, salvage, and treatment. These people include woods managers and other staff, probe contractors, and fall-and-burn contractors. Many industry staff remember areas where beetle-attacked trees remained unsalvaged and the year in which attack occurred. Some of these industry staff are now retired, but would be a valuable source of information.

3. British Columbia Ministry of Forests information.
   Information available from the Ministry of Forests includes maps, photos, orthophotos, and GPS locations of beetle-killed trees acquired for annual overview and beetle mapping processes.

An additional concern in locating stands for sampling is Workers Compensation Board (WCB) regulations regarding working in areas with overhead hazard. The field crew must include a WCB-certified faller and danger tree assessor. There may be other WCB concerns that must be addressed in falling trees in these areas with high proportions of dead trees. Crews should also check with local Ministry of Forests staff to determine where and to avoid areas that may have been treated with the insecticide, MSMA.

3.3 Locate Sample Plot

The goal is to locate sample plots across the widest possible geographic range (within each BGC area) while maximizing efficiency (i.e., filling the sample matrix as quickly as possible). This will involve identifying trees in small areas of stands where as many trees as possible can be sampled from one 400 m^2 plot (11.28 m radius). This could include sampling trees from the range of diameter at breast height (DBH) and years since death in a single plot, and possibly on different SMRs. Maximizing the number of trees in a plot will help reduce overall cost and increase the chance of sampling the full matrix. However, restricting sampling to one tree for each sample matrix cell in each plot will help distribute the samples geographically. Sample plots can then be located in different geographic areas and on different aspects where possible (e.g., north and south aspects).

The process to identify and locate a sample plot is:

1. Identify trees in a 400 m^2 (11.28 m radius) area to meet different matrix cell requirements.
   a) Estimate diameter and SMR with visual estimates.
   b) Estimate years since death using foliage and bark characteristics (Appendix 3).[2]
2. Mark candidate sample trees (temporarily) with flagging tape.
3. Establish a temporary 400 m^2 plot with its center in the middle of the potential sample trees.
4. Confirm that plot is the best location to sample the most trees.

[2] Exact time since death will not be known in most cases in the field, and may only be known after lab analysis of tree ring patterns.

3.4 Establish Plot & Mark Trees

The procedure to establish the sample plot is:

1. Mark plot center with steel stake.
2. Mark witness tree for plot center with metal tag.
3. Demarcate plot into four quadrants (on cardinal directions).
4. Mark stem analysis trees:
   a) Mark sample trees with sample number (use paint).
   b) Use a unique tree number in each plot.
   c) Record sample number and sample matrix characteristics on tally sheet.
5. Mark height sample trees:
   a) Select three lodgepole pine trees of different heights (other than the stem analysis sample trees).
   b) Mark as height sample tree (use paint). A unique number is not required.

3.5 Stand Measurements

The procedure to measure stand and site characteristics in the plot is:

1. Site information:
   a) Record UTM coordinate (post-processed GPS data).
   b) Map plot features (creeks, rocks, timber types, slopes, etc.).
   c) Map site series groups (wet, mesic, dry).[3]
   d) Map slope, position, and aspect.
   e) Record elevation.
2. Increment cores for dendrochronology sequencing:
   a) Select nine live lodgepole pine trees—three from the range of diameter and height classes in each of the dominant, codominant, and intermediate crown classes. These trees can be taken outside the plot.
   b) Where there are no live lodgepole pine trees, select trees of another species (take appropriate notes).
   c) Mark these trees with flagging tape as "dendro samples".
   d) Extract increment core from breast height (BH). Move location up or down if BH is at a branch whorl. The core must be perfectly clean, even, and contain the pith (this will require special training). For asymmetrical trees, take core at a position intermediate between the long and short axes.
   e) Mark core with indelible pencil and store in a straw marked with tree number, date, etc.
3. Site index information:
   a) Establish a 100 m^2 (5.64 m radius) plot at the sample point.

[3] These site series groups must be established for each biogeoclimatic ecosystem classification (BEC) subzone before field sampling begins.

b) Select the largest diameter suitable tree[4] of each species as a site tree.

c) Mark the tree with flagging tape as a “site tree”.

d) Record the height and BH age of these trees.

4. Big tree information (by quadrant) (trees ≥ 12.5 cm DBH).

   a) Use the 11.38 m radius plot.

   b) Start measurements in the first quadrant (NE corner) and proceed clockwise through the plot.

   c) Record for each tree:

      i) Species.

      ii) Tree class (live/dead)

      iii) MPB-attack status (green, red, or grey attack).

      iv) Diameter at breast height (DBH; in centimetres).

      v) Relative crown class (dominant, codominant, intermediate, suppressed).

      vi) Stem analysis sample tree number (where applicable).

      vii) Height (m) for height sample trees.

5. Small tree information (trees ≥ 1.3 m in height and < 12.5 cm DBH):

   a) Establish a 3.99 m radius plot at plot center.

   b) Demarcate along cardinal directions (as with big tree plot).

   c) Record measurements in same manner as for the big tree plot (quadrant 1 through 4).

   d) Record for each tree:

      i) Species.

      ii) Tree class (live/dead).

      iii) DBH.

      iv) Beetle-attack status (green, red, or grey attack).

6. Regeneration information (trees <1.3 m in height):

   a) Use 3.99 m plot for small trees.

   b) If the total number of trees is estimated to be more than 100, split the plot and sample one-half or one-quarter.[5]

   c) Record for each tree (by quadrant):

      i) Species.

      ii) Height (visually estimated).

7. Coarse woody debris information:

   a) Use VRI procedures.

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[4] A tree suitable to estimate site index must not be suppressed or have any damage on the stem that impacted height growth.

[5] Procedure to split the regeneration plot is: a) split the plot in half along the N–S and E–W divisions so that the two half-plots each contain about the same number and condition of regenerating trees; b) flip a coin to select the half-plot to measure; c) if the half-plot is estimated to contain more than 100 trees, flip the coin again to select one of the quarter plots.

b) A synopsis of methods is:
   i) Locate first 24 m transect at random bearing from plot center.
   ii) Locate second 24 m transect at 90^{o} to first.
   iii) Measure coarse woody debris larger than 7.5 cm in diameter along transects.
   iv) Include all fallen and leaning dead trees.

3.6 STANDING TREE MEASUREMENTS

The procedure to measure sample trees prior to falling is:

1. Prepare tree for measurements:
   a) Mark BH and stump height (0.3 m) with paint.
   b) Mark north and south with paint (a line from stump to BH).
   c) Mark tree number (below BH) with paint.
2. Take digital picture of tree and stand.
3. Record external tree characteristics:
   a) DBH (cm).
   b) Proportion of bark intact at BH (%).
   c) Foliage conditions:
      i) Color.
      ii) Proportion remaining (10% classes).
   d) External check characteristics (by 2.5 m logs):
      i) Bark:
         (1) Proportion intact (%).
      ii) Checks:
         (1) Number.
         (2) Average width (mm).
         (3) Average length (m).
      iii) Spiral grain:
         (1) Degree of twist (cm/m).
   e) Fine branches. Classify[6] the amount of fine branches (that hold needle fascicles) remaining as:[7]
      i) 100–75% remaining.
      ii) 74–1% remaining.
      iii) None remaining.
   f) Call-grade stem.[8]

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[6] Taken from Newberry, J.E., Lewis, K.J., and Walters, M.B. 2004. Estimating time since death of *Picea glauca* x *P. englemanni* and *Abies lasiocarpa* in wet cool sub-boreal spruce forest in east-central British Columbia. Can. J. For. Res. 34: 931-938.

[7] This may be best done or confirmed after the tree is felled (if branches fall off when the tree hits the ground).

3.7 Fallen Tree Measurements

The procedure to fall sample trees and to cut bolts and discs is:

1. Fall tree for destructive sampling:
   a) Fall tree below 0.3 m mark if possible; if not possible, fell above mark.
   b) Fall tree so as to not interfere with other sample trees.
   c) Adhere to all WCB regulations.
2. Measure crown characteristics:
   a) Total height (ground to tip). If top is broken (before falling), measure to break and record diameter and proportion of bark intact at break. If tree breaks from falling, reconstruct the pieces and take measurements accordingly.
   b) Height to base of former live crown (if discernable).
3. Mark disc locations:
   a) Mark tree at the stump height (0.3 m) and every 2.5 m thereafter.
   b) Mark north (or south) on tree at each disc location.

3.8 Disc Measurements

1. Cut stem analysis discs:
   a) At marked locations, cut disc about 3–5 cm thick (large enough to not split and dry during transport and measurement).
   b) Move location of cut up or down from target height to avoid branch whorls or stem deformities.
   c) Record target and actual height (m).
   d) When discs fall apart during cutting and cannot be reconstructed for measurement, cut another disc within 30 cm, provided it is the same size and characteristics. Note the change in actual disc height on field card.
   e) Do not take discs at top of tree for stem diameters that are less than 10 cm.
   f) Mark discs on the lower side (where measurements will be taken). Note tree number and section height.
2. Cut disc from tree at BH:
   a) Mark as BH disc with tree number. The disc is collected for tree-ring sequencing, not detailed check measurements.
3. Prepare discs for transport to lab.
   a) Immediately store discs in burlap sacks, and place in a cool and shady place.

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[8] There are currently no definitions of call-grades related to mountain pine beetle-killed trees (the information from this project will help develop those definitions). However, interim grades should be developed for this project and the correlation between these grades and internal characteristics can be analyzed after the stem analyses are complete. These grades should be developed as a special project or as part of pilot testing these methods. Other measurements in this project are recorded by 2.5 m logs, thus this may also be the appropriate log length for call-grading.

b) Label sacks with tree and disc numbers.

c) Place in cold storage within 24 hrs (if possible).

3.9 Bolt Measurements

Measurements for each 2.5 m log include:

1. Spiral grain:
   a) Degree of spiral grain (cm/m).
   b) On older trees, this may be seen by visible checks.
   c) Bark may have to be removed where intact.[9]
2. Secondary insect attack:
   a) This will include *ips*, ambrosia, turpentine beetles and other insects.[10]

3.10 Lab Measurements

The lab procedures to take detailed measurements of the sample discs will be confirmed in the spring of 2005. Forintek is developing a machine-vision and digital image-analysis system that may provide a less costly and more consistent method for some disc measurements described here. Discs could be processed at Forintek or at a temporary lab near the sampling areas using the Forintek software.

Preliminary manual methods to take the measurements in the lab are:

1. Label disc:
   a) Mark four quadrants (cardinal directions).
   b) Label north.
   c) Place the disc so the tree number is visible on the side from which photo will be taken.
2. Take high-resolution digital photo (to scale, using copy stand). This is required as a visual record of the disc, and may link with Forintek's image-analysis software.
3. Measure on each disc:
   a) Diameter (cm).
   b) Bark thickness.
   c) Proportion of bark intact.
   d) Moisture content (MC). Measure at in the middle of the sapwood and heartwood at north and south directions.
   e) Blue stain:[11]
      i) Area and width of stain.

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[9] This requires pilot testing to develop best methods.

[10] More work is needed to better describe the secondary insects that may be encountered and the level of attack.

[11] Paprican (Paul Watson) is working on a method to quantify the degree of blue stain using color (intensity, hue, etc.) and infrared characteristics. The degree of blue stain is important in pulping, because it impacts the bleaching process. The methods used to measure blue stain should be confirmed with Paprican prior to operational implementation.

    ii) Pattern of stain.
    iii) Degree of stain.

f) Checks (start at 360^{o} and proceed clockwise):
    i) Azimuth.
    ii) Depth (average of a straight line).
    iii) Width (at surface).
    iv) Pattern.[12]

g) Decay:[13]
    i) Location of decay.
    ii) Area and width of decay.
    iii) Type of decay.
    iv) Assessment of whether or not present before MPB attack.

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[12] Develop codes through pilot testing.

[13] One option is to use the provincial VRI Net Volume Adjustment Factor (NVAF) methods to identify and map decay (NVAF field manual sections 5.4.6.13 [page 45] to 5.6.4.15 [page 49]). The other option is to use a system under development by Paprican that estimates the extent and intensity of stain from digital image analysis of infrared scanning data. Detailed information on decay may be important for export potential, but may require more detailed analyses than can be completed with this project.

APPENDIX 1 – RELATED CANADIAN FOREST SERVICE MOUNTAIN PINE BEETLE PROJECTS

The shelf life project is only one of several underway or planned by the Canadian Forest Service. Some of these projects include:

1. **Shelf life.**
   This project is part of the overall shelf life project.
2. **Lumber recovery.**
   This work is approved and will be completed by Forintek. (CFS initiative 1.B.2).
3. **Pulping characteristics.**
   This work is approved and will be completed by Paprican. (CFS initiative 1.B.3).
4. **Ingress and stand dynamics.**
   This work is proposed by a graduate student at the University of Northern British Columbia. The work would sample older MPB-attacked stands to examine differences in understorey characteristics. (CFS initiative 1.A.3).

APPENDIX 2 – WOOD CHARACTERISTICS RELATED TO SHELF LIFE

We discussed the issue of shelf life with product-supply managers from several processing plants throughout the British Columbia interior. The following characteristics related to MPB-killed lodgepole pine wood were considered important in relation to shelf life:

Lumber

- Number of checks.
- Depth of checks (depth is less important if cracks are longitudinal along log).
- Spiral checks are generally reported as unacceptable.
- Orientation of checks (e.g., longitudinal versus spiral).
- Depth and degree of blue stain. Acceptability of stain is market and product specific. Stain seems acceptable for domestic markets, but not for export to Japan.
- Years since attack (one company reported purchasing logs no older than 2–3 years since attack).

Plywood

- Presence of checks. Few and shallow surface checks are acceptable if they can be removed quickly during peeling.
- Depth of checks.
- Moisture content of logs. Excessively dry logs cause knife chatter, which causes skips and an uneven face on the veneer. Log moisture content is highly variable and unpredictable.

Poles

- Presence of cracks, checks, or breaks. No checking is acceptable other than surface cracks that can be removed during peeling.
- Depth and degree of blue stain. Only minor blue stain is permitted. Minor stain is defined as no more than one quarter of the end surface area or sapwood rings.

House Logs

- Natural logs:
  - Number of checks.
  - Depth of checks (cannot exceed one-half the diameter).
  - Orientation of checks (excessive spiral check is not acceptable).
- Logs for lathe or dowels:
  - Similar to above but depth and width governed by final manufactured log diameter.

Oriented Stand Board

- Moisture content (no apparent disqualifying physical features, but a steady diet of dry wood requires installation of modified lay up [orienting] bars to address number of smaller flakes and pins).
- Blue stain may be an issue if it results in not meeting grade standards associated with water retention and expansion.

Pulp

- This is under review by Paprican and member companies. Researchers feel there may be significant deterioration after 3–5 years due to drying and shrinkage of cell walls with accompanying decline in fibre strength.

APPENDIX 3 – TREE CHARACTERISTICS RELATED TO TIME SINCE DEATH

The guidelines to estimate years since death in this project are:

Years Since Death	Characteristics
1 yr	red attack – no needle loss.
2–4 yrs	red attack – ranges from some to almost all needles lost.
5–7 yrs	grey attack – all needles gone, some small branches lost, some trees falling.
8+ yrs	grey attack – all small branches lost, many trees falling.

Other researchers have given guidelines to estimate time since death as:

Tegethoff et al. (1977) noted for southeastern Idaho:

Years Since Death	Characteristics
1–3 yrs	Needles bright orange to straw-colored to grey. Some foliage lost.
3–5 yrs	No needles. Most small twigs supporting needle fascicles lost.
5+ yrs	No small twigs. Bark peeling.

Cole and Amman (1969) noted for western Wyoming:

Years Since Death	Characteristics
1 yr	Needles bright orange to straw-colored.
2 yrs	Needles dull orange. Most foliage retained.
3 yrs	Needles dull orange to grey. Most foliage lost.
4 yrs	No needles. Most small twigs supporting needle fascicles lost.
5+ yrs	Bark peeling.

Tegethoff, A.C., Hinds, T.E., Eslyn, W.E. 1977. Beetle-killed lodgepole pine are suitable for powerpoles. For. Prod. J. 27(9): 21-23.

Cole, W.E. and Amman, G.D. 1969. Mountain pine beetle infestations in relation to lodgepole pine diameters. Res. Note INT-95. Ogden, UT: U.S. Department of Agriculture, forest Service, Intermountain Forest and Range Experiment Station; 7 pp.

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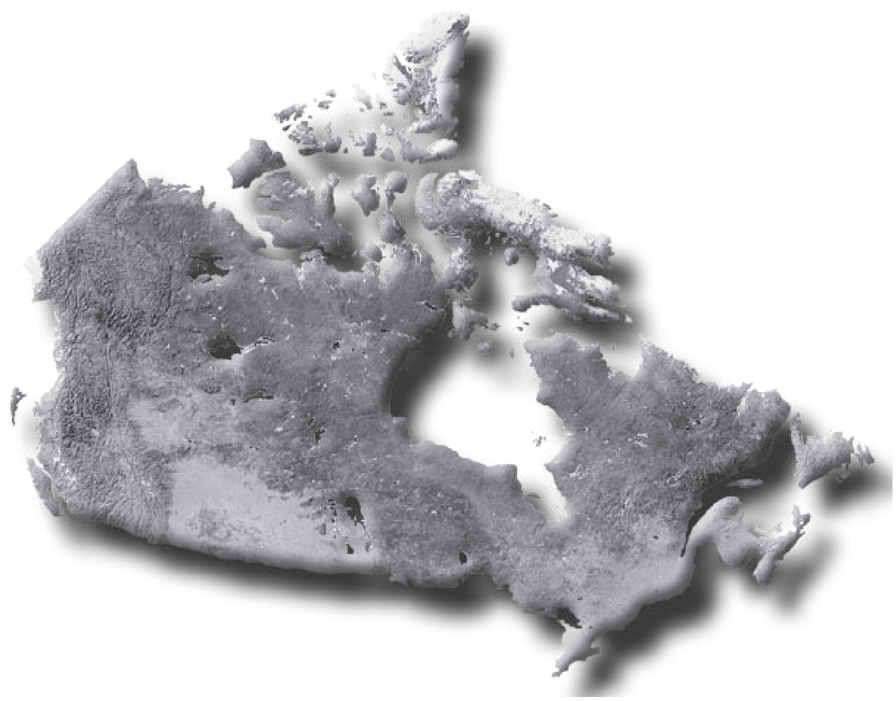

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