FREP

REPORT #11

FOREST AND RANGE EVALUATION PROGRAM

March 2007

A Timber-Focussed Evaluation Of Partially Harvested Areas: Are Stand Conditions Consistent With Government's Objectives For Timber?

Sustainability of Forest and Range Resources Through Science and Stewardship

Library and Archives Canada Cataloguing in Publication Data.

A Timber-Focussed Evaluation of Partially Harvested
Areas: Are Stand Conditions Consistent with Government's
Objectives for Timber?

(FREP report ; #11)

Issued also on the Internet.

Citation:

British Columbia Ministry of Forests. 2007. A Timber-Focussed Evaluation of Partially Harvested Areas: Are Stand Conditions Consistent with Government's Objectives for Timber? B.C. Min. For. Range, For. Prac. Br., Victoria, B.C. <http://www.for.gov.bc.ca/hfp/frep/publications/index.htm>

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List of Acronyms

FPB	Forest Practices Branch
FREP	Forest and Range Evaluation Program
MOFR	Ministry of Forests and Range
TASS	Tree and Stand Simulator
BEC	Biogeoclimatic Ecosystem Classification
IDFdm	Dry Mild Interior Douglas Fir
ICHmw	Moist Warm Interior Cedar-Hemlock
MSdk	Dry Cool Montane Spruce
ESSFdk	Dry Cool Engelmann Spruce-Subalpine Fir
NAR	Net Area to be Reforested
PPSWP	Probability Proportional to Size With Replacement
UTM	Universal Transverse Mercator
FAIB	Forest Analysis and Inventory Branch
DFP	Deviation From Potential
RTEB	Resource Tenures and Engineering Branch
SPF	Spruce, Pine, Fir
Pli	Lodgepole pine
FVS	Forest Vegetation Simulator
OAF	Operational Adjustment Factor
PAS	Permanent Access Structure
NSR	Not Satisfactorily Restocked
AAC	Allowable Annual Cut
CRIT	Coast Region Implementation Team
SU	Standards Unit
SPAR	Seed Planning and Registry Information System

Executive Summary

In 2006, the ministry's Forest and Range Evaluation Program (FREP) initiated a project to develop methods to evaluate in partial-cut areas the degree to which government's objectives for timber (as specified in the Forest and Range Practices Act, FRPA) were being met. Methods for both routine and intensive evaluation were developed and then used in a trial evaluation. This report provides the 2006 draft version of the routine and intensive evaluation procedures and presents the results of their application in partial-cut stands in a management unit in south-eastern BC.

Although the FRPA objectives set by government for timber include competitive delivered wood costs and the opportunity to exercise harvesting license rights, the evaluation focuses solely on the third objective - "to maintain or enhance an economically valuable supply of commercial timber." Because the FRPA objectives set by government for timber are so broad, and some components of them are not well suited to FREP evaluation, a portion of the objectives is not addressed by the evaluation procedure.

The routine evaluation procedure classifies a sample point into one of seven condition classes based on field observation of stocking level, the amount of poor quality retained trees, and the ratio of value to volume removal. The method provides the evaluator with an interpretation of the class in terms of the degree of consistency with government's objectives for timber. In addition, surveyors using the routine evaluation procedure assess 17 other factors that could impact the achievement of the FRPA timber objective.

At a sample point, surveyors using the intensive evaluation procedure collect detailed measurements on stumps, live and dead standing trees, and fallen trees. From these measurements, the following indicators are computed:

- the level of stocking,
- the volume of merchantable dead or down wood,
- the volume of live pine remaining,
- the volume of non-pine harvested,
- the degree of site occupancy by poor quality trees, and
- the value/volume removal ratio.

The observed levels of these variables are examined, and compared to relevant benchmark levels where available, to support judgements of the degree to which field conditions are consistent with government's objectives for timber.

The intensive evaluation procedure also employs stand growth simulation to forecast volume development at the sample location and compare it to the volume trends predicted under two management alternatives - clearcut and no harvest. The forecasts provide insight into the implications over time of the current condition. The comparisons provide benchmarks against which the volume trends predicted under current conditions can be assessed for degree of consistency with government's objectives for timber.

In 2006 the newly developed evaluation methods were applied in a test evaluation. In the test, survey crews collected intensive evaluation data and made routine evaluation assessments at 25 sample points. The sample points were randomly located within a population of 677 hectares that had been partially harvested from 2000-2002 within a management unit in south-eastern BC. This sample design generates a statistically valid, representative sample of the population and permits inferences back to the whole population.

Surveyors using the routine evaluation procedure classified 22 of 25 sample locations as highly consistent with government's objectives for timber. Of the eight overstory factors that were assessed, the most significant concerns arose over the growth potential of retained trees, the species diversity in the residual overstory, the risk of windthrow, and the harvesting of trees that were not threatened with imminent death. Of the nine understory factors assessed, the most significant concerns arose over understory tree species diversity and the interference of poor quality trees with the growth of crop trees.

All but one of the intensive evaluation indicators were at levels considered to be consistent with government's objectives for timber. An average 125 m3/ha of non-pine species was harvested during the partial cutting. This was considered not consistent with government's objectives for timber given the beetle outbreak and the associated importance of focussing the harvest on pine and conserving non-pine volume for future harvest. Predicted trends in volume development for the current stands, when compared to the trends predicted for two alternative management scenarios, were judged to be consistent with government's objectives for timber. The simulations predict that over the next 50 years standing volume would be greatest if the

areas were not harvested. However, under the no harvest management option, considerable volume would be lost to beetle attack. When harvested volume is considered and added to standing volume, the observed partial cutting provides the greatest cumulative volume over the next 50 years.

Taken together, the full suite of indicators suggest that the conditions in the partially harvested population are generally consistent with government objectives for timber. However, the FRPA timber objective can be more fully realized by:

i) decreasing the harvest of non-pine species,

ii) increasing the species diversity of (desirable) understory trees,

iii) among understory trees, decreasing the frequency of poor quality trees interfering with the growth of superior crop trees, and

iv) when re-harvesting partial-cut areas, prioritizing for overstory removal those areas with predicted growth rates considerably below that of clearcuts.

As briefly mentioned in this executive summary, and discussed at length in the body of the report, many cautions and limitations apply to the results, conclusions and recommendations from this pilot evaluation.

Many components of the evaluation procedures require, or provide opportunities for, future refinement and development. The routine evaluation method should be completely revised to create one that evaluates conditions over an entire cutblock. In addition, FREP should consider developing methods that adopt a landscape- or forest-level perspective on the degree to which current practices are achieving government's objectives for timber. The test evaluation identified a need to improve some of the field procedures, especially recognizing stump species. Better training should be provided to field crews to help them understand the routine evaluation questions. Other stand growth models, such as TASS or SORTIE, could be used, and if they were used some changes to the intensive evaluation field procedures would be required. There are opportunities to enhance the evaluation by integrating other data sources into the evaluation – e.g., planting records, timber cruise information, etc. The benchmarks and critical values used in the evaluation should be reviewed and information assembled to refine and further substantiate them.

The evaluation protocols reveal that some aspects of quality and excellence in partial-cut timber management are not incorporated in the typical partial-cut stocking standard. When providing training or guidance documents related to partial-cut stocking standards, or the silvicultural aspects of partial cutting, ministry staff should endeavour to communicate all of the dimensions of excellence in partial harvest timber management that are identified in the FREP partial-cut timber-goal evaluations.

With some additional data collection, and establishing sample locations consistent with the appropriate sample design, the measurement protocol can be used to estimate differences among populations, track trends in indicator values over time, or look for associations with auxiliary variables.

There are many limitations to the routine and intensive evaluation approaches documented here. Alternative formulations of the government's objectives for timber are possible and could lead to very different evaluation methods, indicators, and possibly, results. Evaluations such as this one that are designed to compare outcomes to a stated goal can not definitively identify the cause of any observed outcome. Thus, the evaluation cannot conclusively identify to what degree the observed conditions are due to good planning, experienced staff, particular treatments and practices, or good fortune. By itself the evaluation does not identify the most feasible, cost-effective changes that will further the achievement of the objective. Nor does it determine if the observed conditions represent the optimal balancing of government's objectives for timber with other management objectives. Rather than claim to be the final arbiter of these debates, the evaluation aims to contribute to these discussions by providing high quality, defensible estimates of indicators that portray the state of the timber goal.

Ministry and licensee staff, and other interested parties, need to develop some familiarity with FREP evaluations and learn how to use them as part of the broader process of assessing the sustainability, and driving the continual improvement, of forest management in BC.

ACKNOWLEDGEMENTS

We gratefully acknowledge the following individuals for their review comments, suggestions for improvements, or assistance with the project: Brian Amies, Ralph Archibald, Andre Arsenault, Bryce Bancroft, Frank Barber, Dave Basaraba, Catherine Bealle Statland, Lorne Bedford, Peter Bradford, Cam Brown, Lil Cacaci, Ian Cameron, Rocky Chan, Terry Chow, Paul Chalifour, Steve Chatwin, Michelle Cleary, Dave Coates, Merle Collinge, Dave Cornwell, Sean Curry, Ken Day, Kathy Danchuk, Cam Donaldson, Jim Dunkley, Tracy Earle, Dennis Farquharson, Paul Frasca, Gerry George, Jim Goudie, Jim Grace, George Harper, Mike Jull, Lyn Konowalyk, Bruce Larson, Phil LePage, Ivan Listar, Bob MacDonald, Leslie McAuley, Janet Mitchell, Rod Negrave, Tannis Nelson, Grant Nisho, Brent Olsen, Peter Ott, Sam Otukol, Mike Pelchat, Bernie Peschke, Denis Petryshen, Brian Raymer, Brian Russell, Will Smith, Barry Snowdon, Peter Stroes, Klay Tindall, Kori Vernier, Robert Volkman, Dave Weaver, Roger Whitehead, Craig Wickland, Ralph Winter, Alex Woods, Ken Zielke, and Abdel-Azim Zumrawi. For field data collection, we thank Ian Boyd, Tracy Earle, and Teressa Peters of Forsite Inc. Ian Moss of ForesTree Dynamics Consultants completed the PrognosisBC simulations. Martin Watts of Forcomp Forestry Consulting Ltd. compiled the sample data and prepared most of the figures in this report.

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1.0 Introduction

Partial cutting may help, or it may hinder, the effort to manage forests in a sustainable manner. Improper partial cutting can result in areas stocked with damaged, diseased, slow-growing trees whose low residual volume and value precludes further harvest (Oliver and Larson 1996, Kenefic and Nyland 2005). However, when well executed, partial cutting can salvage value from beetle-attacked stands, conserve live trees for future harvest, and create conditions that meet biodiversity, visual quality, and habitat objectives. As a result, evaluations of partial cutting practices, policies, and outcomes are urgently required, and both resource professionals and the public have an interest in them.

With the current mountain pine beetle outbreak, a common partial cutting practice in BC's interior is to salvage lodgepole pine from mixed species stands. Worldwide, within both the public and academic circles, the merits of salvage harvesting is being intensely debated (e.g., Hughes and Drever 2001, Oregon Society of American Foresters 2003, Eng 2004, Lindenmayer et al. 2004, Burton 2006, Lindenmayer 2006, Parfitt 2007). Because of the potential widespread application of partial cutting to extract lodgepole pine, and the possibility that it could either improve or degrade provincial forest resources, it is critical to evaluate the resource condition where this practice has occurred.

With the implementation of FRPA (Forest and Range Practices Act), the Ministry of Forests and Range (MoFR) initiated the Forest and Range Evaluation Program (FREP). In FRPA, the government states objectives for each of 11 resource values (e.g., soils, fish, biodiversity, etc). Timber is one of the 11 values. For each of these values, FREP aims to develop methods to evaluate the degree to which the objective is being met (BC Ministry of Forests and Range 2005). These evaluations are intended to be used by many parties, including forest managers and other stakeholders to monitor resource condition, operational foresters to continuously improve practices, and policy makers for evidence-based policy evolution. FREP has developed evaluation procedures, and FREP evaluations have been completed, for many of the FRPA values (see http://www.for.gov.bc.ca/hfp/frep/indicators/table.htm). This report describes the initial steps taken to develop FREP evaluation methods for the timber value in areas that have been partially harvested.

As specified in FRPA's Forest Planning and Practices regulation (FPPR (s. 6)), the objectives set by government for timber are to:

a) maintain or enhance an economically valuable supply of commercial timber from British Columbia's forests,

b) ensure that delivered wood costs, generally, after taking into account the effect on them of the relevant provisions of this regulation and of the Act, are competitive in relation to equivalent costs in relation to regulated primary forest activities in other jurisdictions, and

c) ensure that the provisions of this regulation and of the Act that pertain to primary forest activities do not unduly constrain the ability of a holder of an agreement under the Forest Act to exercise the holder's rights under the agreement.

The evaluation presented in this report, and the evaluation methods developed to-date, focus on that portion of the timber goal that is described in FPPR s. 6(a). Thus, they examine the degree to which stand conditions in partially harvested areas are consistent with the government's objective to maintain or enhance an economically valuable supply of commercial timber. The impact of partial harvesting on other FRPA values is not considered.

FREP aims to develop methods for both rapid, routine evaluations and more intensive evaluations that involve more detailed data collection and analysis. Procedures for intensive evaluation were fully developed and applied in the evaluation presented here. Procedures for routine evaluation were partially developed and tested.

In broad terms the purpose of this project was to evaluate the results of recent partial cutting in a management unit in south-eastern BC, build FREPs capability to evaluate partial cutting, and make recommendations to improve partial cutting practices and evaluation capability (Appendix 1). The preliminary FREP evaluation methods described in this report will evolve and be refined in subsequent years.

This report describes both the methods that were developed to evaluate partial-cuts and the results of the application of these methods in a specific partial-cut population. The body of the report provides a concise presentation of the trial evaluation. Supplementary materials, including material required for future evaluations (such as field procedures and field sheets) and rationales substantiating the evaluation methods and indicators, are provided in the appendices.

2.0 Background

2.1 *Forest Management Context*

The evaluation was conducted in partial-cut stands in a forest management unit in south-eastern BC[1]. Elevation at the sample locations ranged from 940 to 1700 m, and samples were located in four BEC units: IDFdm2, ICHmw1, MSdk, and ESSFdk. Before harvest, the stand types included Douglas-fir mixed stands at lower elevations, pine-dominated stands at middle elevations, and spruce-fir stands at higher elevations. Lodgepole pine, common in many of the stand types, comprises 46 per cent of the management unit's timber volume (BC Ministry of Forests 2001). High populations of mountain pine beetle occur in and around the area.

A primary harvesting objective of the license-holder is to harvest lodgepole pine to capture value and volume before it deteriorates due to beetle attack, conserve non-pine trees for future harvest, and control the spread of the beetle. This has been the primary driver of partial cutting in the management unit. In the management unit, harvest practice is also influenced by the desire to manage aesthetics, cutblock adjacency, riparian areas, biodiversity, wildlife habitat, seasonal harvesting opportunities, and harvesting economics. Much of the partial harvesting involves removing lodgepole pine from mixed species stands. In these stands, key management choices include where to (and where not to) harvest; the amount and spatial pattern of retention; the tree species, sizes and conditions to remove (and retain); the effort to expend monitoring and salvaging trees that subsequently are attacked, die, or blowdown; the size of gaps to create; and the nature of reforestation treatments (e.g., site preparation, planting, brushing, and slashing poor quality advance regeneration).

The site plans from those cutblocks that were selected for sampling suggest a range of potential risks to the government's objectives for timber, including root disease; bark beetles; windthrow and snow damage; creation of gaps too numerous, small and dispersed to manage; the species and quality of released advance regeneration; post-harvest stocking levels; the species, value, growth potential and condition of retained trees; and regeneration-limiting site conditions that must be addressed to achieve successful reforestation (e.g., frost, brush hazard, browsing, etc).

1 It is a standard FREP protocol to not release the identity of the management unit or license holder(s).

Typically, in the management unit timber is harvested with ground-based skidding, but some cable harvesting is used. In areas sampled, the silvicultural systems were characterized by the prescribing foresters as irregular shelterwood, group shelterwood, irregular group shelterwood, uniform shelterwood, strip shelterwood, intermediate cut, and clearcut with reserves. In many cutblocks, the next harvest is anticipated in 15-30 years.

The licensee operating in the area cooperated fully with the evaluation, providing site plans, advice on access, road radios, discussion of evaluation issues, and other assistance. However, they were not directly involved in the data collection, compilation, and interpretation or in making evaluative judgements. Although the condition of harvested areas is tested against the FRPA timber objective, the areas sampled in the test evaluation were harvested under the Code. They are not "FRPA blocks". Moreover, effectiveness evaluations are not compliance audits and thus the evaluation made no attempt to relate observations to any legal obligations.

2.2 *The Evaluation*

The evaluation can be characterized as a goal-oriented evaluation in that it is set-up primarily to assess the degree to which a stated goal is being (or will be) achieved. Also, the evaluation is outcome-focussed, in that the emphasis is on outcomes - stand conditions following harvest and reforestation. The focus is not on the adequacy of planning processes, reforestation expenditures, activities undertaken, staff knowledge levels, and management systems. All goal-oriented evaluations are built on a logic model that describes how the observed elements relate to the goal. The logic model expresses the logic and rationale that links the observations to the conclusions that they support about the degree to which the goal is being achieved (McDavid and Hawthorn 2006).

There are four key concepts embedded in the goal ("to maintain or enhance an economically valuable supply of commercial timber"). The first is the notion of amount (or volume), as in a supply of timber. The second is the notion of value, as in economically valuable supply and commercial timber. The third is a temporal element such that both current and future volume and value are relevant to the goal. The fourth is the notion of level, to maintain or enhance supply, so that volume and value should be high relative to stand and site potentials. Thus, the evaluation is based on the assertions that

i) the critical factors that determine the level of goal achievement are unit-area timber volume and unit-area timber value,

ii) both current (post-harvest) and future levels of volume and value must be assessed, and

iii) they should be assessed against the benchmark of stand and site potential.

Current volume and value can be directly observed in partial-cut areas. Future volume and value, and volume and value recovery (i.e., growth) rates, can be forecast with a stand growth simulator. In addition, factors that influence these quantities in known ways can be observed in partial-cut stands. Collectively, these indicators, and their linkage to the goal, are summarized in Appendix 2.

Goal-oriented or outcome-focussed evaluations are common in many fields. The development of the evaluation procedure followed the well-established format of

i) identifying the dominant factors or conditions that control goal achievement,

ii) deriving indicators (or measures) for them, and

iii) establishing reference values or comparative benchmarks to assist in interpreting the observed levels of the indicators in terms of the degree to which the goal was (or will be) achieved.

3.0 Methods

3.1 *Overview*

Sample points were randomly located in a defined population of partially harvested areas in a management unit in south-eastern BC. At each sample point, various tree and site attributes were measured. This data was used to characterize current condition at the sample point and to initialize PrognosisBC simulations of future condition. Also, at each sample point, FREP routine evaluation indicators were assessed. From the current condition, the yield forecasts, and the routine evaluation indicators, the degree to which conditions in the partial-cut area are consistent with the FRPA timber goal was assessed. From the results, recommendations were made for improving partial-cut practices, evaluation methods, and policy.

3.2 *Population*

The target population was all of the NAR (net area to be reforested) in areas that were partially cut from 2000 to 2002 in a certain management unit in south-eastern BC. A population list (sample frame) was assembled from the data in RESULTS by extracting all forest cover polygons (strata) with more than 75 layer 1 trees per hectare in cutblocks with disturbance start dates 2000-2002 in the management unit.[2] The population totaled 677 hectares, located in 56 separate forest cover polygons in a total of 49 cutblocks (Appendix 3).

3.3 *Sample Size and Location*

Polygons were randomly selected from the polygon list with probability proportional to size (area) with replacement (PPSWR). Each time a polygon was selected, a map of the polygon was acquired and a sample was randomly located within the polygon (Appendix 3). This process, widely used in forest inventory, yields a self-weighting, representative, statistically valid sample of the population. Twenty-five random sample points were established in the field.

3.4 *Plot Layout and Measurements*

A cluster of three sub-plots was arranged around each sample center point (Appendix 4). At each sub-plot center, the following data was collected:

1. In a prism plot, live standing trees with dbh≥12.5 cm were measured for species, diameter, height, height to crown base, timber quality class, root disease symptoms indicator, and comments.
2. In a prism plot, merchantable[3] dead or fallen trees were measured for live/dead status, standing/fallen status, species, diameter, height, root disease symptoms indicator, and comments.
3. In a fixed radius plot, stumps with diameter≥12.5 cm were measured for species, stump diameter, stump height, and comments. For conifer stumps, species was recorded as “Xc” when surveyors could not determine species.

2 The following tree size classes are used in this document: (i) Layer 1 is trees with dbh≥12.5 cm; (ii) Layer 2 is trees with 7.5≤dbh≤12.4 cm; (iii) Layer 3 is trees with height ≥1.3 m and dbh≤7.4 cm; (iv) Layer 4 is trees with height <1.3 m. RESULTS is the software application that contains silviculture information on areas harvested in BC.

3 Merchantability minimum was a 17.5 cm dbh conifer with a 5 m merchantable log.

4. In a fixed radius plot, live trees with dbh<12.5 cm were measured for species, diameter, height, live crown ratio, origin, condition class, and comments.
5. In a fixed radius plot, well-spaced tree count by layer by species group (preferred and acceptable) was collected.

At the sample center, site characteristics were recorded (BEC, slope, aspect, elevation, and UTM), FREP routine evaluation indicators were assessed (see section 3.8), and other observations were recorded (see Appendix 4 Field Procedures). Field data was recorded on field sheets created for the evaluation (Appendix 5) and later entered into an Excel workbook (Appendix 6).

3.5 Current Condition

The sample data was compiled to characterize current stand condition, pre-harvest stand condition, and timber removed at harvest at each sample location. To estimate the volume of harvested trees, dbh was estimated from stump diameter, and height was predicted from height-diameter equations fit to sampled trees (Watts 2007). Tree volumes were estimated with the provincial tree volume equations using the FAIB Interactive Tree Compiler v2.12.21. Compilations included merchantable volume (m^3/ha) by species (pre-harvest, removed in harvest, and currently standing), value ($/ha) by species, (pre-harvest, removed in harvest, and currently standing), overstory tree basal area (m^2/ha), overstory tree basal area classed as poor timber quality (m^2/ha), merchantable dead or down volume (m^3/ha), DFP[4], understory tree density (trees/ha), density of understory trees classified in poor condition (trees/ha), percent of pre-harvest volume removed, and percent of pre-harvest value removed. For each sample, sub-plot values were averaged and the result, a single observation from the sample location, used in all subsequent analyses.

Multi-layer well-spaced density was computed for each sample as follows. In a 3.99 m radius plot at a sub-plot center, layer 1 trees were tallied to a maximum of three with no minimum inter-tree distance. Layer 2 trees were tallied to a maximum of four with a 2.0 m minimum inter-tree distance from other tallied layer 1 and 2 trees. Layer 3 trees were tallied to a maximum of five with a 2.0 m minimum inter-tree distance from other tallied layer 1, 2, and 3 trees. Layer 4 trees were tallied to a maximum of six with a 2.0 m minimum inter-tree distance from other tallied layer 1, 2, 3, and 4 trees. Well-spaced tree counts were summed over the layers and the total was capped at a maximum of six trees per plot. The three sub-plot totals in the sample were averaged. The plot average was expanded to a per hectare basis.

3.6 Future Condition

For each sample location, data was compiled to initialize forecasts of future conditions by the PrognosisBC stand growth simulator. Before simulation, 60 percent of the large lodgepole pine was removed to simulate the losses expected by forest health experts due to the ongoing mountain pine beetle outbreak (Terry Shore, personal communication, 2006). For each sample location, stand development under three alternative management scenarios was examined. The scenarios were:

1. No harvest: the development of the pre-harvest stand following the death of 60 percent of the lodgepole pine with dbh≥15 cm.
2. Current stand: the development of the current stand following the death of 60 percent of the standing lodgepole pine with dbh≥15 cm.
3. Clearcut: the development of a clearcut planted at 1600 trees per hectare with an even mixture of the preferred species.

Stand growth simulations were conducted with PrognosisBC version 3.1.

3.7 Value

For pre-harvest condition, harvest removal, current condition, and forecast future condition, timber value was estimated as volume (m^3/ha) multiplied by log price ($/$m^3$) by species. Average log sales prices by species were obtained from the ministry's Resource Tenures and Engineering Branch (RTEB, Table 1), with one exception - deciduous was valued at $0/$m^3$. Percent volume removed was computed as volume harvested divided by pre-harvest volume times 100%. Percent value removed was computed as value harvested divided by pre-harvest value times 100%.

4 DFP is a measure of stocking (Martin et al. 2005a,b)

Table 1. Timber value by species group.

Species	Average Price[1] ($/m^3)
SPF (spruce, lodgepole pine, and abies)	56.87
Douglas-fir and western larch	72.91
Hemlock	51.60
Cedar	95.53
White pine	85.00
Yellow pine	71.95
Deciduous[2]	0.00

1 BC Interior Log Market report for March, 2006 published by Revenue Branch, MoFR.

2 Value changed to zero for study area to reflect local, current timber value.

3.8 *Routine Evaluation Indicators*

A procedure for conducting rapid assessments of partial cutting was developed for use in FREP routine evaluations (Appendix 7). The procedure was developed largely from expert opinion of the factors known to influence volume and value in partial-cut areas. The development process included several field sessions with operations staff to test and refine the approach. The draft procedure assigns a sample point to one of seven condition classes based on three indicators: stocking, amount of poor timber quality trees, and the ratio of value to volume percent removal. For each condition class, the procedure states the associated degree of consistency with the timber goal (high, medium, or low). To add detail to the crude classification, an additional 18 factors that potentially impact the goal are assessed and the level of each factor qualitatively rated as high, medium, low, or not applicable (Appendix 7).

4.0 Results

4.1 *Current Condition*

At the time of assessment, most of the areas were well stocked (Figure 1). Mean multi-layer density was 1055 well-spaced trees per hectare. At only 2 of 25 sample locations was density less than or equal to 700 well-spaced trees per hectare. Partial-cut areas were also well-stocked when assessed by DFP. Overall mean DFP was 0.08. Only 3 of 25 sample locations had DFP exceeding 0.2. The high level of stocking observed suggests a high degree of consistency with the government's objectives for timber.

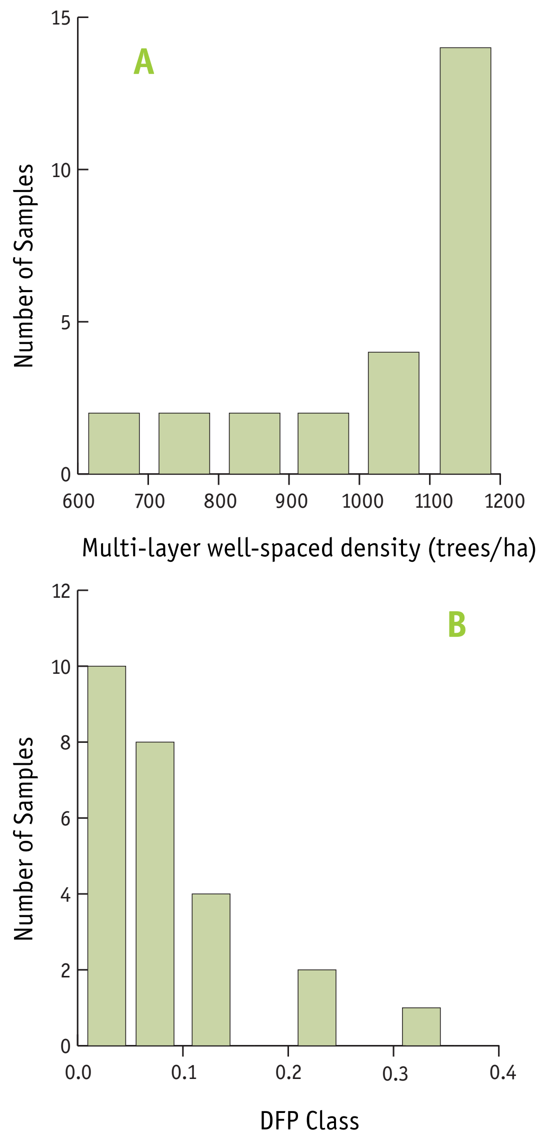

Figure 1. Distribution of stocking levels. Number of samples by (A) well-spaced density class and (B) DFP class. Each observation is the mean of three sub-plot values. 25 samples.

Little merchantable dead or down timber was found in the partial-cut areas (Figure 2). The mean volume of merchantable dead or down timber was 12 m^3/ha. At only 2 of 25 locations was more than 40 m^3/ha observed. The relatively low volume of merchantable dead or down timber suggests a high degree of consistency with the government's objectives for timber.

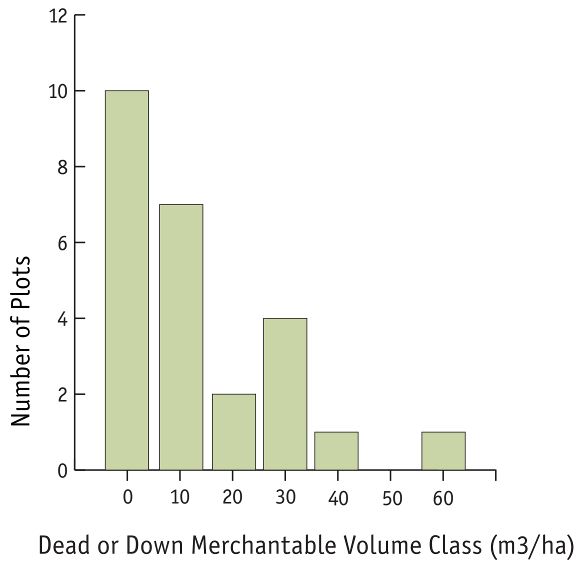

***Figure 2.** Distribution of merchantable dead or down tree volume (m^3/ha). 25 samples.*

Before harvest, lodgepole pine was common in the partial-cut areas (Figure 3). Of the mean pre-harvest volume of 448 m^3/ha, 227 m^3/ha (51 percent) was lodgepole pine (or unknown conifer)[5].

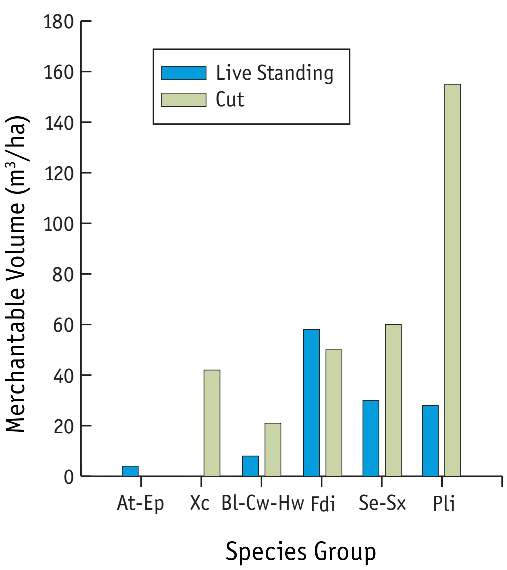

***Figure 3.** Mean volume (m^3/ha) of cut and standing trees by species group. 25 samples.*

At the time of assessment after harvesting, mature lodgepole pine was relatively rare with a mean of 31 m^3/ha, 25 percent of the current standing volume of 126 m^3/ha (Figure 4). Given the threat to lodgepole pine posed by the current mountain pine beetle outbreak, the partial harvest has been relatively successful in extracting trees that are likely to soon decline or die. The observed high percent removal and low remaining volume of lodgepole pine indicates a high degree of consistency with the government's objective for timber. During harvest, an average of 125 m^3/ha of non-pine species was extracted (Figure 5). Given the pressing need to conserve non-pine trees during the beetle outbreak, the relatively high volume removal of non-pine species is judged as exhibiting a low degree of consistency with the government's objectives for timber.

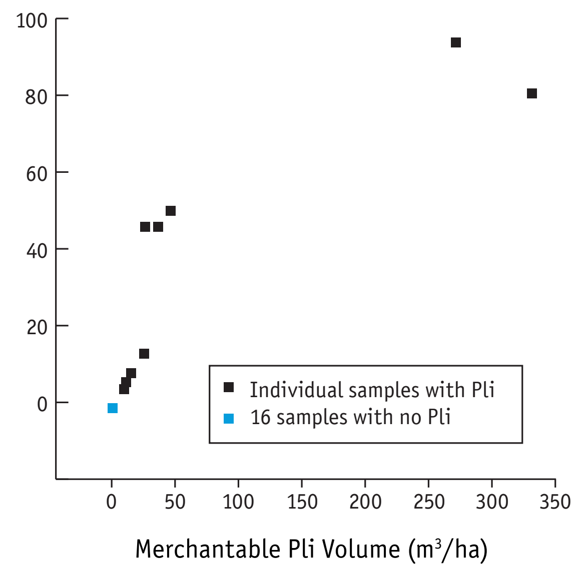

***Figure 4.** Live, standing merchantable volume of lodgepole pine (Pli) expressed in m^3/ha and as a percent of the live standing merchantable volume of all species combined. 16 samples have no remaining pine volume. 25 samples.*

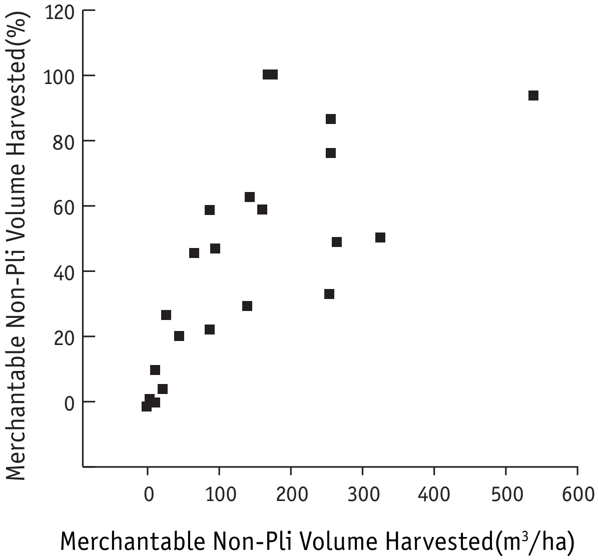

Figure 5. ***Non-pine volume that was harvested expressed in m^3/ha and as a percent of the volume harvested of all species combined. 25 samples.***

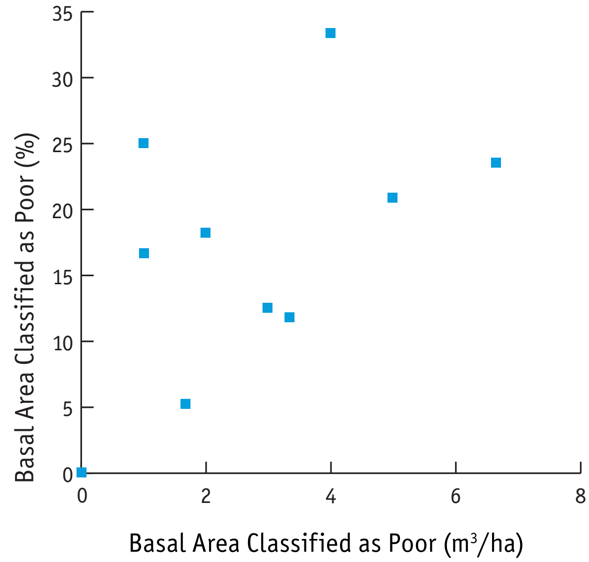

Figure 6. ***Retained overstory classified as poor timber quality. Basal area (m^2/ha) poor quality timber and the basal area poor quality timber expressed as a percent of the total basal area. 25 samples including 14 with no residual overstory trees classified as poor timber quality and one sample with no residual overstory trees.***

Large trees assessed by surveyors as having poor timber quality were relatively rare. Among overstory trees, the mean basal area of poor quality trees was 1 m^2/ha (Figure 6). Of 25 sample locations, 15 had zero m^2/ha, and only 2 had more than 5 m^2/ha, poor timber quality trees. Expressed as a percent of total basal area, poor quality basal area ranged from 0 to 33 percent. In the understory (layers 2-4), poor quality trees were often present at high densities and occasionally were taller than good quality trees. The density of understory trees classified as in poor condition ranged from 0 to 11937 trees per hectare, with a mean of 3340 trees/ha (Figure 7). The difference in mean height between good and poor understory trees ranged from -4.2 to 2 m. The component classified as poor was taller than the good trees at 11 of 25 sample locations, although the height differential only exceeded 1 m at 3 of 25 locations. These measures present a mixed message on growing space occupancy by poor trees. By these measures, the observed conditions are judged as exhibiting a medium degree of consistency with government's objectives for timber.

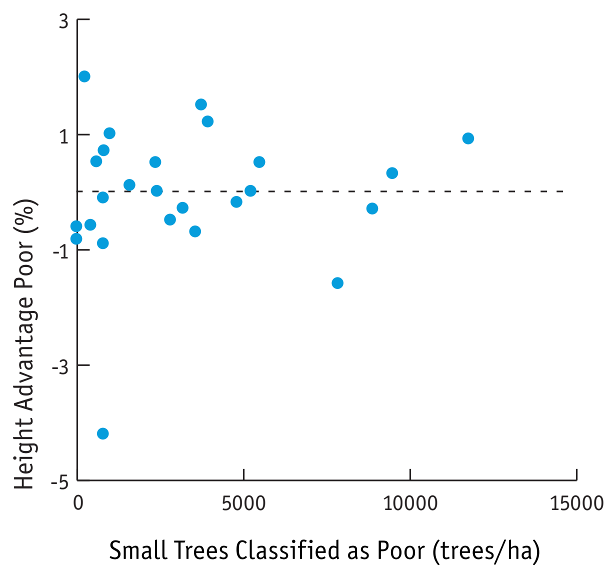

Figure 7. ***Understory classified as poor tree quality. Density (trees/ha) of poor quality layer 2-4 trees and the height advantage of poor trees (mean height of poor trees minus mean height of good trees). 25 samples.***

5 Where field crews could not definitively determine the species of a conifer stump, it was designated as unknown conifer (Xc). The sample mean of 227 m^3/ha includes 40 m^3/ha that was classified as unknown conifer.

Typically, harvesting removed roughly equal proportions of the pre-harvest value and volume (Figure 8). The observed relationship between volume removed and value removed exhibits a high degree of consistency with government's objective for timber.

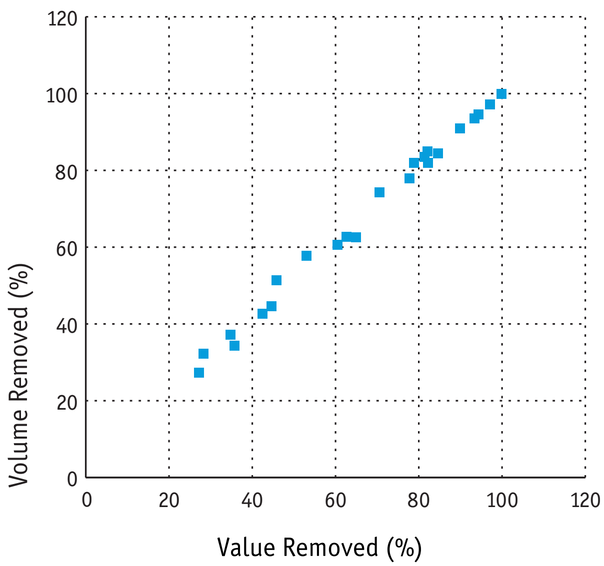

Figure 8. ***Relationship of value removed at harvest to volume removed at harvest. 25 samples.***

4.2 *Routine Evaluation Indicators*

4.2.1 *Routine evaluation condition classes*

Using the procedures developed for routine evaluation, samples were assigned to their condition classes (Table 2).

The observed classification into types, with the associated interpretation, suggests a high degree of consistency with government's objective for timber.

4.2.2 *Factors that impact the overstory*

Utilizing procedures designed for routine evaluations, surveyors completed a rapid, qualitative assessment of eight factors that affect the overstory's ability to contribute to the government's timber objective (Figure 9). In 39 of 200 cases the factor ratings suggest an inconsistency with the government's objectives for timber. Factors 4 and 5 (growth potential of retained trees and overstory species diversity) were ones with field conditions most frequently judged by surveyors as tending to act against the achievement of government's objectives for timber. Risk of windthrow and the harvesting of trees that were not threatened with imminent death (typically, harvesting species not threatened by beetle) were also identified as concerns. Taken together the ratings of the overstory factors suggest that the current overstory conditions exhibit a medium level of consistency with government's objectives for timber.

Table 2. ***Number of samples by condition class with associated interpretation.***

		Degree to which observed condition meets FRPA objectives for timber		
	Condition class	**Low**	**Medium**	**High**
1:	Stocked by residual overstory, value removal did not greatly exceed volume removal			3
2:	Stocked by residual overstory, value removal greatly exceeded volume removal			
3:	Stocked by residual overstory, value removal moderately exceeded volume removal			
4:	Not fully stocked by residual overstory, high level of poor quality timber retained			
5:	Not fully stocked by residual overstory, low level of poor quality timber retained, high level of seedling and sapling stocking			19
6:	Not fully stocked by residual overstory, low level of poor quality timber retained, low level of seedling and sapling stocking			
7:	Not fully stocked by residual overstory, low level of poor quality timber retained, medium level of seedling and sapling stocking		3	

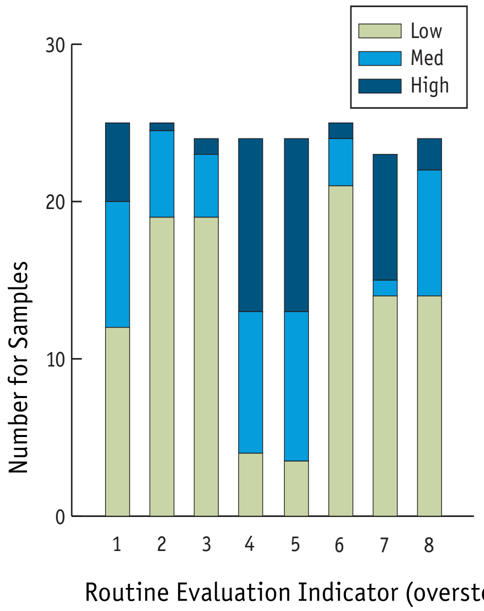

Figure 9. ***For each overstory factor, the number of samples classified as high, medium, and low. The factors are: (1) risk of windthrow, (2) risk of root disease, (3) risk that other factors will cause decline or death of overstory trees, (4) growth potential of retained overstory trees, (5) tree species diversity, (6) damage to retained trees, (7) risk of imminent death faced by harvested trees, and (8) retention of most valuable species groups. The scores (high, medium, and low) are a subjective assessment of the degree to which the observed condition acts contrary to the government's objectives for timber. 25 samples. NA scores omitted.***

4.2.3 Factors that impact the understory

Utilizing procedures designed for routine evaluations, surveyors completed a rapid, qualitative assessment of nine factors that affect the understory's ability to contribute to the government's timber objective (Figure 10). In 36 of 175 cases the factor ratings suggest an inconsistency with the government's objectives for timber. Factor 11, the probability of additional natural regeneration, was most frequently assessed by surveyors as tending to act against the achievement of government's objectives for timber. Tree species diversity and interference with the growth of crop trees by other poor quality trees were also identified as concerns. Taken together the ratings of the understory factors suggest that current understory conditions exhibit a medium level of consistency with government's objectives for timber.

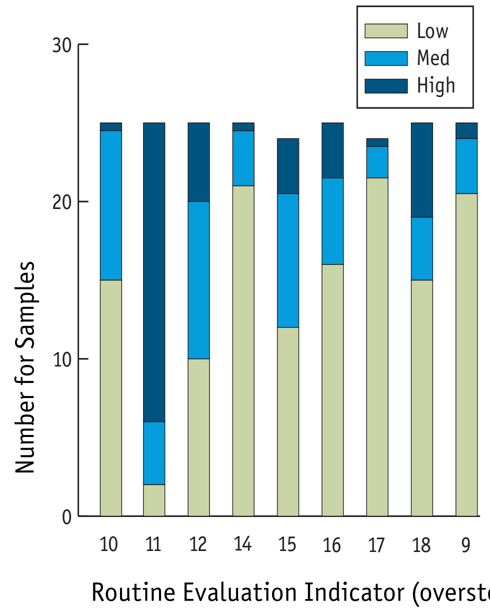

Figure 10. ***For each understory factor, the number of samples classified as high, medium, and low. The factors are: (9) forest health risk, (10) non-crop vegetation competition risk, (11) probability of additional natural regeneration, (12) tree species diversity, (14) shade tolerance matched to local shading conditions, (15) more productive species re-established, (16) more valuable species re-established, (17) desirable advanced regeneration destroyed in logging, and (18) preferred crop trees free from interference by other poorer quality trees. The scores (high, medium, and low) are a subjective assessment of the degree to which the observed condition acts contrary to the government's objectives for timber. 25 samples. NA scores omitted.***

4.3 *Future Condition*

Compared to the option of not harvesting, the observed partial cutting on average results in less standing volume now and for the next 50 years (Figure 11, Figure 12, Table 3). However, in terms of cumulative volume (harvested volume plus current standing volume), over the next 50 years the observed partial cutting at most sample locations yields more timber volume than the no harvest option, partly due to the assumption that 60% of standing pine volume dies due to beetle attack and is not recovered.

Compared to the option of clearcutting, the observed partial cutting results in more standing volume now and for the next 50 years. In terms of cumulative volume, over the next 50 years the observed partial cutting is marginally superior to the option of clearcutting. Beyond roughly 50 years, merchantable volume begins to accumulate most rapidly in the clearcut scenario.

Of the three scenarios, standing volume over the next 50 years is greatest in the no harvest, least in the clearcut, and intermediate in the partial-cut. However, when the volume extracted at harvest is also considered, the difference among management alternatives is reduced and cumulative volume is greatest in the partial-cut, least in the no harvest, and intermediate in the clearcut.

On balance, the levels of volume forecast for the current condition, when compared against comparable values for the clearcut and no harvest management scenarios, are judged as generally consistent with the government's objectives for timber.

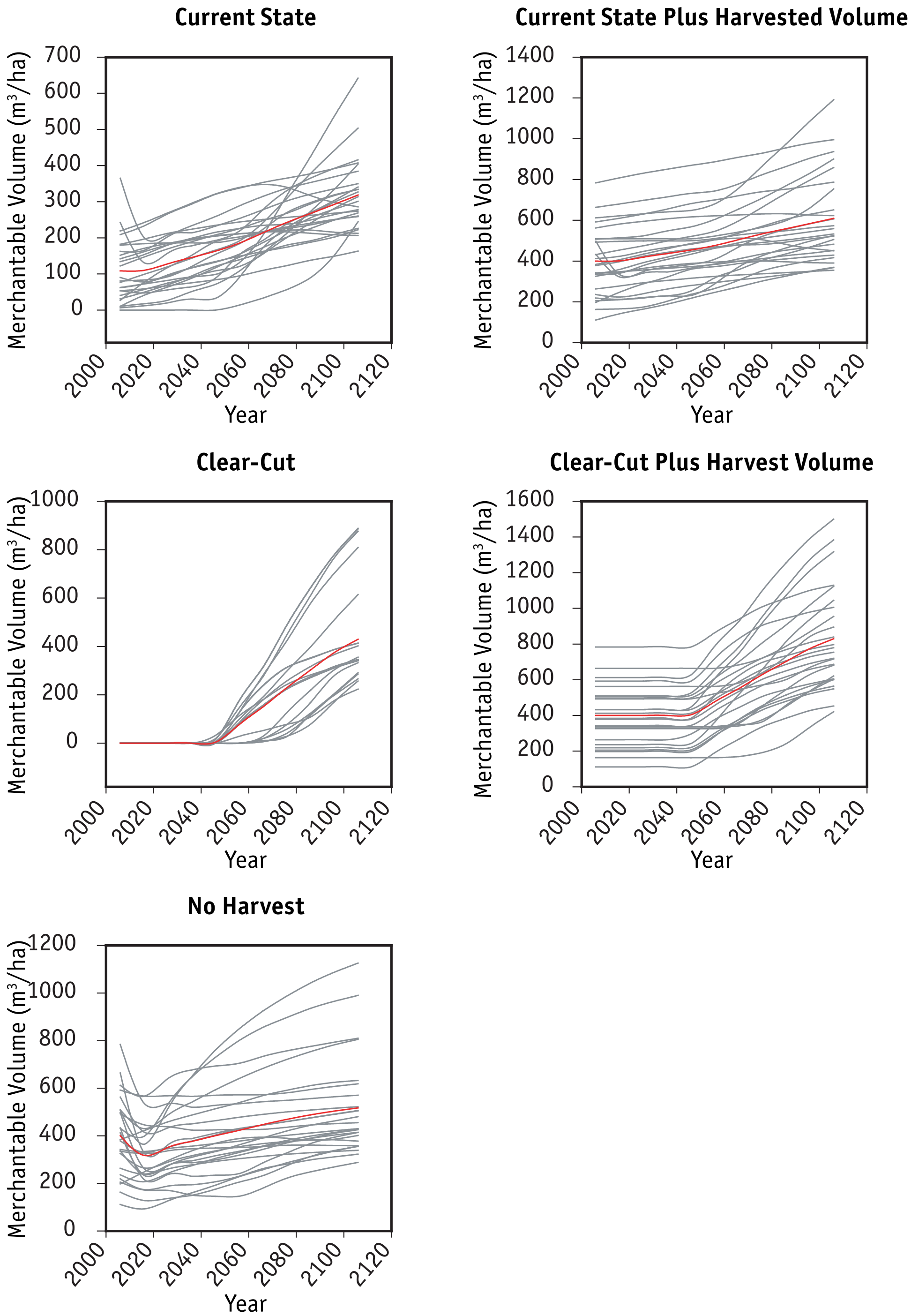

Figure 11. ***Forecasts of standing volume and cumulative volume (standing plus harvested) under three management scenarios: current state, no harvest, and clear-cut.***

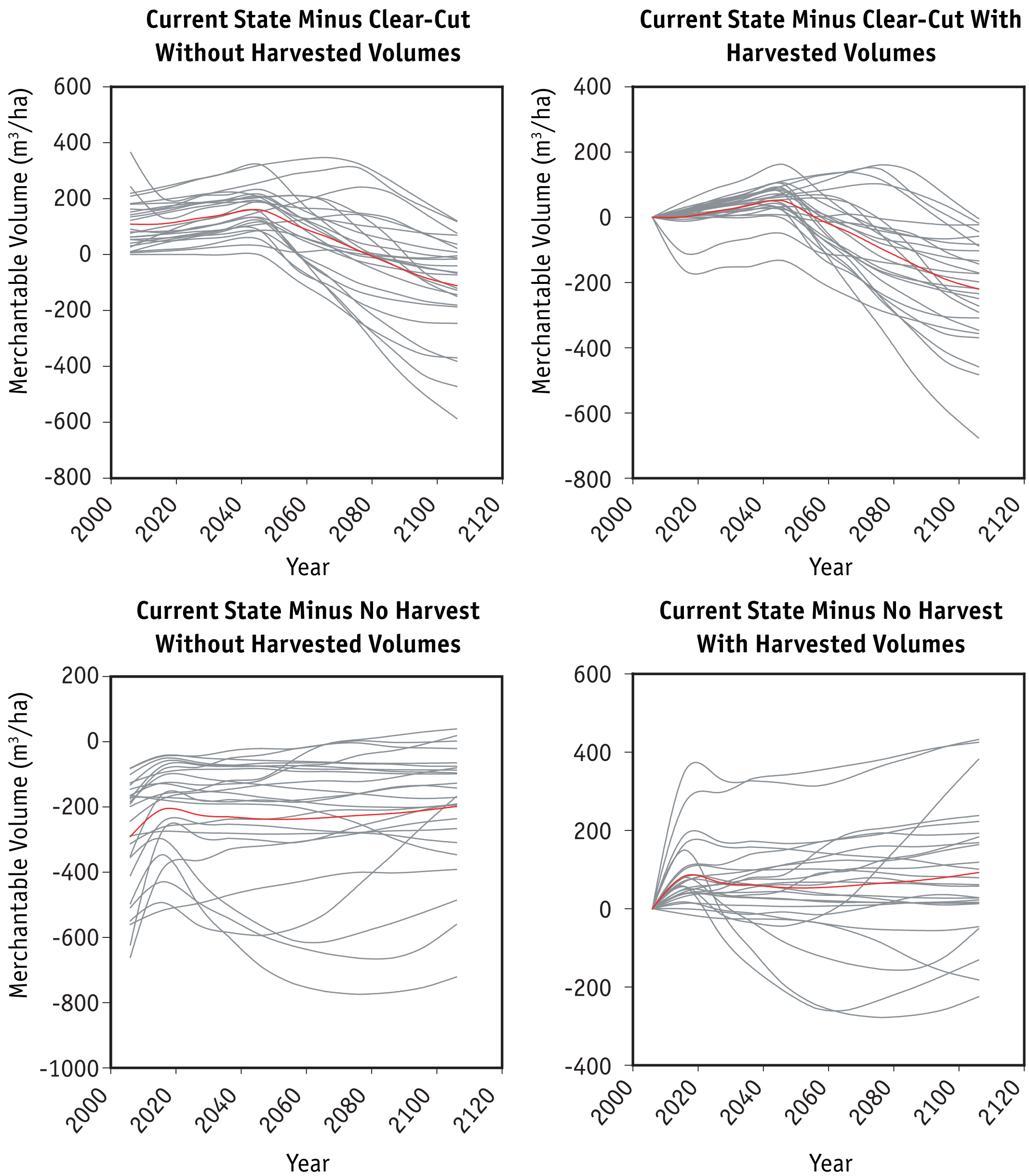

Figure 12. Forecast volume differences (current state minus alternative) for both standing volume and cumulative volume (standing plus harvested).

Table 3. Mean volume and standard error (in brackets) of PrognosisBC forecasts for standing and cumulative volume in 2036 and 2066 under the current, no harvest, and clearcut scenarios.

		Scenario		
Year	**Volume**	**Current**	**No Harvest**	**Clear-Cut**
2036	Standing	146 (15)	376 (31)	0 (0)
	Cumulative	437 (34)	376 (31)	400 (34)
2066	Standing	214 (14)	447 (38)	150 (19)
	Cumulative	505 (33)	447 (38)	549 (40)

4.4 Summary of Indicators

The judgements of the degree of consistency with government objectives for timber are summarized over all indicators (Table 4).

Table 4. Summary of the judgements of degree of consistency with the goal.

		Degree of Consistency		
Type	**Indicator**	**Low**	**Medium**	**High**
Routine	Condition class			✓
	Overstory factors		✓	
	Understory factors		✓	
Intensive - current condition	The level of stocking			✓
	Volume of merchantable dead or down wood			✓
	Volume of pine remaining			✓
	Volume of non-pine harvested	✓		
	The degree of site occupancy by poor quality trees		✓	
	Value removal relative to volume removal			✓
Intensive - forcast condition	Forcast future volume			✓

5.0 Discussion

5.1 *Field Procedures*

Determining the species of cut stumps proved difficult (Figure 13). Difficulty increased as time since harvest increased, stump height decreased, the number of tree species at the sample location increased, and the amount of retained bark decreased. As a result, in the test evaluation the estimates of pre-harvest species composition, and the species composition of harvest removal, are less reliable than the estimates of the current species composition of standing trees. In areas that had been harvested more than once in recent years, it was sometimes difficult to determine whether the stump originated in the most recent harvest. Heavy site preparation, and stump removal on skid trails, sometimes obscured stumps or moved them in or out of the stump plot. Stumps cannot be reliably assessed in stumped areas.

Percent live crown was initially included in the assessment of tree condition. However, it was dropped when it became clear that it was difficult to identify a critical value that seemed appropriate over all conditions that were encountered. Although the field procedures specify criteria for assessing tree condition, a degree of subjectivity remains in this procedure.

Many small trees are knocked down during harvest and many others fall over in the first few years after harvest. In the intensive evaluation, stumps with diameter < 12.5 cm and dead or down trees with dbh < 17.5 cm, are not tallied. Therefore, the pre-harvest stand component with dbh<17.5 cm was poorly estimated in the evaluation (Figure 14).

In some cases, it was difficult to distinguish planted from naturally regenerated trees. Field crews were not provided with planting records and information on the genetic worth of planted trees. Therefore, field crews did not assess the routine evaluation indicator #15: degree to which stocking in the seedling and sapling layer is dominated by genetically improved (A class) trees.

Once at the sample center, a two-person crew completed data collection in roughly three hours.

A great deal of additional data could be collected. First, most effectiveness monitoring programs (e.g., Kershner et al. 2004, Reeves et al. 2004), and many of the other FREP evaluations (e.g., the FREP riparian evaluation), record the management practices that have been applied at the sample location. This information is used to post-stratify the data, look for differences in indicator levels with practices, and support conclusions on which practices are associated with good (and poor) outcomes (e.g., Woodsmith et al. 2005). Second, in addition to practices, a great variety of other data could be collected on site conditions, operational constraints and management objectives. Later, the relationships between these variables and the indicator values could be examined to better understand and explain the evaluation results. Third, to support interpretations and recommendations, surveyors could identify practices that they believe would have improved the observed levels of the indicators. Surveyors could answer questions such as: Is there a management practice that could have been conducted that would have resulted in a better indicator level (or factor rating)? What is that practice? If that practice had been applied, what would be the current level of the indicator (or factor rating)?

However, there are many reasons to exercise discipline and judiciously limit the collection of additional data. In a comprehensive review of the monitoring and evaluation literature from many disciplines, Stem et al. (2005) recommend that "practitioners should be clear about their information needs and gather the minimum amount of information required to meet these needs given the available resources." It could be argued that it is not within the scope of FREP to record some observations, such as the amount of money that has been spent on silviculture at the sample location. In some cases, the value derived from the extra data may not justify the cost of collecting, analyzing, and managing it. There may be better, cheaper ways to gain the insight that this additional data and analysis might provide. With a point-based sample, it can be difficult to determine which treatments were applied at the sample point, even if it is known that certain treatments were applied somewhere in the cutblock. Also, some of this extra information is so obviously subjective, and potentially controversial, that it may cast disrepute on what is otherwise an objective assessment. Some observations cannot be reliably made in the field - e.g., the genetic worth of planted trees or the type of logging equipment used. If it is desired, this type of data could be gathered in an office-based data collection phase and merged with the field data to support additional indicators and analyses.

Figure 13. ***Stump species was sometimes difficult to identify in the test evaluation.***

Figure 14. ***Small diameter trees in the stand before harvest were frequently not detected by the field procedures.***

5.2 *Data Compilation and Assigning Value*

Some minor quirks surfaced with the use of the tree volume compiler. On a few occasions when estimating dbh from stump diameter, the dbh estimated by the compiler exceeded the stump diameter.

The value assigned is a gross value that does not account for harvesting, reforestation, or other costs. Also, in valuing the timber future costs and revenues were ignored. A single value is assigned to pine, but the value of dead pine can differ greatly from the value of live pine. Some participants in the evaluation noted that a separation of balsam, spruce, and pine value would be preferable in future evaluations. Although RTEB provides a value for deciduous, it was assumed zero for the area of application. The licensee responsible for the sampled areas contended that the evaluation methods over-estimated value removed because in partial cutting they retain the larger, better quality trees. In the evaluation, value was assigned on the basis of $/m^3 so that no price differentials for tree size and grade were used.

5.3 *Models*

The evaluation is partly dependent on stand growth model forecasts for comparative predictions under the no harvest, clearcut, and partial-cut scenarios. Historically, the models and modelling teams in BC have specialized within this wide range of stand conditions. Model users have been advised to use certain models for partial cutting predictions and other models for clearcutting predictions. No single growth model in BC has been considered equally reliable across this wide range.

PrognosisBC, like the other members of the FVS family, has a very large number of input parameters. To simplify the analysis, none of the model extensions were used (e.g., the western root disease and natural regeneration extensions). Many input options were not used and using them could lead to different yield predictions. PrognosisBC would not accept all of the BECs that were sampled and so we used the closest approximation BEC accepted by the model. The model would not grow trees with heights under four feet. So, all trees below this size were given a dbh of 0.1 inches to get the model to accept and grow them.

Certain changes in the intensive evaluation field procedures will be required (or simply advisable) to use other stand growth models. For example, it may be desirable to measure height and age on site trees to estimate site index for TASS simulations.

Other alternative management scenarios could be constructed that might provide an additional useful benchmark – e.g., a scenario of best partial-cutting for timber production or a scenario that emulates the yields forecast for comparable partial-cut stands in the applicable Timber Supply Review.

In this study it was assumed that the current MPB outbreak would kill 60 percent of the mature lodgepole pine in the study area. In a provincial-level projection of the MPB outbreak, Walton et al. (2007) predict a mortality rate of 80%. If 80% mortality had been assumed, the yield predictions under the "no harvest" option would be further reduced, thus increasing the relative superiority of both the partial harvest and clearcut management alternatives.

The yield predictions are used, primarily, for a relative comparison of scenarios. Therefore, no attempt was made to reduce model potential yields with OAFs. As a result, the predicted volumes likely exceed what should be expected operationally, but the relative comparisons among scenarios remain valid.

5.4 *Sampling*

The evaluation characterized the condition of the NAR (net area to be reforested) in a defined population of stands that have been partially harvested in a specific management unit. Thus, the percent of permanent access structure (PAS), a factor that impacts the timber goal, is not assessed in this evaluation. The FREP evaluation protocol for the soil value, however, does assess the area occupied by PAS. The condition of other populations (non-NAR, older harvests, and other geographic locations) cannot be inferred from this sample. The design generated a set of point samples from the population. This design does not produce polygon-level assessments of attributes such as polygon average basal area per hectare, polygon average well-spaced trees per hectare, and the size and location of NSR (not satisfactorily restocked) patches.

Assembling an accurate and complete sampling frame proved problematic for partially cut areas. Several methods were tried and abandoned. In the end, the frame was constructed from, and the population defined by, all of the relevant forest cover polygons (strata) in RESULTS with more than 75 layer one trees/ha. This method generated a population that included harvested areas that some foresters do not consider classic partial-cuts, such as small openings and clearcuts with reserves. In addition, the method missed some smaller partially cut areas that were below the size threshold requiring reporting into RESULTS.

The plot layout was partly determined by the desire to estimate DFP and well-spaced density using the traditional 3.99 m radius silviculture plots. If these variables were not required, plot layout could be changed. The current design may not be optimal to characterize areas for TASS, SORTIE, or other growth model simulations.

The evaluation describes the conditions in the forest at the time of sampling. However, because these areas were recently harvested, conditions may be dynamic and changing rapidly. In some areas, planting may not be complete, natural ingress may be ongoing, brush competition may be increasing, windthrow may not yet have stabilized, and additional harvest entries or treatments may be imminent. A second critical time-related issue is that the sample indicates how areas were being cut 4-6 years ago. But in the last half decade harvesting practices have changed in response to many factors including the enormous increase in the beetle outbreak. Thus, the observed indicator levels may not reflect current management. A recent study found that current harvest activity in the broader area around the sample was focussed on stands dominated by lodgepole pine (BC Ministry of Forests and Range 2007). The licensee operating in the study area reported that the proportion of non-pine harvested has decreased in recent years to roughly 20 percent. More generally, some of the indicators, such as non-pine harvested, are certainly a relevant reflection of the timber goal today under the current beetle situation. But it might be inappropriate to apply these retroactively to areas that were harvested in the past under a different situation. The licensee reported that when the areas were cut, only some of the AAC was needed for beetle salvage and beetle management, so that the remainder was applied to conventional harvesting. Today's focus on concentrating the harvest in pine and conserving non-pine was not as strong in the past. Thus, the indicator *non-pine harvested* may not provide a valid reflection of the timber goal when it is applied to areas harvested before there was widespread, heavy beetle attack.

The standard error for the sample means of many of the key variables are provided in the tables in Appendix 8. Typically, standard error in percent (standard error divided by sample mean times 100) was in the range of 5–20 percent. An increase in sample size would increase precision of the sample means and confidence in the evaluation results. For a range of variables, Figure 15 portrays the effect of an increase in sample size on the standard error in percent.

If the evaluation method is applied in a study design that seeks to estimate differences among populations, track trends in indicator values over time, or look for associations with auxiliary variables, additional data collection will likely be required. These more advanced study designs and analyses are not described in this report but are common in the effectiveness monitoring literature (e.g., Woodsmith et al. 2005, Houde et al. 2005, Stadt et al. 2006).

Power analysis (Legg and Nagy 2006) could be conducted, using the variability found in the test evaluation, to guide future decisions on sample size, and possibly other design considerations such as sub-plot number and size, and understand the statistical properties of future evaluations.

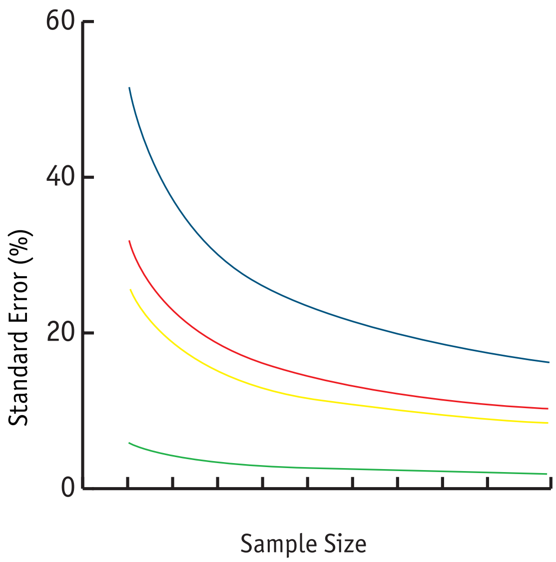

Figure 15. ***Relationship between sample size and standard error in percent for the basal area of poor quality large trees (blue), density of poor condition small trees (red), standing merchantable volume (yellow), and multi-layer well-spaced tree density (green).***

5.5 *Indicators*

The indicators are designed to be relevant to most partial cutting in the BC interior so that the evaluation method can be used elsewhere. To some degree, unique local circumstances can be accommodated by varying the weight and emphasis placed on each of the indicators. The indicators pine remaining and non-pine removed are not relevant to most of the coast. The methods were tested in the southern interior of the province. They have not been tested in the central and northern interior and on the coast.

Although broadly applicable, the indicators may not be appropriate for some special circumstances, such as helicopter logging in areas outside of the conventional timber harvesting landbase.

Some indicators have implications for non-timber values that are opposite to their implication for the timber value. For example, retained deciduous trees and dead or down wood are generally beneficial to wildlife habitat and biodiversity (Bunnell et al. 2004). However, they can diminish timber volume and value and as a result high levels of them are taken in the evaluation to indicate inconsistency with government's objectives for timber (Figure 16). The practice of beetle-proofing, sometimes used to increase resistance to beetle in pure pine stands (Whitehead et al. 2004), is poorly handled by the evaluation. Beetle-proofed stands score low on the indicator pine remaining in a partial-cut area (Figure 17). In addition, inherent conflicts exist among some of the timber indicators. For example, a harvest that eliminates pine from the overstory scores well in terms of the indicator pine remaining while scoring poorly on the indicator overstory tree species diversity. These types of problems are common when using indicators to portray the status of a broad, complex, multi-faceted goal (Hagan and Whitman 2006). Problems such as these with the indicators could be resolved by developing more sophisticated indicators or by the skilful interpretation of the current simple generic indicators.

A single score that integrates many or all of the indicators would be very useful to portray overall condition. Reeves et al. (2004, 2006) provide a relevant example where they integrate numerous indicators to generate a single, composite score for watershed condition in order to monitor achievement of the riparian objectives in the Northwest Forest Plan. However, it is difficult to resolve all interactions among indicators and assign weights that reflect the relative importance of the many indicators to the goal. Nevertheless, effort to devise a consolidated score will help clarify the relationship of indicators and factors to the goal.

The routine evaluation does not include in the classification into condition classes several important intensive evaluation indicators, including pine remaining and non-pine harvested.

For the routine evaluation, the classification into a discrete number of condition classes could be replaced with a system that:

i) scores the observed levels of the three indicators that determine the condition classes and

ii) combines these scores to generate an overall score.

Under this approach, the high, medium, and low ratings of the factors would continue as modifiers to the numeric score. A second option is to eliminate the distinction between indicators and factors, score each of them, total the scores, and interpret status based on the total score.

There are many alternative ways to organize and structure the routine evaluation. After appropriate indicators (and factors) have been selected, questions remain about how best to package, organize, and present them for field use. An examination of the FREP routine evaluation forms for other FRPA values finds a great variety of approaches. There is merit in examining these and other alternative formulations for the routine evaluation. There is utility in a FREP program-wide review of formats and possibly guidance on the desired format for future FREP checklists.

The evaluation does not distinguish between the harvest of live and dead pine. However, this situation, common in the BC interior, has implications for the indicators that relate to value.

Other types of indicators could be added to the evaluation. For example, the evaluation uses only condition indicators, and not the pressure and management response indicators that are common in some evaluations (Hagan and Whitman 2006). From a broad scale perspective, a relevant pressure indicator might be the amount of area partially harvested in one year. Planning indicators are a type of management response indicator. A relevant planning indicator, for example, might be that stand condition is assessed before harvest to determine the cut and leave that will achieve the timber-goal, or that harvesting is guided by a written strategy that has been formulated to achieve the timber goal. To this point, the evaluation has focussed exclusively on condition indicators.

Although no problem arose in the test evaluation, the indicator based on the ratio of value removed to volume removed may be unstable with low volume removals. Alternative formulations, such as the difference between % of value removed and % of volume removed, might prove to be both more stable and more visually revealing.

In the routine evaluation procedure, field crews had some difficulty interpreting the questions that were used to assess the overstory and understory factors. Also, it is necessary to re-phrase the factor questions so that the evaluators' assessments of low, medium, and high relate in a consistent way to the degree of conformance with government's objectives for timber. At present there is little to guide the surveyor in the assignment of a rating of low, medium or high to the various factors. Improvement here will make this component of the evaluation more objective and repeatable and make the information provided by it more accurate.

The current assessment process does not evaluate the spatial arrangement of overstory and understory trees in terms of whether it is efficient for future harvest, whether the observed block design will isolate timber, and whether another spatial arrangement would have been better. Several reviewers noted this as an important factor that should be added to the evaluation. Similarly, the timber goal can be compromised during partial cutting by excessive soil compaction and skid trail construction – issues that are not addressed in the current version of the evaluation. Also, harvest, salvage, slash management, and silviculture practices can change fire risk, but this factor is not specifically assessed in the evaluation.

Several reviewers suggested that multi-layer well-spaced density, summed over all four layers, was not an accurate measure of stocking in a population with wide variation in stand structure. In future evaluations, a more appropriate depiction may be obtained from an XY scatterplot of overstory basal area and understory well-spaced density.

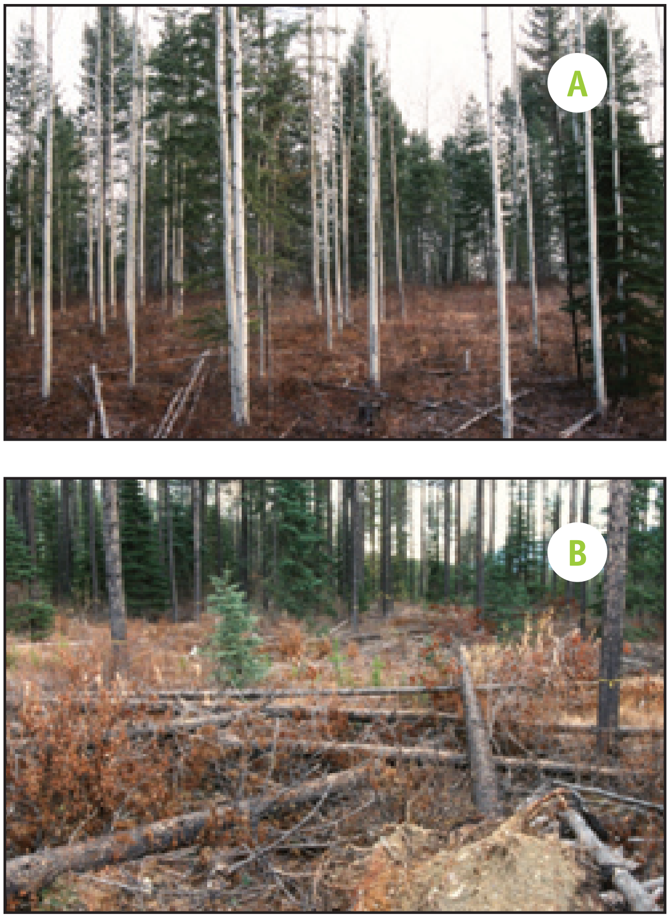

Figure 16. ***Partial cut areas with (A) conifer removed and deciduous retained and (B) blowdown score poorly on the evaluation, but may be desirable for various non-timber values.***

One report reviewer questioned how the indicator dead or down, and the evaluation generally, related to the "take or pay policy." This policy allows timber to be left on site if the licence-holder finds it uneconomic to remove and has paid the Crown for it. The relationship is complex. The dead or down indicator pertains to merchantable trees only, so timber left on site that is of a species that is not commercial, or a size or condition that is not merchantable, is not counted in the indicator. Also, logs left on site are not measured in the field procedure. Trees that are of a commercial species and are in good condition that are left live and standing contribute to the stocking indicator, whether or not the licence-holder has paid for them. Standing live trees that of poor timber quality are included in the indicator basal area poor timber, whether or not licence-holder has paid for them. Thus, some timber left on site, conforming to the take or pay policy, is included in the dead and down indicator, some is not included, and some is included in other indicators. In relation to the take or pay policy, and all other circumstances, indicators must be interpreted intelligently. Users must critically consider what the results mean and what is the appropriate management response given the unique circumstances of each particular evaluation.

Figure 17. ***Beetle-proofed stands score poorly on the indicator for pine remaining in a partial-cut area.***

5.6 *Benchmarks and Critical Values*

For some of the indicators used in the evaluation, and many indicators used elsewhere, the data to establish relevant benchmarks and set critical values is weak (Hagan and Whitman 2006). In some cases, benchmarks should be informed by indicator levels that are achieved under good (and poor) management. More sampling is needed to identify these levels. In other cases, benchmarks can be set based on management expectations, such as the stocking benchmark of 700 well-spaced trees per hectare that is commonly accepted in the BC interior. In other cases, a relevant benchmark is defined by an indicator's natural background levels. For some applications, the benchmarks and critical values will need to be localized. Growth and yield simulation studies could be used to help justify and refine the appropriate levels for benchmarks and critical values. In the interim, benchmarks could be established at indicator levels that roughly translate to a 10-20% reduction in volume or value. In general, the method would be improved by further developing the benchmarks to which observed indicator levels are compared.

5.7 *Scale Issues and Other Formulations of the Timber Goal*

The objectives set by government for timber in section 6 of the FPPR are in three parts. However, the evaluation addresses only the first part – "to maintain or enhance an economically valuable supply of commercial timber." The second part is to "ensure that delivered wood costs…are competitive." This suggests the potential for a FREP evaluation of the degree to which the observed partial cutting and post-harvest condition achieve, now and in the future, low delivered wood costs. The third part, in simple terms, is to ensure that government policies "do not unduly constrain" the ability of a licensee to operate. Thus, this evaluation considered only one of the three distinct sub-objectives that comprise the government's objectives for timber as stated in FRPA.

An "economically valuable supply" might be conceived as one where the return merits the cost incurred to produce it. Net present value could be proposed as an appropriate metric to represent the objectives set by government for timber. From this perspective, an economically valuable supply is sustained or enhanced when the discounted sum of current and future harvesting, silviculture and other relevant costs and revenues are maximized. In contrast, the adopted assessment approach does not consider costs and "time value" of money (addressed by discounting). Though this approach was not incorporated into the evaluation procedure, in those cases where intensive data is collected and stand development forecast with a stand growth model, an economic perspective could be added to the analysis of the intensive data (e.g., Haight and Monserud 1990).

This evaluation is focused on assessing condition in areas that have been partially harvested. The rest of the forest that is outside of this population is ignored. However, a broader scale assessment that locates the partial-cut population within the context of the larger, surrounding forest is also possible. This alternative could utilize forest-level simulation to examine the long-term impact of harvesting and reforestation alternatives on volume and value flow from a forest encompassing both the partial-cut population and the rest of the forest area (e.g., Nelson 2006). With this type of evaluation, FREP could address questions like the following. To most fully achieve the FRPA timber goal, are the right stands being selected for harvest (in the right order), are the right stands being left unharvested, and is partial cutting being applied to the right stands to the right degree? Another approach would be to monitor and report some simple forest-level indicators such as the total area harvested and the area partially harvested annually within a management unit. This type of information would provide context for the interpretation of the results of a within partial-cut population evaluation. Clearly, these broad scale assessments may be a key area for future development of the FREP program. Many of the indicators that might be used in a forest- or landscape-scale evaluation will differ from those used in the routine and intensive evaluations described in this report.

Many potential users requested that FREP develop an evaluation procedure that leads to a conclusion for an entire block. The current evaluation procedure assesses condition at a single observation point. Foresters, however, typically relate to cutblocks. Partial-cut areas are often heterogeneous, a mosaic of stand structures within a block, and this variability poses challenges for developing a method that leads to a reliable, defensible judgement on a cutblock at reasonable cost. One possible approach is to record observations at a set of sample points within a cutblock, translate the observations at each sample point to a score (e.g., a score on a scale of 1 to 100), and average the scores at all sample points within the block to depict the overall level of achievement of the FRPA timber-goal. Developing a cutblock-level evaluation method is an area requiring development in subsequent years within the FREP program. It is most cost-effective and practical to evolve the routine - not the intensive - evaluation procedure to operate at the cutblock level.

Some reviewers suggested that the evaluation should be structured around the concept that the target level for the timber goal varies among sites. Under this view, to meet the government's FRPA timber goal, a stand should be cut and reforested in a way that maximizes the timber goal subject to satisfying the management objectives and constraints that necessitated the partial harvest. Future work on partial-cut evaluation could consider whether it is desirable and practical to evaluate an observed condition against this floating benchmark (the post-harvest condition that maximizes the timber-goal subject to satisfying the management objectives and constraints that necessitated the partial harvest). However, this assessment would be rather subjective and expert field crews would be required to obtain results likely to be accepted by a wide range of stakeholders.

5.8 *The Broader Management Context*

The evaluation uses a standard, generic set of indicators to test stand conditions against a single management goal. While developing the evaluation methods, users repeatedly raised concerns about how to reconcile this approach with the full and complex reality of multiple management goals and unique local circumstances. One view is that the indicators, benchmarks, and critical values used in the evaluation should be tailored to the specific management objectives and constraints that apply in the evaluated area. The alternate view holds that this degree of local calibration is not practical inside the evaluation method. Rather, post-harvest condition should be compared to a generic benchmark of quality timber management, regardless of the local situation. Then, after scoring the condition in this way, the particulars of the local management objectives and constraints should be considered in the process of judging whether the achieved condition is reasonable. This later option is the approach adopted in the assessment process outlined here. To support this assessment, a section could be added to the evaluation where evaluators describe:

i) why the indicator (or factor) has the observed value,

ii) what change to management practice would improve the result, and

iii) to what estimated level would the change improve the indicator.

To provide guidance to this interpretation phase of the evaluation, it may be desirable to write a guide to interpreting timber-goal evaluation results. The evaluation sheds light on timber volume and value, and provides valid estimates, but it does not address all considerations that must be integrated to form an opinion on whether overall management is good.

5.9 *Monitoring and Evaluation*

Data from a network of remeasured permanent monitoring plots could be particularly helpful. The appropriate design for, and examples of the potential uses of, a growth and yield monitoring program are well documented in BC (e.g., JS Thrower and Associates Ltd. 2000, 2002). Within the ministry, permanent monitoring plots are the responsibility of Forest Analysis and Inventory branch (FAIB). Also, at this time, FAIB intends to monitor on an annual basis the volume harvested by species by management unit in the BC interior. This initiative could prove to be a useful source of information for FREP.

FREP evaluations can conceivably address a very wide range of partial cutting questions. An evaluation, such as this one, that is designed to assess the degree to which a stated goal is being achieved, is not be optimal for achieving other possible evaluation objectives - such as identifying the impediments to improving outcomes, determining the most feasible, cost-effective ways to improve practices, and estimating the extent to which an observed result is due to a particular practice. Though this evaluation can shed light on some of these issues, it was not specifically designed to accomplish these ends and thus it can only suggest possible answers that will require confirmation through additional work. More broadly, this evaluation was not a comprehensive assessment of partial cutting. Is it an appropriate role for FREP to conduct a broader evaluation of partial-cut practice? If so, significant changes are required to the evaluation. A broader evaluation might gather evidence on inputs, efforts, planning, and resources to support recommendations on changing practices. If this is desired, it could be developed as a separate component that can be added to the routine evaluation procedure operating at the cutblock-level.

Districts cannot rely solely on this evaluation to meet their needs for a comprehensive evaluation of partial cutting. A district's evaluation needs are typically much broader than the scope of this timber-focussed evaluation. However, some important district needs can be addressed by this evaluation. In addition, districts can add data collection to the FREP procedure to help the district meet their broader evaluation needs.

This evaluation used the approach of triangulation (multiple methods and lines of evidence) common to evaluations in many fields (McDavid and Hawthorne 2006). The use of multiple methods provides the most insight and reliable assessment. To capture these benefits in future evaluations, it may be best to combine routine evaluations with a sub-sampling of intensive evaluation. Last, it may be possible to generate timber-goal assessments from the data collected in other FREP evaluations (such as the FREP biodiversity evaluation). This could be a first step toward an integrated multi-objective FREP evaluation.

5.10 *Partial Cutting Silviculture Policy and Stocking Standards*

A key requirement, arguably the most significant silvicultural policy requirement of government, is that harvested areas must satisfy the stocking standards assigned to them. The general form of these standards is that crop tree stocking must equal or exceed a specified minimum. In partial-cut areas, stocking standards are expressed in various terms, including basal area per hectare and well-spaced trees per hectare. Typically, these standards require that within the NAR, no contiguous area greater than one or two hectares is permitted to have a level of crop tree stocking that is less than the standard. Guidelines describe the characteristics that a tree must have in order to be classified as a crop tree and contribute toward satisfying the stocking standard (e.g., BC Ministry of Forests 2000, 2002).

A comparison of the indicators developed in this evaluation to the simple, single measures of the stocking standards highlights the fact that in partial-cut areas there are some dimensions of timber management excellence that are not reflected in the stocking standard. Training programs (such as the now-defunct Silviculture Institute of BC) and guidance documents (such as the Coast Forest Region's CRIT paper on partial cutting (BC Ministry of Forests 2006)) help ensure that those planning and implementing partial cutting are aware of those important aspects of partial cutting excellence that are not captured by BC's simple partial-cut stocking standards.

6.0 Conclusions

6.1 *FREP Evaluation Methods*

1. The intensive evaluation procedure is generally ready for application in partial-cut populations in the BC interior. To use other stand growth models (such as TASS or SORTIE) in the intensive evaluation some changes in procedure are required. A small test is warranted with TASS, and possibly SORTIE, in partial-cut areas in the northern or central interior to identify, make, and test the necessary changes to the intensive evaluation procedure.
2. Additional work is required to adapt the intensive evaluation procedure to coastal conditions.
3. The routine evaluation procedure needs much more work. Using the current routine evaluation procedure as a starting point, the procedure should be completely re-worked to devise a method that operates at the cutblock (or SU) level. In this process, the indicators, factors, and overall approach of the routine evaluation should be discussed with potential users and the research community.
4. The factor questions require some standardization and improvement to make the factor ratings of evaluators more objective and repeatable. In future implementations, more effort needs to be spent training field crews in the factor questions.
5. The benchmarks and critical values used in both the routine and intensive evaluations would benefit from further development, testing, and substantiation. In some cases this will involve seeking input from forest managers, potential users, and the research community. In other cases this will involve assembling data to estimate normal background levels or indicator levels operationally achievable under good management.
6. Stand growth simulation could be used to test and refine the evaluation procedures. Over a range of post-harvest conditions, the evaluation procedure should be able to consistently separate good from poor outcomes as predicted by the simulator.
7. Better methods are required for identifying stump species. Additional training, better identification methods, or some other solution to this problem needs to be found.

8. The utility of evaluations can be increased by adding a small number of carefully chosen additional observations. In some cases, this may include integrating information from other data sources into the evaluation – e.g., silviculture data from RESULTS or licensee systems such as GENUS, data on the genetic worth of planted trees (from SPAR), timber cruise information, harvest billing (scale data), etc. Challenges will arise because the basic spatial unit for these data elements varies (e.g., cutblock, cutting permit, SU, or forest cover polygon (stratum) within the cutblock).

9. Evaluation approaches based on a landscape- or forest-level formulation of the government's objectives for timber would be most useful. These may entail forest-level modelling of harvesting and reforestation options to identify the management scenario that will best achieve government's objectives for timber. Current practice could then be evaluated by comparing it to this best timber management scenario.

10. The evaluation focussed on outcomes, not inputs (such as expenditures on treatments), activities (such as the number of surveys and treatments), and processes (such as systems and operating procedures used in managing areas). If FREP wants to expand the scope of the evaluation, the methods could be enhanced to gather information on activities undertaken, costs incurred, effort expended, and so on.

11. It is important to continue discussing evaluations with ministry and licensee staff, and other interested parties. Discussion is needed on the strengths and weaknesses of evaluations, the appropriate use of evaluation results, as well as debate as to the appropriate focus for FREP evaluations. One challenge for FREP is to develop technically sound evaluation protocols. However, a second challenge, equally important and meriting substantial effort, is to help develop people and processes so that science-based evaluations are used in managing BC's forests. Every pilot of a new protocol could include a phase to test processes for utilizing FREP evaluation results.

12. Data from other monitoring efforts may be useful to FREP. For timber-oriented evaluations, data from remeasured growth and yield monitoring plots could be especially valuable. The ministry's Forest Analysis and Inventory Branch is the lead in this area.

13 The FRPA objectives set by government for timber are very broad, encompassing delivered wood costs relative to competitors, constraints on operations, and maintaining wood supply. Some components of the objectives are better suited to FREP evaluation than others. Thus, it seems both likely and reasonable that FREP evaluation of the FRPA resource value timber will continue to focus on a manageable portion of the full objectives.

6.2 *Conditions in the Evaluation Test Area*

1. Stand conditions in the partial-cut population are generally consistent with the government's objectives for timber.

2. Many dimensions of stand condition in the population of partial-cut areas are strongly contributing to government's objectives for timber, including prompt, full stocking; low levels of dead or down timber; low levels of poor timber quality overstory trees retained; most pine volume removed; and balance in value and volume removal. However, the high volume of non-pine species removed during harvest was judged not consistent with government's objectives for timber, given the current beetle-outbreak. In addition, the results of the evaluation raise moderate concerns over understory tree species diversity and interference by poor quality trees with the growth of understory crop trees. Partial cutting has reduced standing volume, captured pine volume that was expected to be lost to the beetle and extracted a lot of volume in other species. If maintained in their current condition, some of the residual stands will achieve lower rates of volume production over the long-term than they would if they were clearcut.

3. In these partial-cut areas, government's objectives for timber would have been (or will be) more fully realized by

   i) reducing the harvest of non-pine tree species,

   ii) increasing understory tree species diversity,

   iii) reducing interference with crop trees by poor quality trees, and

   iv) when a follow-up harvest pass is possible, prioritize overstory removal in areas where long-term production rates are anticipated to lag significantly below rates possible under clearcut.

6.3 *Silviculture Policy*

1. Some aspects of excellence in partial-cut timber management are not reflected in partial-cut stocking standards. Training programs and guidance documents can help ensure that resource professionals are well-aware of:

    i) all of the factors that determine the quality of partial-cut timber management and

    ii) suitable indicators of the degree to which conditions in partially harvested areas will maintain or enhance an economically valuable supply of commercial timber.

7.0 Recommendations

7.1 *FREP Evaluation Methods*

1. FREP should initiate a small project to apply the intensive evaluation method in partial-cut areas outside of the southeast using TASS, or possibly SORTIE, for yield forecasting. This test should aim to make the changes to the intensive procedure necessary to supply the data required for TASS (or SORTIE) growth model simulations.
2. FREP should develop the intensive and routine evaluation procedures for application in coastal partial-cut populations.
3. In 2009, FREP should consider gathering intensive evaluation data at 50 sample locations randomly located within the complete population of area partially harvested in the province in 2005. This initiative would further test the procedures, introduce FREP staff to the procedures, generate baseline data to characterize timber condition, and help set benchmarks and critical values.
4. FREP should i) standardize the factor questions so that the ratings relate in a consistent way to the degree of goal achievement, and ii) work to make the factor ratings more objective and repeatable through training, aids to guide ratings, and so on. In addition, FREP should try to devise indicators that can be computed from the detailed tree measurements that replace or parallel some of the factors.
5. Using the current routine evaluation procedure as a starting point, FREP should completely re-work the procedure to devise a method that delivers a conclusion at the cutblock (or SU) level.
6. Once FREP is satisfied with the intensive evaluation method, FREP should complete all follow-up steps required to make the method operationally available, including developing a training package, field cards, and data storage procedures.
7. FREP should give consideration to initiating a project to use stand growth simulation to test, refine, and validate the evaluation procedures. Over a range of post-harvest conditions, the evaluation procedures should consistently separate good from poor timber outcomes as predicted by the simulator.

8. FREP should continue efforts to discuss FRPA timber-value evaluations with forest managers, potential users, and the research community. Discussions should aim to make interested parties more familiar with evaluations, what they offer and what their limitations are, and how to properly interpret and use their results. Each pilot of a new FREP protocol should include a phase to practice using the evaluation results.
9. FREP should initiate a project to test, refine, and further substantiate the benchmarks and critical values.
10. FREP should initiate work to improve the accuracy of stump species identification.
11. FREP should consider additional data collection in the evaluations. For all data elements it should be clear that the benefits of collection outweigh the costs and that the purpose that this data is collected to serve can not be better achieved in another way. To both the routine and intensive evaluations, the following types of additional data collection should be added: i) the key factors that the assessor believes have contributed to the observed indicator levels, and ii) the significant opportunities to improve the indicator levels by a change in management practices.
12. FREP should consider developing evaluation methods that provide a landscape- or forest-level perspective on the government's objectives for timber. For example, evaluations that use forest-level modelling of harvesting and reforestation options to compare current approaches with those that will best achieve government objectives for timber.
13. FREP should consider commissioning a team to develop an algorithm to produce an overall composite score from the many individual indicators.
14. FREP should consider whether evaluations of other components of the timber goal, or other formulations of the timber goal, are warranted. More broadly, FREP should consider whether it is appropriate to broaden it's timber evaluations beyond the current narrow focus on judging whether outcomes are consistent with FRPA objectives. In particular whether to collect information on treatments, expenditures, resources, efforts, plans, and so on. If so, this should be developed as a component that can be added to a routine evaluation operating at the cutblock scale.
15. FREP should review the recent partial-cut evaluation work by the Forest Practices Board, Coast Forest Region, and other related work, as well as the evaluation work of Alex Woods, to identify ways to improve the FREP timber evaluations. FREP should contribute to identifying the appropriate roles for various groups developing, conducting, and reporting the results of timber-related evaluations. FREP should plan for the development of a comprehensive set of FRPA timber-value evaluation tools. FREP should work toward a unified evaluation method applicable to the full spectrum of post-harvest conditions (clearcut to partial-cut).
16. FREP should maintain communication with the ministry's Forest Analysis and Inventory Branch (FAIB) to ensure that they are aware of FREP's program and information needs and to support the efforts of FAIB to establish a network of permanent stand growth monitoring plots.

7.2 *Partial Cutting Practices*

The results of the test evaluation lead to the following recommendations for partial-cutting in the evaluation test area and beyond.

1. Forestry professionals should work to continue achieving in the test area, and to achieve elsewhere in the province, high stocking levels, low levels of dead or down merchantable timber, high levels of pine removal, low level of retention of poor quality timber, value removals not greatly exceeding volume removals, and low level of damage to retained trees.
2. Forestry professionals should work to improve in the test area, and achieve elsewhere in the province, high levels of retention of non-pine trees of high timber quality, high levels of diversity of desirable understory tree species, and low levels of interference with crop trees by poor quality trees.
3. When a follow-up harvest pass is possible, overstory removal should be prioritized in areas with production rates that are expected to lag significantly below the rates possible under clearcut over the long-term.

7.3 *Silviculture Policy*

1. FREP should ensure that the appropriate staff within the ministry's Forest Practices Branch are aware of the many dimensions of excellence in partial-cut timber management that are revealed by the set of evaluation indicators. FREP should advise the appropriate Forest Practices Branch staff that this evaluation highlights that some aspects of quality, excellence, and performance are not captured in the typical part-cut stocking standard. FREP should advise the appropriate Forest Practices Branch staff that when providing training or guidance documents related to partial cut stocking standards, or the silvicultural aspects of partial cutting, staff should communicate all of the components of partial-cut timber management excellence that are identified in the FREP partial-cut timber-goal evaluations.

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Appendix 1. Project Plan

Project Title	Timber-focussed evaluation of partially harvested areas in a management unit in south-eastern BC	
Project Lead	Patrick Martin, Forest Practices Branch, Ministry of Forests and Range	Phone No. 250-356-0305 / Email: Pat.Martin@gov.bc.ca
Project Purpose	This project is focussed on the timber value under FRPA (Forest and Range Practices Act). In broad terms the purpose of the project is to evaluate the results of recent partial cutting in a management unit in south-eastern BC, build FREPs (FRPA Resource Evaluation Program) capability to evaluate partial cutting, and make recommendations to improve partial cutting practices, standards, and evaluation capability. More specifically: 1. For areas partially harvested in a management unit in south-eastern BC, characterize post-harvest stand condition in terms of its implications for government's goal to "maintain or enhance an economically valuable supply of commercial timber" (part of the government's objective for timber, FPPR s. 6(a)). 2. Add to FREP's capability to evaluate partial cutting in other areas of the province. 3. Make recommendations for improving harvesting and silviculture practices, partial harvest stocking standards and their implementation and administration, and FREP's partial cutting evaluation capability. In 2007, a second phase may be added to the project to i) collect additional data and ii) evaluate the effectiveness of the Rocky Mountain Forest District (RMFD) DFP (Deviation From Potential)-based stocking standard in assuring that partially harvested areas are healthy, diverse, valuable, and productive.	
FREP question(s)/ research question(s) project will attempt to answer	In terms of the FREP priority questions (2006/07 FREP Resource Value Priority Questions List – Version 1.4), this project will make a substantial contribution to addressing Question #11 (Are partial cutting forest practices sustainable as measured by maintenance of forest productivity? Are regeneration opportunities under partial cutting being maintained or diminished?). The specific questions that this project will address are: 1. What is the condition of a defined population of partially harvested areas in a management unit in south-eastern BC? 2. Are post-harvest stand conditions consistent with the goal of maintaining or enhancing an economically valuable supply of commercial timber? 3. Based on the results of the evaluation, what are the recommendations for improving practices, standards and evaluations? The second phase of the project will address FREP priority question #17 (What new, creative and innovative forest and range practices have resulted from FRPA? Were these innovative practices more effective and/or efficient in achieving the resource value objectives set by FRPA?). Specifically, is RMFD's new DFP-based stocking standard effective – especially relative to the traditional stocking standard that it replaced - at ensuring that partially harvested areas are healthy, diverse, valuable, and productive?	
Objective(s)	The objectives of the project are to: 1. Provide an accurate quantification of stand conditions in a defined population of partially cut areas in a management unit in south-eastern BC; 2. Assess the impact of post-harvest stand condition on the FRPA timber goal using stand growth forecasting techniques; 3. Develop and test new methods for evaluating partial cutting that can be adapted to other evaluations in other locations; 4. Develop and test simple indicators that can be used in FREP timber-focussed routine evaluations of partial cutting; and	

Objective(s) (con't)	5. Based on evaluation results, make recommendations to improve practices, standards and evaluations. The objective of phase 2 of the project is to provide insight into the effectiveness of the RMFD DFP-based stocking standard in partial cuts.
Background Situation	Under certain circumstances, partial cutting is required for the sound management of forests. However, when it is used inappropriately, or poorly executed, partial cutting can harm stands and reduce their value to society. In some portions of BC, partial cutting is common. As a result, evaluations of partial cutting practice and standards are urgently required, and both resource professionals and the public have an interest in them. With the current mountain pine beetle outbreak, a common partial cutting practice in BC's interior is to salvage lodgepole pine from mixed species stands. For this harvesting practice, it is useful to: 1. develop methods to describe post-harvest condition in a population of partial-cut stands, 2. forecast the future development of these partial-cut stands, 3. interpret the current and predicted conditions in terms of their impact on government's FRPA objectives for timber, 4. conduct a test of the data collection and analysis methods, and 5. complete an evaluation for a given partial-cut population. In 2003, in response to industry and ministry dissatisfaction with traditional stocking standards, the RMFD adopted a new type of stocking standard for partially cut areas – the "DFP-based stocking standard." Outside of the RMFD many others are interested in (or concerned about) developing new types of stocking standards, or using DFP-based stocking standards, to regulate partial cutting. At various locations around the province, there is great concern about partial cutting and whether standards are effective at protecting resource values. With the introduction of FRPA in 2004, the format and content requirements for stocking standards were generalized, opening the possibility of widespread innovation in the form and content of stocking standards. Phase 2 of this evaluation (if it proceeds) will provide a quantitative assessment of the effectiveness of one new type of standard in protecting critical elements of the FRPA timber value. The phase 2 component of the evaluation will be of interest to foresters working with partial cutting anywhere in the province. The evaluation methods will provide a worked example that can be adapted in future evaluations of other stocking standard formulations. The method that will be developed for evaluating partial cuts relative to the FRPA timber goal will be of interest, and adaptable for use, province-wide. Finally, the recommendations will have applicability outside of the RMFD.
Scope (In & Out)	The evaluation focuses on aspects of the FRPA timber value, though partial cutting has implications for other values. The evaluation is not a comprehensive assessment of partial cutting. For example, issues of timber pricing, waste billing and visual quality management, key drivers of partial cutting practice, will not be addressed. Districts cannot rely solely on this evaluation to meet their needs for a comprehensive evaluation of partial cutting or the new RMFD DFP-based stocking standard. District's evaluation needs are much broader than this scope of this project. However, some important district needs will be addressed by this project. In addition, the project will be structured to help district's meet their broader evaluation needs. The project will characterize the condition of the NAR (net area to be reforested) in a defined population of stands in a management unit in south-eastern BC that have been partially harvested. The condition of other populations (non-NAR, older harvests, and other geographic locations) cannot be inferred from this sample. The design generates a set of point samples from the population. It will not produce polygon-level assessments of attributes such as polygon average basal area per hectare, polygon average well-spaced trees per hectare, and the size and location of NSR (not satisfactorily restocked) patches. The project is an effectiveness evaluation not a compliance audit.

Scope (In & Out) (con't)	The population may include stands that have been harvested in the last several years. In some of these areas, planting may not be complete, natural ingress may be ongoing, and windthrow may not yet have stabilized. The project has a limited budget and a tight delivery schedule. To manage within the budget limits, sample size will be relatively small and the assessment of RMFD's DFP-based stocking standard has been structured as a second phase. The project is designed so that it can be scaled up if more resources become available. To manage within the limited time frame, opportunities for review and consultation will be limited. The evaluation relies heavily on stand growth model forecasts as this is the direction from FPB FREP staff.
Method/Actions	The basic steps are outlined below. 1. Create a project plan. Circulate the plan for review. Update the plan based on the review comments. 2. Pilot test the data collection, management, summary, and analysis procedures. Update the project plan based on the results of the pilot. 3. Develop a preliminary set of routine indicators for the FRPA timber value that are suitable for partial-cut stands. 4. Develop a sample frame of candidate polygons. Randomly select 30 sample locations in the population plus another 10 as backup. 5. At each sample point, sample standing trees (species, diameter, #/ha, height, live crown ratio, and condition class), stumps (species, diameter, and #/ha), site characteristics (BEC, slope, aspect, and elevation), stocking (well-spaced tree count by layer), and timber goal indicators (possibly amount, dimension, quality/value group, stocking, species value group, species productivity, growth potential, genetic worth of planted trees, etc). 6. Enter field data into a database. 7. Compile data to describe post-harvest condition (e.g., mean and distribution of retained tree basal area per hectare by species, #/ha retained, DFP, etc). 8. Compile data to prepare inputs for PrognosisBC. Develop four alternative management scenarios: current stand condition, stand condition before harvest, clearcut and plant, and best partial harvest timber management. 9. For each sample, conduct 50-year PrognosisBC simulations to forecast stand development under the four scenarios. Extract predicted merchantable volume per hectare and apply timber values to compute value per hectare over time. Compute the deviation of current stand condition from each scenario. 10. Analyze the results to assess the implications of current post-harvest condition on the FRPA timber goal and to develop recommendations for improving practices and standards. 11. Summarize results in a report. 12. In phase 2, i) analyze data (and possibly conduct survey simulations) to characterize situations where the alternative standards are superior, inferior, and similar to the traditional standards; and ii) test the preliminary indicators by assessing the strength of association between the indicators and the forecasts of long-term volume and value.

Key Deliverables/ Milestones and Timelines (Attach more detailed workplan if known)	**Deliverable/Milestone**	**Responsibility**	**Timeline**
Estimated Cost (Total and breakdown)	See Table 2		
Stakeholder Involvement	FPB FREP staff: P. Bradford and F. Barber Project Leader: Patrick Martin Project Sponsors: Lorne Bedford and Ralph Winter District contacts: P. Chalifor, L. Konowalyk, and D. Petryshen Licensee contacts: D. Basaraba, P. Frasca, and K. Tindall Southern Interior Regional contact: I. Listar Technical advisors to be determined: inventory/cruising specialist, growth and yield modeling specialist, statistician, and operational and research silviculturists		
Risk Management	There are numerous risks to the successful execution of this project. The limited budget and short time frame pose risks that will be managed by tightly adhering to the project schedule, and by the narrow focus for the project and the modest sample size targets. Some of the methods are untested and this poses risks that will be managed by pilot testing the procedures, seeking the advice of various specialists, and by the small scale of the first year of the project.		
Quality Management	Quality will be assured through: 1. Peer-review of work plan. 2. Selection of qualified contractors for data collection, database management, growth model simulations, and analyses. 3. Quality assurance provided by the Project Leader on the field work.		
Other (e.g. related initiatives or considerations of note)	Related initiatives include: 1. Forest Practices Board special project on partial cutting. 2. Coast region evaluation of partial cutting. 3. Numerous other initiatives around partial cutting are underway in the ministry, including a review by B. Raymer		
FREWG Approval	**Name**	**Date**	
Comment			
Project Team Commitment and sign-off			

Appendix 2. Relation of Indicators to the Goal

The evaluation is founded on assumed relationships between the indicators and the goal. The conditions in partial-cut stands that contribute to maintaining or enhancing an economically valuable supply of commercial timber are well known. Centuries of practical experience and research support a few fundamental principles, widely accepted by silviculturists, and well-articulated in the definitive silviculture texts (e.g., Oliver and Larson 1996, Smith et al. 1997). These basic principles for managing partial-cut areas for timber volume and value were used to create the set of indicators. For the intensive and the routine evaluations, the indicators and relationships to the goal are described in tables A2-1 and A2-2, respectively.

Table A2-1. Indicators used in intensive evaluation and their relation to the goal.

	Indicator	Relation to the goal
1.	Predicted future volume trend	When predicted future standing volume, cumulative volume yield, or volume recovery rate, compare favourably with stand and site potentials, stand conditions are consistent with government's objectives for timber.
2.	The level of stocking	Vacant growing space results in volume and value losses. When the partially cut area is adequately stocked, stand conditions are consistent with government's objectives for timber.
3.	Volume of merchantable dead or down wood	A high volume of merchantable dead or down wood, if it is not recovered, results in lost volume and value. When partially cut areas do not contain large volumes of merchantable dead or down wood, stand conditions are consistent with government's objectives for timber.
4.	Level of pine removal	In the study area, mature lodgepole pine is in imminent danger of attack by mountain pine beetle. Value, and eventually recoverable volume, declines following attack. Extracting pine captures volume and value that will likely be lost. Under these conditions, when the level of pine removal is high, conditions are consistent with government's objectives for timber.
5.	Level of non-pine removal	In the study area, there is a high standing volume of lodgepole pine and it is in imminent danger of attack by mountain pine beetle. Conserving other tree species (e.g., avoiding the harvest of non-pine species) provides a future supply of volume and value and allows the AAC and harvest effort to be focused on extracting the pine that is in immediate risk of loss. Under these conditions, when the level of non-pine harvest removal is low, conditions are consistent with government's objectives for timber.
6.	The degree of site occupancy by poor quality trees	Standing and future volume and value are reduced when high levels of poor quality trees are retained during partial harvesting. When the degree of site occupancy by poor quality trees is low, stand conditions are consistent with government's objectives for timber.
7.	Value removal relative to volume removal	With a light removal, site growing space is largely captured by the remaining canopy trees. Under these conditions, seedlings and saplings can not readily grow into the canopy, so value production must come mostly from the residual canopy trees. Removing the high value component and retaining a heavy canopy of low value trees, thus reduces both standing value and the value production potential. When the percent of pre-harvest value removed from stands does not greatly exceed the percent of pre-harvest volume removed, conditions are consistent with government's objectives for timber.

In addition to indicators developed for use in intensive evaluation, indicators and factors were developed for use in routine evaluations (Table A2-2).

Table A2-2. ***Indicators and factors used in routine evaluation and their relation to the goal.***

Stand component		Indicator or factor	Relation to the goal
Overstory	1.	Indicator: growing space occupancy by poor quality trees	Volume and value production are reduced when high levels of poor quality trees are retained during partial harvesting.
	2.	Indicator: value removal relative to volume removal	Value production is reduced when a partial cut removes the most valuable component and leaves the least valuable component to expand into the released growing space and, by competing with them, reduce the ability of the more valuable trees to grow.
	3.	Factor: Risk of windthrow	Standing volume and value, and net production rates of volume and value, are reduced by heavy unsalvaged windthrow. A high risk that retained trees will blow down indicates that the timber goal may not be met.
	4.	Factor: Risk that root disease will cause decline or death of overstory trees	Standing volume and value, and net production rates of volume and value, are reduced by root disease. A high risk that root disease will damage retained trees indicates that the timber goal may not be met.
	5.	Factor: Risk that other factors will cause decline or death of overstory trees	A high risk that other factors will cause decline or death of retained trees indicates that the timber goal may not be met.
	6.	Factor: Growth potential of retained overstory trees (considering percent live crown, tree size and maturity, live pointy tops, etc)	Volume and value growth may be reduced if retained trees have low growth potential.
	7.	Factor: Diversity of tree species in overstory (considered relative to pre-harvest species diversity)	Risk of catastrophic loss to volume and value may be increased, and the reliability of volume and value yield reduced, if the diversity of overstory tree species is reduced.
	8.	Factor: Frequency and severity of damage to retained trees (considering crown, stem, and roots)	Volume and value growth may be reduced if retained trees are damaged.
	9.	Factor: Likelihood that if they were not harvested, the extracted trees would have soon experienced decline or death	Cumulative volume and value production is increased if trees likely to soon die are harvested.
	10.	Factor: If, among the overstory trees before harvest, one species group was considerably more valuable, what proportion of these trees were retained?	Future value production is enhanced if retained trees include some from the high value species group.

Understory	11.	Indicator: stocking	Volume and value growth are reduced by low levels of stocking
	12.	Factor: Forest health risk to understory (considering root disease, budworm, mistletoe, etc)	Net production rates of volume and value, and yield reliability, are reduced by severe pest damage to the understory. High forest health risk to understory trees indicates that the timber goal may not be met.
	13.	Factor: Non-crop vegetation competition risk to understory	Net production rates of volume and value are reduced by severe non-crop vegetation competition with understory crop trees. High risk of vegetation competition indicates that the timber goal may not be met.
	14.	Factor: Probability of additional natural regeneration in the future (considering seed supply, seedbed, environmental stress, abundance of germinants, natural regeneration on similar sites, etc)	Net production rates of volume and value are reduced when partial cutting opens stands and understory stocking is inadequate to capture unutilized growing space. When this occurs, a low probability of additional natural regeneration indicates that the timber goal may not be met.
	15.	Factor: Diversity of tree species in understory (considered relative to pre-harvest species diversity, site plan preferred and acceptable species, etc)	The reliability of future yield is reduced when the diversity of desirable understory tree species is much less than it could be. A level of understory tree species diversity well below potential indicates that the timber goal may not be met.
	16.	Factor: Degree to which stocking in the seedling and sapling layer is dominated by genetically improved (A class) trees	Net production rates of volume and value are reduced when stocking in the seedling and sapling layer is not dominated by genetically improved (A class) trees. A level of stocking domination by genetically improved (A class) trees well below potential indicates that the timber goal may not be met.
	17.	Factor: Degree to which the shade tolerance of seedlings and saplings is matched to local shading conditions	Due to reduced tree survival and health, net production rates of volume and value are reduced when the shade tolerance of seedlings and saplings is poorly matched to local shading conditions. Poor correspondence between the degree of shading and the shade tolerance of seedlings and saplings indicates that the timber goal may not be met.
	18.	Factor: Abundance of the more productive tree species	Net production rates of volume and value are reduced when species differ substantially in productivity and the more productive species are not present in significant amount. A low presence of the more productive species indicates that the timber goal may not be met.
	19.	Factor: Abundance of the more valuable tree species	Net production rates of value are reduced when species differ substantially in value and the more valuable species are not present in significant amount. A low presence of the more valuable species indicates that the timber goal may not be met.
	20.	Factor: Amount of large, desirable advanced regeneration destroyed in logging	
	21.	Factor: Degree to which the preferred crop trees are free from interference by other poorer quality trees?	Net production rates of volume and value are reduced when the growth of preferred understory crop trees is impeded by interference from other poorer quality trees.

Appendix 3. Sample Selection

To select samples, a master list of all of the polygons that comprise the population was assembled from the data in RESULTS (Table A3-1). The sum of polygon areas was computed (677.2 hectares) and the lower and upper bounds of cumulative area were calculated for each polygon. Forty random numbers between zero and 677.2 were obtained using the random number generator in Excel (Table A3-2). Each time a random number fell within the cumulative area interval of a polygon, one ground sample was located in that polygon. To randomize the location of the sample point within the polygon, the current standards unit and forest cover maps were obtained for the cutblock that contained the selected polygon. A grid was laid over the polygon shape and each grid intersection that is within the NAR of the polygon was numbered. Grid points that fell on permanent access structures (roads and landings) and mapped reserves (primarily WTPs) were out of the population and not numbered. Using a random number table, a random number was selected that was ≤ the total number of grid points. The sample point was indicated on the polygon map at the selected grip point. Two additional points, replacement points, were also randomly located (using the same procedure) on the polygon map. If the survey crew found the selected point was not within the NAR of the selected polygon, the first (and if necessary the second) replacement points were used. Figure A3-1 illustrates the process for one polygon (CP/block/polygon: 177/13/A) that was selected once and thus contained one sample.

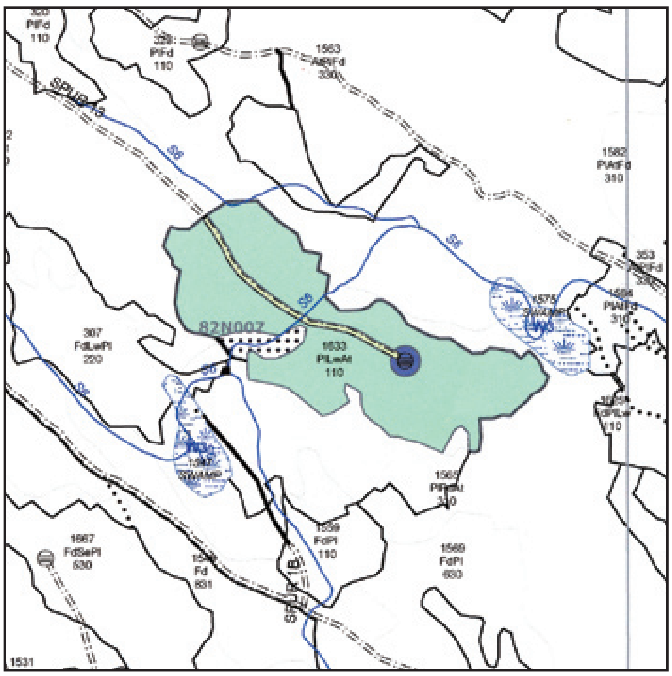

Figure A3-1-A. Example of the sample location process. This block contains a single forest cover polygon and a single standards unit with matching boundaries. The polygon was selected only once for sampling.

Figure A3-1-B. Example of the sample location process. A uniform grid was photocopied onto the cutblock map. Grid points within the polygon NAR were identified, numbered, and one number selected at random for the sample location. Two additional points were selected at random to serve as replacement points. In the field, crews used the map to determine distance and bearing to the sample point.

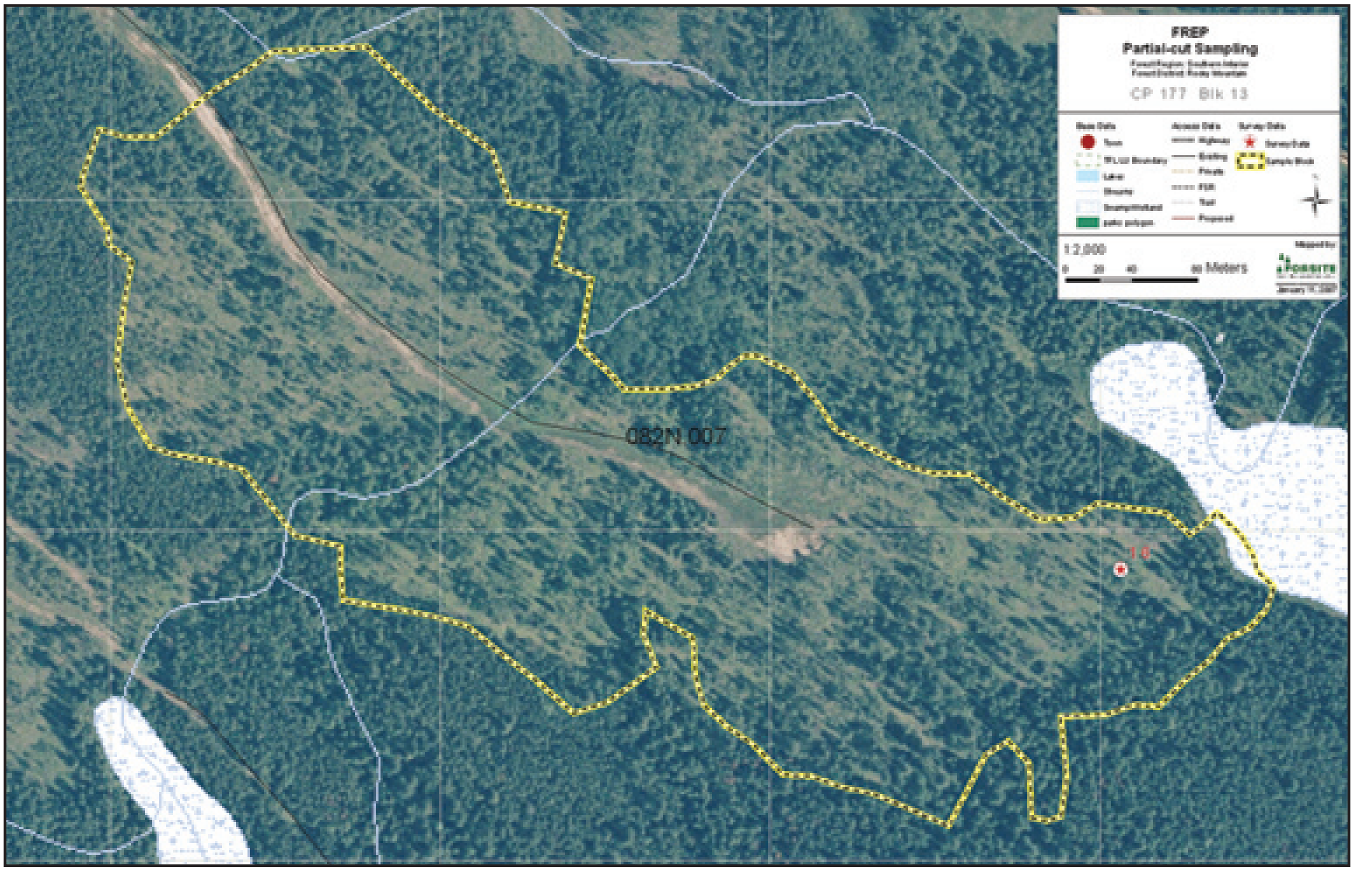

Figure A3-1-C. ***Example of the sample location process. GPS coordinates were taken at the sample point and later overlaid on the orthophoto.***

Table A3-1: ***Population list with cumulative areas and the polygons within which samples were located. Forest cover polygons in the management unit with layer 1 density > 75 total trees per hectare and disturbance start dates 2000-2002. Data source: RESULTS June 9, 2006. Data extracted by Mei-Ching Tsoi.***

Cutting permit	Timber mark	Cutblock	Disturbance start date	Opening ID	Silviculture polygon ID	Polygon net area (ha)	Stocking status code	Stocking type code	Refer-ence year	Layer 1 stem density (#/ha)	Cumulative polygon area (ha)	Cumulative area interval lowest value	Cumulative area interval highest value	Sample numbers
177	14/177	7	1/1/2001	97035	A	15.3	IMM	ART	2003	80	15.3	0	15.3	
177	14/177	13	2/1/2001	97041	A	13.4	IMM	ART	2003	80	28.7	15.300	28.7	16
177	14/177	6	2/1/2001	97034	A	5.3	IMM	ART	2002	80	34	28.700	34	
157	14/157	16	9/14/2001	66057	A	6.4	IMM	ART	2003	80	40.4	34.000	40.4	6
175	14/175	5	2/1/2000	88020	A	27.3	IMM	ART	2002	82	67.7	40.400	67.7	20
159	14/159	109	6/1/2001	50074	A	13.7	IMM	ART	2003	100	81.4	67.700	81.4	25, 36
175	14/175	20	1/1/2001	96434	A	39.5	IMM	NAT	2003	115	120.9	81.400	120.9	5
160	14/160	8	8/1/2000	65208	A	56.2	MAT	NAT	2002	156	177.1	120.900	177.1	4,8,32
157	14/157	15	10/1/2000	66056	A	9.1	MAT	NAT	2002	160	186.2	177.100	186.2	23
175	14/175	18	1/1/2001	96427	A	10.4	IMM	NAT	2003	160	196.6	186.200	196.6	
179	14/179	4	1/29/2002	105773	A	11.3	IMM	NAT	2003	164	207.9	196.600	207.9	26
175	14/175	11	3/1/2000	88025	A	8.1	IMM	NAT	2003	167	216	207.900	216	38
177	14/177	14	2/1/2001	97043	A	33.7	IMM	NAT	2003	180	249.7	216.000	249.7	
175	14/175	4	1/1/2000	88019	A	3.7	IMM	NAT	2002	200	253.4	249.700	253.4	18
175	14/175	13	2/1/2000	88027	A	8.1	IMM	ART	2002	200	261.5	253.400	261.5	12
175	14/175	17	2/1/2000	88031	A	3.1	IMM	NAT	2002	200	264.6	261.500	264.6	
160	14/160	7	8/18/2000	65207	A	34	MAT	NAT	2002	200	298.6	264.600	298.6	30
157	14/157	19	12/20/2000	66060	A	4	IMM	NAT	2003	200	302.6	298.600	302.6	
170	14/170	39	1/1/2000	85006	A	10.7	IMM	NAT	2003	222	313.3	302.600	313.3	17
170	14/170	39	1/1/2000	85006	C	9.5	IMM	NAT	2003	240	322.8	313.300	322.8	1
175	14/175	15	2/1/2000	88128	A	5.6	IMM	NAT	2002	240	328.4	322.800	328.4	
175	14/175	3	2/1/2000	88018	A	13.2	IMM	NAT	2002	240	341.6	328.400	341.6	29
175	14/175	19	1/1/2001	96431	A	12.1	IMM	NAT	2001	273	353.7	341.600	353.7	13, 21
160	14/160	6	8/1/2000	65206	A	2.9	MAT	NAT	2002	280	356.6	353.700	356.6	
157	14/157	21	11/1/2000	66062	A	6.9	MAT	NAT	2002	280	363.5	356.600	363.5	
157	14/157	19	12/20/2000	66060	C	5	MAT	NAT	2003	280	368.5	363.500	368.5	
177	14/177	11	11/14/2001	97039	A	13.4	IMM	ART	2004	280	381.9	368.500	381.9	
163	14/163	274	11/19/2001	56467	1A	3.7	IMM	NAT	2005	280	385.6	381.900	385.6	
177	14/177	10	11/27/2001	97038	2B	4.7	IMM	ART	2004	280	390.3	385.600	390.3	
179	14/179	3	1/29/2002	105772	A	4.2	IMM	NAT	2003	280	394.5	390.300	394.5	
164	14/164	4	9/10/2002	90287	B	19.3	IMM	NAT	2004	300	413.8	394.500	413.8	
175	14/175	12	1/1/2000	88026	A	7.6	IMM	NAT	2003	320	421.4	413.800	421.4	
175	14/175	1	2/1/2000	88016	A	4.7	IMM	NAT	2002	320	426.1	421.400	426.1	
177	14/177	12	1/1/2001	97040	A	2.1	IMM	NAT	2003	320	428.2	426.100	428.2	
132	14/132	11	1/2/2002	105051	1A	3.4	IMM	NAT	2003	320	431.6	428.200	431.6	

Table A3-1: *(continued)*

												Cumulative area interval		
Cutting Permit	Timber mark	Cutblock	Disturbance start date	Opening ID	Silviculture polygon ID	Polygon net area (ha)	Stocking status code	Stocking type code	Refer-ence year	Layer 1 stem density (#ha)	Cumulative polygon area (ha)	lowest value	highest value	sample numbers
132	14/132	6	1/14/2002	106220	A	3.1	IMM	NAT	2003	320	434.7	431.600	434.7	
177	14/177	10	11/27/2001	97038	1A	7.3	IMM	ART	2005	325	442	434.700	442	
179	14/179	10	1/18/2002	106274	A	4.3	IMM	NAT	2004	360	446.3	442.000	446.3	
132	14/132	36	11/20/2002	113563	A	6	IMM	ART	2004	360	452.3	446.300	452.3	
177	14/177	3	10/1/2001	97031	A	22.9	MAT	NAT	2003	382	475.2	452.300	475.2	24
132	14/132	3	8/13/2002	108458	2B	2.7	IMM	NAT	2004	400	477.9	475.200	477.9	33
177	14/177	1	1/1/2001	97030	A	24.1	IMM	NAT	2003	419	502	477.900	502	27, 35, 37, 40
157	14/157	18	10/1/2000	66059	A	4	MAT	NAT	2002	440	506	502.000	506	
175	14/175	9	1/1/2000	88046	A	28.5	IMM	NAT	2002	457	534.5	506.000	534.5	10
179	14/179	14	3/13/2002	106276	1A	13.5	MAT	NAT	2004	467	548	534.500	548	2, 28, 31, 34
158	14/158	235	6/20/2001	44841	A	10	MAT	NAT	2003	480	558	548.000	558	3, 7
132	14/132	7	8/13/2002	108460	A	5.1	IMM	NAT	2003	480	563.1	558.000	563.1	
179	14/179	4	1/29/2002	105773	B	10.7	IMM	NAT	2003	491	573.8	563.100	573.8	14
175	14/175	20	1/1/2001	96434	B	3.2	IMM	NAT	2003	520	577	573.800	577	
179	14/179	3	1/29/2002	105772	B	4.9	IMM	NAT	2003	533	581.9	577.000	581.9	
159	14/159	118	7/1/2000	50157	A	70.1	IMM	NAT	2001	562	652	581.900	652	15, 19, 22, 39
175	14/175	7	1/1/2000	88022	A	7.1	IMM	NAT	2004	629	659.1	652.000	659.1	9, 11
179	14/179	2	2/27/2002	105771	B	1.1	IMM	NAT	2003	680	660.2	659.100	660.2	
132	14/132	39	12/7/2002	113559	A	6.2	IMM	ART	2004	800	666.4	660.200	666.4	
132	14/132	3	8/13/2002	108458	1A	5.3	IMM	NAT	2004	833	671.7	666.400	671.7	
175	14/175	16	2/1/2000	88030	A	5.5	IMM	ART	2004	933	677.2	671.700	677.2	

Table A3-2. ***Forty random numbers between zero and 677.2 and the associated sample number.***

Random number	Sample number	Random number	Sample number	Random number	Sample number
320.3	1	588.4	15	336.3	29
539.1	2	21.3	16	293.0	30
551.4	3	312.6	17	543.2	31
137.1	4	249.9	18	146.6	32
118.2	5	640.6	19	476.3	33
35.8	6	57.1	20	545.7	34
551.5	7	346.9	21	483.2	35
136.4	8	628.0	22	73.0	36
653.2	9	179.2	23	491.6	37
521.4	10	468.3	24	212.9	38
652.2	11	80.7	25	609.5	39
258.6	12	202.4	26	495.7	40
348.2	13	486.0	27		
563.7	14	541.2	28		

Table A3-3. ***Sample numbers by forest cover polygon with some polygon characteristics and cutblock identifiers.***

Timber mark	Cutting permit	Cutblock	Silviculture polygon ID	Polygon net area (ha)	Disturbance start date	Opening ID	Stocking status code	Stocking type code	Reference year	Forest cover layer code	Layer 1 stem density (#/ha)	Sample numbers
14/132	132	3	2B	2.7	8/13/2002	108458	IMM	NAT	2004	1	400	33
14/157	157	15	A	9.1	10/1/2000	66056	MAT	NAT	2002	1	160	23
14/157	157	16	A	6.4	9/14/2001	66057	IMM	ART	2003	1	80	6
14/158	158	235	A	10	6/20/2001	44841	MAT	NAT	2003	1	480	3, 7
14/159	159	109	A	13.7	6/1/2001	50074	IMM	ART	2003	1	100	25, 36
14/159	159	118	A	70.1	7/1/2000	50157	IMM	NAT	2001	1	562	15, 19, 22, 39
14/160	160	7	A	34	8/18/2000	65207	MAT	NAT	2002	1	200	30
14/160	160	8	A	56.2	8/1/2000	65208	MAT	NAT	2002	1	156	4,8,32
14/170	170	39	A	10.7	1/1/2000	85006	IMM	NAT	2003	1	222	17
14/170	170	39	C	9.5	1/1/2000	85006	IMM	NAT	2003	1	240	1
14/175	175	3	A	13.2	2/1/2000	88018	IMM	NAT	2002	1	240	29
14/175	175	4	A	3.7	1/1/2000	88019	IMM	NAT	2002	1	200	18
14/175	175	5	A	27.3	2/1/2000	88020	IMM	ART	2002	1	82	20
14/175	175	7	A	7.1	1/1/2000	88022	IMM	NAT	2004	1	629	9, 11
14/175	175	9	A	28.5	1/1/2000	88046	IMM	NAT	2002	1	457	10
14/175	175	11	A	8.1	3/1/2000	88025	IMM	NAT	2003	1	167	38
14/175	175	13	A	8.1	2/1/2000	88027	IMM	ART	2002	1	200	12
14/175	175	19	A	12.1	1/1/2001	96431	IMM	NAT	2001	1	273	13, 21
14/175	175	20	A	39.5	1/1/2001	96434	IMM	NAT	2003	1	115	5
14/177	177	1	A	24.1	1/1/2001	97030	IMM	NAT	2003	1	419	27, 35, 37, 40
14/177	177	3	A	22.9	10/1/2001	97031	MAT	NAT	2003	1	382	24
14/177	177	13	A	13.4	2/1/2001	97041	IMM	ART	2003	1	80	16
14/179	179	4	A	11.3	1/29/2002	105773	IMM	NAT	2003	1	164	26
14/179	179	4	B	10.7	1/29/2002	105773	IMM	NAT	2003	1	491	14
14/179	179	14	1A	13.5	3/13/2002	106276	MAT	NAT	2004	1	467	2, 28, 31, 34

Appendix 4. Field Procedures

Timber evaluation of partially harvested areas in the BC interior - October 19, 2006

A. From the site plan record the preferred and acceptable species for the sample location. Get the site plan map that shows the location of any areas excluded from the NAR.

B. Go to the sample center and mark the point with a ribbon labelled with the sample number.

C. Determine whether the sample center is in the NAR of the selected forest cover polygon (i.e., the "stratum"). If it is not, record this on the field sheets. Do not sample here. Go to the first Replacement Point in the stratum and repeat step B.

D. Select plot sizes

  a. Observe large tree sizes and density (live, standing trees with dbh ≥ 12.5 cm). Select the BAF prism that will come closest to including 20 live, standing trees in total over the three sub-plots and will rarely reach out more than 10 m at any sub-plot. Record the selected BAF and use the same BAF at each of the three sub-plots for both live, and dead and down, large trees.

  b. Observe small tree density (live trees with dbh < 12.5 cm). Select from three plot sizes: 3.99 m, 2.8 m, and 2.0 m radius. Select the plot size that will come closest to including 20 trees in total over the three sub-plots. Record small tree plot size and use the same radius at each of the three sub-plots.

  c. Observe stump density (stumps from the recent harvest with diameter ≥ 12.5 cm). Select from three plot sizes: 6.91 m, 5.64 m and 3.99 m radius. Choose the plot size that will come closest to including 20 stumps in total over the three sub-plots. Record stump plot size and use the same radius at each of the three sub-plots.

E. Record site data. Consider an area roughly 20 m around the sample center. Record BEC unit (zone/subzone/variant) and the dominant site series, elevation (m), slope (%), and aspect (degrees). Record UTM at sample center.

F. The sample consists of three sub-plots. The sub-plots are 10m from the sample center at 0, 120, and 240 degrees.

G. For each sub-plot, establish the center for the sub-plot, 10 m from the sample center. Mark the sub-plot center with a ribbon labelled with sample number and sub-plot number. Decide whether the sub-plot is in the NAR of the selected stratum. If it is not, record this on the field sheets and do not sample this sub-plot.

H. For each sub-plot that is in the NAR in the selected stratum, do the following:

1. Collect large tree data on live, standing trees

  a. With the prism, identify all standing, live trees that are within the NAR of the selected stratum, appear "in" with the prism, and have dbh ≥ 12.5 cm.

  b. Check all borderline trees.

  c. From 0 degrees and proceeding clockwise, for each "in" tree, record sub-plot number, tree number, species, dbh (in cm to the nearest 0.1 cm), total height (in m to the nearest 0.1 m), height to crown base (in m to the nearest m), whether root disease symptoms are observed (N=no, Y=yes; symptoms may include crown thinning, stress cone crops, reduced leader growth, basal resinosis, fruiting bodies (mushrooms), and rhizomorphs) and timber quality class.

  d. Two timber quality classes are recognized: Good and Poor. A tree is of poor timber quality if it:

  - is a deciduous tree species, or
  - has a break, fork, or major crook/sweep in the lower ½ of the stem, or
  - has a wound (an injury that removes a portion of the bark and cambium from the tree but does not penetrate into the sapwood) that girdles more than a third of the stem circumference, a wound on a supporting root within 1 m of the stem, or a gouge (a cut penetrating the sapwood or deeper) in the stem; or
  - has less than 50% sound wood, or
  - is not healthy.

  In addition, smaller layer 1 trees are of poor timber quality if they do not have a live, "pointy" top.

  e. For each "in" tree, imagine a line extending from sub-plot center to the tree center and continuing an equal distance beyond the tree. If the point where this imaginary line terminates is not in the NAR of the selected stratum, then record this tree twice. Give the duplicate line the tree number 900 plus the original tree number and then copy over all of the other data (sub-plot number, species, dbh, height, etc).

f. If there are no "in" trees, record this on the field sheet.

2. **Collect large tree data on dead or fallen trees**

   a. From 0 degrees and proceeding clockwise, identify trees that are "in," have dbh ≥ 17.5 cm, that contained at least one merchantable log at the time of harvest (5-m log of sound wood to a minimum 10 cm top, commercial species), and are,

      i) standing dead,

      ii) down and live,

      iii) down and dead

   A leaning or fallen tree is "in" when the horizontal distance from sub-plot center to the center of the stem on the top side at dbh is less than the critical distance.

   b. For each "in" tree that meets the preceding criteria, record sub-plot number, tree number, the tree as (L)ive or (D)ead, the tree as (S)tanding or (F)allen, species, dbh (in cm to the nearest 0.1 cm), total height (in m to the nearest 0.1 m), and whether root disease symptoms are observed (N=no, Y=yes; symptoms may include crown thinning, stress cone crops, reduced leader growth, basal resinosis, fruiting bodies (mushrooms), and rhizomorphs).

   c. For each "in" tree, imagine a line extending from sub-plot center to the tree center at dbh and continuing an equal distance beyond the tree. If the point where this imaginary line terminates is not in the NAR of the selected stratum, then record this tree twice. Give the duplicate line the tree number 900 plus the original tree number and then copy over all of the other data (sub-plot number, species, dbh, height, etc).

   d. If there are no "in" trees, record this on the field sheet.

3. **Collect stump data**

   a. In the circular, stump plot centered on the sub-plot center, find all stumps originating in the recent harvest that have stump diameters ≥ 12.5 cm

   b. From 0 degrees and proceeding clockwise, for each stump, record sub-plot number, stump number, species, diameter (in cm to the nearest cm), and stump height (in cm to the nearest cm).

   c. When stump species is unknown, record as species code "X"

   d. If there are no stumps, record this on the field sheet.

4. **Collect small tree data**

   a. In the circular small tree plot around the sub-plot center, find all standing, live trees with height > 20 cm and dbh < 12.5 cm. Reduce the height minimum if that is necessary in order to include all of the planted seedlings. A leaning small tree is "in" when the horizontal distance from sub-plot center to the point of germination is less than the plot radius.

   b. From 0 degrees and proceeding clockwise, for each tree, record sub-plot number, small tree number, species, a visual estimate of dbh (in cm to the nearest cm), a visual estimate of total height (in m to the nearest 0.1 m), a visual estimate of percent live crown (in percent to the nearest 10%), tree origin code (P=planted, N=natural, U=unsure), and tree condition class. Two tree condition classes are recognized: Good and Poor. A tree is of poor condition if it:

      - has a break, fork, or major crook/lean/sweep in the stem, or
      - lacks a live, pointy top, or
      - has a large, deep wound, or
      - has less than 40% live crown, or
      - has stemwood decay, or
      - is not healthy (consider the free-growing damage criteria).

   c. If there are no small trees, record this on the field sheet.

4. **Collect stocking data**

   a. In a 3.99-m circular plot centered on the sub-plot center, collect stocking data.

   b. To be tallied, trees must have acceptable health, form, and vigour.

   c. Collect multi-layer stocking data

      - Count the number of layer 1 trees (preferred and acceptable species, separately) to a maximum of 3. No MITD.
      - Count the number of layer 2 trees (preferred and acceptable species, separately) to a maximum of 4. To be tallied, trees must be 2 m from all other tallied layer 1s and 2s.
      - Count the number of layer 3 trees (preferred and acceptable species, separately) to a maximum of 5. To be tallied, trees must be 2 m from all other tallied layer 1s, 2s, and 3s.

- Count the number of layer 4 trees (preferred and acceptable species, separately) to a maximum of 6. To be tallied, trees must be 2 m from all other tallied layer 1s, 2s, 3s, and 4s.

I. Complete FREP, preliminary, timber-focus, partial cutting routine indicators at the sample center.

J. Take a few photographs showing representative conditions and unusual features. Record comments for the photos.

K. Double check that the field sheets are complete and legible before leaving the sample location.

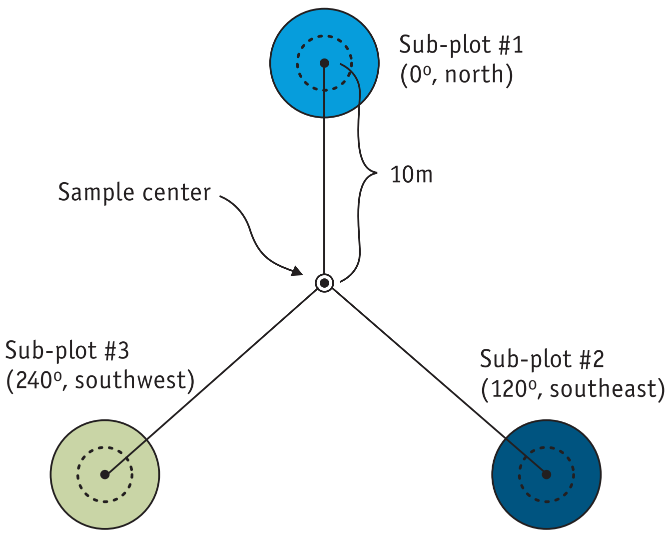

Figure A4-1. Layout of the sub-plots at the sample location.

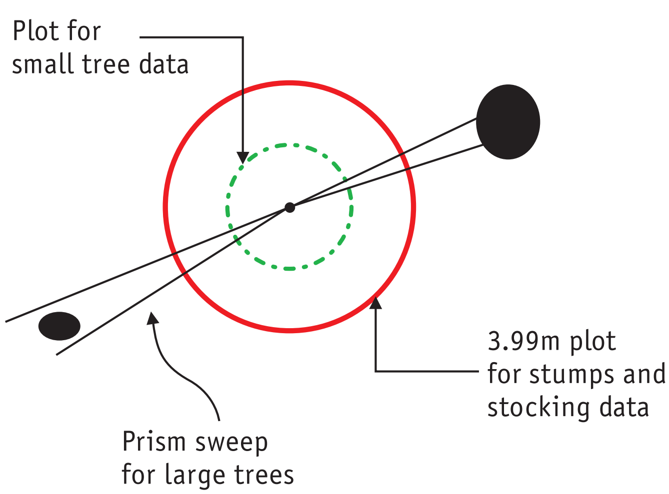

Figure A4-2. A sub-plot includes a small tree plot, a stump plot, a 3.99 m stocking plot, and a prism sweep around the sub-plot center. The small tree and stump plots can take several sizes. In this example, the stump plot radius is 3.99 m.

Borderline trees

The tree is "in" if

$$\left(DBH \cdot \frac{0.5}{\sqrt{BAF}}\right) \geq \text{the horizontal distance from plot center to tree center.}$$

Selecting BAF

Table A4-1. Critical distance by BAF by tree dbh.

dbh (cm)	BAF (m) 1	2	3	4	5	6	7	8	9	10
20	10	7	6	5	4	4	4	4	3	3
30	15	11	9	8	7	6	6	5	5	5
40	20	14	12	10	9	8	8	7	7	6
50	25	18	14	13	11	10	9	9	8	8
60	30	21	17	15	13	12	11	11	10	9
70	35	25	20	18	16	14	13	12	12	11
80	40	28	23	20	18	16	15	14	13	13
90	45	32	26	23	20	18	17	16	15	14
100	50	35	29	25	22	20	19	18	17	16

Table A4-2. Plot radius factors by BAF.

BAF	Plot radius factor (PRF)	BAF	Plot radius factor (PRF)
1	0.5000	7	0.1890
2	0.3536	8	0.1768
3	0.2887	9	0.1667
4	0.2500	10	0.1581
5	0.2236	11	0.1508
6	0.2041	12	0.1443

Appendix 5. Prototype Field Sheets

SAMPLE CARD – FRONT

Sample number: *EE-S1* Page 1 of 8

Administration:

Location Name: *Sheep Camp* Licence/ CP / Block: *XXXXX/185/005* Mapsheet / Opening: *82G031/119*

Standard Units: *1* Stratum (forest cover polygon): *A* Date: *May 22, 2006* Crew: *PJM*

Access Notes:

0 Km – From center of bridge over Chilliwack River, drive west on Vedder Road

26.3 km – Turn left (east) onto Ralph FSR

29.6 km – Cross bridge and stay left at intersection

31.8 km – Tie point where small stream passes under road through culvert

From tie point, sample center is 156 m at 127 degrees

Access Map:

SAMPLE CARD – BACK

Sample number: EE-S1 Page 2 of 8

Site:

BEC: MSdm1/01 Aspect(deg): 125 degrees Slope(%): 21%

Elevation: 820m UTM: 465631 5478119

Silviculture:

Preferred Species: Fd, Lw, Pl, Sx Acceptable Species: Bl Source: Results

Comments (eg: weather, procedure problems, dropped sub-plots, photos, etc.):

Clear and sunny. Sub-plot #2 (120 degrees) dropped because on permanent road.

Photos EE-S1-P1, P2, and P3 show typical conditions at sub-plots 1, 2, and 3, respectively.

Plot layout Map (show non-NAR, SU boundary, dropped sub-plot, etc):

LARGE TREE (LIVE AND STANDING) PLOT CARD

Sample number: EE-S1 Page 3 of 8

Licence / CP / Block / Stratum: XXXXX/185/005 or Mapsheet / Opening./ Stratum: 82G031/119

Large tree plot BAF: 5

Sub-plot Number	Tree Number	Species	DBH (cm)	Total Height (m)	Height to crown base (m)	Root disease symptoms? (Y, N)	Timber Quality (G, P)	Comment
1	1	Fd	32.5	25.9	15	Y	P	Root disease
1	2	Pl	29.5	21.6	16	N	G	
1	3	Bl	56.7	27.1	15	N	G	
2								Subplot #2 dropped because on permanent road
3	1	Fd	26.5	21.9	11	N	P	Dead top
3	901	Fd	26.5	21.9	11	N	P	Dead top, duplicate edge tree
3	2	Pl	35.9	28.1	15	N	G	
3	3	Sx	44.1	30.0	17	N	G	
3	4	At	28.8	25.7	20	N	P	

LARGE TREE (DEAD OR FALLEN) PLOT CARD

Sample number: EE-S1

Licence / CP / Block / Stratum: XXXXX/185/005 or Mapsheet / Opening./ Stratum: 82G031/119

Large tree plot BAF: 5

Sub-plot Number	Tree Number	(L)ive/ (D)ead	(S)tanding/ (F)allen	Species	DBH (cm)	Total Height (m)	Root disease symptoms? (Y, N)	Comment
1	1	D	F	Fd	32.5	20.9	Y	Recent windthrow
1	2	D	S	Pl	29.5	21.6	N	Recent MPB-killed
2								Subplot #2 dropped because on permanent road
3								No dead or fallen trees

SMALL TREE PLOT CARD

Sample number: EE-S1

Page 5 of 8

Licence / CP / Block / Stratum: XXXXX/185/005 or Mapsheet / Opening./ Stratum: 82G031/119

Large tree plot BAF: 5

Sub-plot Number	Tree Number	Species	DBH (cm)	Total Height (m)	Percent live crown (%)	Origin (P, N, U)	Tree Condition (G, P)	Comment
1	1	Pl	0	0.5	50	P	G	
1	2	Fd	0.5	1.5	60	N	P	Multiple forks
2								Subplot #2 dropped because on permanent road
3	1	Bl	0	1.1	70	N	G	
3	2	Bl	3.5	3.1	80	N	G	
3	3	Bl	3.0	2.5	70	N	G	

STUMP PLOT CARD

Sample number: EE-S1 Page 6 of 8

Licence / CP / Block / Stratum: XXXXX/185/005 or Mapsheet / Opening./ Stratum: 82G031/119

Stump plot radius (m): 5.64

Sub-plot Number	Stump Number	Species	Diameter (cm)	Stump height (cm)	Comment
1					No stumps in sub-plot #1
2					Subplot #2 dropped because on permanent road
3	1	Pl	26.9	30	
3	2	Pl	41.7	27	
3	3	X	50.0	21	
3	4	Fd	37.1	35	
3	5	Fd	45.5	28	

STOCKING CARD - FRONT

Sample number: EE-S1 Page 7 of 8

Licence / CP / Block / Stratum: XXXXX/185/005 or Mapsheet / Opening./ Stratum: 82G031/119

		WS tree count by species group		
Sub-plot Number	Layer	p	a	Comment
1	1	1	-	
1	2	1	1	
1	3	-	-	No layer 3 trees
1	4	2	2	
2				Sub-plot #2 dropped because on permanent road
3	1	2		
3	2	3		
3	3	-	1	
3	4	1	-	

FREP ROUTINE INDICATORS PLOT CARD

Sample number: EE-S1 Page 8 of 8

Licence / CP / Block / Stratum: XXXXX/185/005 or Mapsheet / Opening./ Stratum: 82G031/119

Factors related to the overstory	
Risk of windthrow	Low
Risk that root disease will cause decline or death of overstory trees	Medium
Risk that other factors (specify:________________________) will cause decline or death of overstory trees	Low
Growth potential of retained overstory trees (consider percent live crown, tree size and maturity, live pointy tops, etc)	Medium
Diversity of tree species in overstory (consider relative to pre-harvest species diversity)	High
Frequency and severity of damage to retained trees (consider crown, stem, and roots)	Low
Likelihood that if they were not harvested, the extracted trees would have soon experienced decline or death	High
If, among the overstory trees before harvest, one species group was considerably more valuable, what proportion of these trees were retained?	High
Factors related to the understory	
Forest health risk to understory (consider root disease, mistletoe, etc)	Low
Non-crop vegetation competition risk to understory	Low
Probability of additional natural regeneration in the future (consider seed supply, seedbed, environmental stress, abundance of germinants, natural regeneration on similar sites, etc)	Low
Diversity of tree species in understory (consider relative to pre-harvest species diversity, site plan preferred and acceptable species, etc)	Low
Degree to which stocking in the seedling & sapling layer is dominated by genetically improved (A class) trees	No Evaluated
Degree to which the shade tolerance of seedlings and saplings is matched to local shading conditions	Low
If among potential seedling and saplings, one species group is considerably more productive, extent to which this group is present in significant numbers?	High
Amount of large, desirable advanced regeneration destroyed in logging?	Low
Degree to which the preferred crop trees are free from interference by other poorer quality trees?	Medium

Appendix 6. Excel Worksheet Data Format

1. Sample card - front and back

Sample Number	CP / Block / SU	BEC: Zone, subzone, variant	BEC: Dominant site series	Aspect (degrees)	Slope (%)	Elevation (m)	Comment
1	170/39/3	ICHmw1	04/01/05	140	-25	1114	
2	179/14/1	IDFdm[2]	01/04/03	338	0	1158	
3	158/235/1	MSdk	01	227	-34	1261	
4	160/8/1	ESSFdk	01/03	40	-31	1677	
5	175/20/1	MSdk	01/04	59	-10	1154	

2. Large tree (Live and Standing) plot card data

Sample Number	CP/ Block/ SU	Large tree plot BAF	Sub-plot Num-ber	(large tree live and standing) Tree Number	Species	DBH (cm)	Total Height (m)	Height to crown base (m)	Root disease symp-toms? (Y, N)	Timber Quality (G, P)	Comment
1	170/39/ C	3	1	1	Fdi	43.2	26.8	19.7	N	G	
1	170/39/ C	3	1	2	Fdi	40.9	33.7	25.7	N	G	
1	170/39/ C	3	2	1	Fdi	46.5	27.5	20.9	N	G	
1	170/39/ C	3	2	2	Fdi	42.2	25.7	17.7	N	G	
1	170/39/ C	3	2	3	Fdi	38.5	26	15.4	N	G	

3. Large tree (Dead or Fallen) plot card data

Sample Number	CP/ Block/ Stra-tum	Large tree plot BAF	Sub-plot Num-ber	(large tree dead or fallen) Tree Number	(L)ive or (D)ead	(S)tanding or (F)allen	Species	DBH (cm)	Total Height (m)	Root disease symp-toms? (Y, N)	Comment
1	170/39/ C	3	1								no trees
1	170/39/ C	3	2								no trees
1	170/39/ C	3	3								no trees
2	179/14/ I	3	1	1	D	F	Sx	28.7	19.2	N	
2	179/14/ I	3	2								no trees

4. Stump plot data

Sample Number	CP/ Block/ SU	Stump plot radius (m)	Sub-plot Num-ber	(stump plot) Stump Num-ber	Species	Diameter (cm)	Stump height (cm)	Comment
1	170/39/ C	5.64	1	1	Xc	28	42	
1	170/39/ C	5.64	1	2	Fdi	33	41	
1	170/39/ C	5.64	1	3	Fdi	13	43	
1	170/39/ C	5.64	1	4	Xc	45	19	
1	170/39/ C	5.64	1	5	Fdi	26.5	21.5	

5. Small tree plot card data

Sample Number	CP/ Block/ SU	Small tree plot radius (m)	Sub-plot Num-ber	(small tree plot) Tree Num-ber	Species	DBH (cm)	Total Height (m)	Percent live crown (%)	Origin (P, N,U)	Tree Con-dition (G, P)	Comment
1	170/39/ C	2.8	1	1	Fdi	0	1.2	90	N	G	
1	170/39/ C	2.8	1	2	Fdi	0	1.2	90	N	G	
1	170/39/ C	2.8	1	3	Bl	7	2.8	20	N	P	lg sweep
1	170/39/ C	2.8	1	4	Bl	0.5	1.3	80	N	G	
1	170/39/ C	2.8	1	5	Fdi	0	0.9	80	N	G	

6. Stocking card - front

				WS count by species group		
Sample Number	CP/ Block/ SU	Sub-plot Num-ber	Layer	Preferred species	Acceptable species	Comment
1	170/39/ C	1	1	0	0	no trees layer 1
1	170/39/ C	1	2	0	2	
1	170/39/ C	1	3	0	1	
1	170/39/ C	1	4	5	0	
1	170/39/ C	2	1	0	0	

8. FREP routine indicators plot card						
Factors related to the overstory	**1**	**2**	**3**	**4**	**5**	**...**
1. Risk of windthrow:	M	L	M	M	M	
2. Risk that root disease will cause decline or death of overstory trees:	L	L	L	M	L	
3. Risk that other factors (specify:______________________________) will cause decline or death of overstory trees:	L	L	L	L	L	
4. Growth potential of retained overstory trees (consider percent live crown, tree size and maturity, live pointy tops, etc):	L	H	M	L	M	
5. Diversity of tree species in overstory (consider relative to pre-harvest species diversity):	M	L	H	M	L	

Appendix 7. Routine Evaluation Procedure

Procedure for a FREP routine evaluation of partial cutting to assess the degree of consistency with government's objectives for timber, January 2, 2006.

This document describes the development of a procedure for FREP routine evaluations of partial cutting to assess consistency with government's objectives for timber. The procedure and the set of timber-goal indicators are preliminary. They are being used to test some concepts, gain experience with the problem, and solicit input. They are not the final procedure and set of indicators approved by FREP for wide-spread use in partial cuts.

1. *The FRPA Timber Value*

The evaluation procedure must assess the state of the partially harvested area with respect to the FRPA "timber value." As specified in the FPPR (s. 6), the objectives set by government for timber are to:

a. maintain or enhance an economically valuable supply of commercial timber from British Columbia's forests,

b. ensure that delivered wood costs, generally, after taking into account the effect on them of the relevant provisions of this regulation and of the Act, are competitive in relation to equivalent costs in relation to regulated primary forest activities in other jurisdictions, and

c. ensure that the provisions of this regulation and of the Act that pertain to primary forest activities do not unduly constrain the ability of a holder of an agreement under the Forest Act to exercise the holder's rights under the agreement.

The EE routine evaluation procedure will focus on that portion of the timber-goal that is described in FPPR s. 6(a). The impact of partial harvesting on other FRPA values will not be considered. Thus, the procedure and indicators must express the degree to which the observed post-harvest condition meets the government's objective to maintain or enhance an economically valuable supply of commercial timber from British Columbia's forests.

2. *Concept Model*

The impact of partial cutting on the goal ("to maintain or enhance an economically valuable supply of commercial timber") can be adequately assessed through its impact on unit-area volume and value. That is, the development of the evaluation method is predicated on the assertion that volume and value are the critical factors that determine the degree of goal achievement. The standing volume and value need to be considered as well as the potential of the partial-cut area to "re-grow" volume and value.

One way to derive a system for rapid, field-based evaluation from these concepts is to specify a limited number of partial harvest scenarios or general types of post-harvest condition. These types should be formulated to reflect the impact of partial cutting on current, and future, volume and value. The following seven general scenarios (types) are proposed.

Three lighter volume removal scenarios are:

1. **Stocked by overstory, value removal does not greatly exceed volume removal.** In this scenario, growing space is fully occupied by the remaining canopy trees and the proportion of value extracted does not greatly exceed the proportion of volume extracted. Thus, if there was a high value component in the overstory, it has been maintained. In this case, the immediate supply of economically valuable timber is maintained. And, as long as the retained trees remain healthy and alive, the supply is maintained into the future. This condition meets the FRPA objective for timber to a high degree.

2. **Stocked by overstory, value removal greatly exceeds volume removal.** In this scenario, growing space is fully occupied by the remaining canopy trees and the proportion of value removed greatly exceeds the proportion of volume removed. With the high value component of the overstory largely removed, and enough overstory left to occupy the site, seedling and sapling growth is greatly suppressed so that the retained canopy trees are the sole source of value production. However, with the canopy dominated by the retained lower value component, the ability of the stand to grow valuable timber is reduced. The short-term supply of valuable timber is not maintained and supply is not maintained or enhanced for the future. This condition meets the FRPA objective for timber to a low degree.

3. **Stocked by overstory, value removal moderately exceeds volume removal.** This scenario is intermediate to the preceding two. This condition meets the FRPA objective for timber to a medium degree.

A heavier volume removal with poor quality of retention scenario is:

4. **Not fully stocked by overstory and high level of poor quality retention.** In this scenario, the harvest removal is so heavy that the residual overstory does not capture all growing space. And, a large amount of the retained growing stock is poor timber quality trees (e.g., low value, slow growing, unhealthy, cull, etc). This type of overstory precludes an acceptable rate of volume and value re-growth. As long as more than some amount (say, y m^2/ha) of retention is poor quality timber, the post-harvest condition cannot "maintain or enhance an economically valuable supply of commercial timber." This condition meets the FRPA objective for timber to a low degree.

Three heavier volume removal with good quality of retention scenarios are:

5. **Not fully stocked by overstory, good quality retention, and good re-stocking.** In this scenario, post-harvest overstory density is not adequate to fully stock the site, but the retained trees are generally of good timber quality, and areas of unoccupied (or incompletely occupied) growing space are filled with quality seedlings and saplings. This condition will "maintain or enhance an economically valuable supply of commercial timber." This condition meets the FRPA objective for timber to a high degree.
6. **Not fully stocked by overstory, good quality retention, and poor re-stocking.** In this scenario, post-harvest overstory density is not adequate to fully stock the site, the retained trees are generally of good timber quality, but areas of unoccupied (or incompletely occupied) growing space are not filled with quality seedlings and saplings. This condition will not "maintain or enhance an economically valuable supply of commercial timber." This condition meets the FRPA objective for timber to a low degree.
7. **Not fully stocked by overstory, good quality retention, and medium re-stocking.** This scenario is intermediate to the two above. This condition meets the FRPA objective for timber to a medium degree.

We assume that these seven general scenarios cover all operationally significant situations and provide an adequate foundation for developing the evaluation procedure. The indicators will be measurable quantities used to classify a partially cut area into one of the seven types. In addition to the indicators, many other factors potentially affect the achievement of the government's objectives for timber. To reflect these additional considerations, a set of factors will be developed. These factors will add detail and depth to the base classification. They will operate as modifiers or additional descriptors appended to the base classification.

3. *Design Choices for the Evaluation Method*

The indicators must be consistent with the type of data that will be collected in the pilot project *(Timber-focussed evaluation of partially harvested areas in a management unit in south-eastern BC)*.

The indicators must be based on simple measurements and calculations. Indicators and factors should be simple and quick for field crews to use.

The system must provide a prompt conclusion in the field as to status in relation to the FRPA timber-goal.

The system and the indicators are designed to be applied at a sample point. They are not designed to evaluate polygon-average condition.

The system leads to a result into three categories (high, medium, and low degree to which the current state meets the FRPA timber objective), not an evaluation over a continuous scale (e.g., 0-100%).

Relative values (e.g., a unit of Fd is worth 1.3 units of Pl) that are based on RTEB average market value data will be used to assign value. As a proxy for volume, basal area will be used.

The system and the indicators will be simple at first, and then complexity will be added to those elements where it yields the greatest improvement.

Where possible, the indicators should be repeatable, not subjective, and based on quantities that are unambiguously measured. However, some important assessments are more subjective (e.g., the risk to seedlings from non-crop vegetation), or are based on a prediction about what might happen (e.g., probability of future windthrow or additional natural regeneration). Items that are assessed subjectively or are based on a prediction (the factors) will be separated from those that can be directly and unambiguously measured (the indicators). The indicators will drive the type classification and the factors will be incorporated as modifiers to the base classification.

And, of course, the indicators and factors must be well-correlated to the goal.

4. *Indicators*

Given the stated timber-goal, the concept model proposed for it, and the system design choices, four indicators are proposed:

- Basal area of commercially valuable overstory trees.
- Ratio of the percent of pre-harvest value removed to the percent of pre-harvest basal area removed.
- Basal area of overstory trees that are classified as poor timber quality.
- Degree of site occupancy by quality seedlings and saplings (as measured by DFP).

Eighteen factors are proposed (see section 7.2, Step #5).

5. *Critical Values*

Based on the experience of the Project Leader with partial cutting assessments in the BC interior, generally accepted threshold values, the DFP table, and some subjective guesses, the following critical values are proposed for the indicators. Thresholds occur when:

- the basal area of commercially valuable overstory trees drops below 23 m^2/ha;
- the ratio percent value removed to percent basal area removed exceeds 1.2 and 1.5;
- the basal area of retained overstory trees that are classified as poor timber quality exceeds 10 m^2/ha; and
- growing space occupancy by quality seedlings and saplings drops below a DFP of 0.33 and 0.12.

6. *Outline of Field Procedure*

Indicators developed from the concepts above could be applied by the field crews in a series of stages.

In the first stage, at a sample point the field crew estimates layer 1 basal area of commercially valuable trees. If this is less than 23 m^2/ha, the crew proceeds to second stage measurements. If commercial basal area equals or exceeds 23 m^2/ha, the crew estimates basal area pre-cut and post-cut by species. The crew determines the percent of pre-cut basal area that has been removed. For each species, basal area is multiplied by relative value and the result is used to estimate the percent of value removal. Based on these measures, the condition is classified as Type 1 (stocked by overstory, value removal did not greatly exceed value removal), Type 2 (stocked by overstory, value removal greatly exceeded volume removal), or Type 3 (stocked by overstory, value removal moderately exceeded volume removal).

If layer 1 basal area of commercially valuable trees is less than 23 m^2/ha at the sample point, the sample point is assessed for its ability to re-grow volume and value. In this second stage, the field crew assesses the timber quality of the residual growing stock. If more than 10 m^2/ha of overstory trees are classified as poor timber quality, then the condition is classified as a Type 4.

If the sample point is not Type 1, 2, 3, or 4, then the level of seedling and sapling stocking is assessed. The field crew assesses whether the sample location is adequately stocked with quality seedlings and saplings, given the amount of overstory. To do this, the field crew obtains DFP (from layer 1 basal area and layer 2-4 well-spaced density). The condition is Type 5 when $DFP \leq 0.12$, Type 6 when $DFP \geq 0.34$ and Type 7 when $0.12 < DFP < 0.34$.

In addition, field crews will assess a list of additional factors to describe the most significant modifiers to the base classification.

The following table is used to relate the type to an assessment of the degree to which the observed condition achieves the government's objectives for timber.

Type	Degree to which observed condition meets FRPA objectives of timber
Stocked by residual overstory, value removal did not greatly exceed volume removal	High
Stocked by residual overstory, value removal greatly exceeded volume removal	Low
Stocked by residual overstory, value removal moderately exceeded volume removal	Medium
Not fully stocked by residual overstory, high level of poor quality timber retained	Low
Not fully stocked by residual overstory, low level of poor quality timber retained, high level of seedling and sapling stocking	High
Not fully stocked by residual overstory, low level of poor quality timber retained, low level of seedling and sapling stocking	Low
Not fully stocked by residual overstory, low level of poor quality timber retained, medium level of seedling and sapling stocking	Medium

When staff interpret the classification, they consider the modifiers (the factors) and their potential impact on the base classification. Last, when forming an opinion on whether the result is appropriate, they consider the context, such as the management objectives and constraints.

7. Discussion

Discussion and acknowledgements have been moved to the main body of the report.

7.1 Procedure for routine evaluations: FRPA timber value in partial cut areas

Introduction

To undertake a FREP, timber-focussed, routine evaluation of a partial-cut area, gather pre-evaluation information in the office (Appendix 2). Then in the field, work through the steps below to classify the field condition into one of seven primary types and assess other important factors to add modifiers to the base classification. Last, when forming a judgement on the adequacy of the result, put the classification into context by considering issues such as the specific management objectives and constraints applicable to the location.

Steps

STEP 1: **Assess commercial basal area retained**

- Commercially valuable basal area remaining_____________

When the routine evaluation is done in conjunction with intensive evaluation data collection, commercially valuable will be defined as conifer tree species in the "good" timber quality class. More generally, commercially valuable may be defined as commercial species of acceptable form, health and vigor.

If less than 23 m^2/ha, proceed to Step #3. If $\geq$23 m^2/ha, proceed to Step #2.

STEP 2: **Assess ratio of value to volume removal**

Complete the Step #2 worksheet (Appendix 3) and transfer the values into the spaces below.

- Percent of pre-cut value that been removed: ____________
- Percent of pre-cut basal area that been removed:________
- % value removed / % basal area removed:_______________

If less than 1.2 (and Step 1 is $\geq$ 23 m^2/ha), then the condition is Type 1. If greater than 1.5 (and Step 1 is $\geq$ 23 m^2/ha), then the condition is Type 2. If between 1.2 and 1.5 (and Step 1 $\geq$ 23 m^2/ha), then the condition is Type 3.

Proceed to Step #5.

STEP 3: **Assess amount of poor quality retained canopy trees**

- Basal area of overstory trees classified as poor timber quality______________________________________

If greater than or equal to 10 m^2/ha, then the condition is Type 4. Proceed to Step #5. If less than 10 m^2/ha, then proceed to Step #4.

STEP 4: **Assess stocking by quality seedlings and saplings**

Refer to Appendix 4 to obtain DFP from the observed basal area and seedling&sapling density.

- DFP____

If less than or equal to 0.12 then the condition is Type 5. If greater than or equal to 0.34, then the condition is Type 6. If 0.12 < DFP < 0.34, then the condition is Type 7.

Proceed to Step #5.

STEP 5: Modifiers

Assess each of the factors listed below to identify significant modifiers to the base classification. If you judge the factor to be in the shaded class, add this code to the base classification.

	Classification		
Factor	**Low**	**Medium**	**High**
1. Risk of windthrow:	1l	1m	1h
2. Risk that root disease will cause decline or death of overstory trees:	2l	2m	2h
3. Risk that other factors (specify:______________________) will cause decline or death of overstory trees:	3l	3m	3h
4. Growth potential of retained overstory trees (consider percent live crown, tree size and maturity, live pointy tops, etc):	4l	4m	4h
5. Diversity of tree species in overstory (consider relative to pre-harvest species diversity):	5l	5m	6m
6. Frequency and severity of damage to retained trees (consider crown, stem, and roots):	6l	6m	6h
7. Likelihood that if they were not harvested, the extracted trees would have soon experienced decline or death:	7l	7m	7h
8. If, among the overstory trees before harvest, one species group was considerably more valuable, what proportion of these trees were retained?	8l	8m	8h
9. Forest health risk to understory (consider root disease, mistletoe, etc):	9l	9m	9h
10.Non-crop vegetation competition risk to understory:	10l	10m	10h
11.Probability of additional natural regeneration in the future (consider seed supply, seedbed, environmental stress, abundance of germinants, natural regeneration on similar sites, etc):	11l	11m	11h
12.Diversity of tree species in understory (consider relative to pre-harvest species diversity, site plan preferred and acceptable species, etc):	12l	12m	12h
13.Degree to which stocking in the seedling&sapling layer is dominated by genetically improved (A class) trees:	13l	13m	13h
14.Degree to which the shade tolerance of seedlings and saplings is matched to local shading conditions:	14l	14m	14h
15.If among potential seedling and saplings one species group is considerably more productive, extent to which this group is present in significant amount?	15l	15m	15h
16.If among the potential seedling and saplings one species group is considerably more valuable, extent to which this group is present in significant amount?	16l	16m	16h
17.Amount of large, desirable advanced regeneration destroyed in logging?	17l	17m	17h
18.Degree to which the preferred crop trees are free from interference by other poorer quality trees?	18l	18m	18h

STEP 6: Overall classification

Add to the base classification of Type, all of the modifiers that you judged to be in a shaded class to obtain the overall classification of the post-harvest partial-cut condition.

Overall classification (base type plus modifiers):

____

STEP 7: Interpret the base classification

Refer to the table below to determine the degree to which the observed condition meets the FRPA objectives for timber.

Type	Degree to which observed condition meets FRPA objectives of timber
Stocked by residual overstory, value removal did not greatly exceed volume removal	High
Stocked by residual overstory, value removal greatly exceeded volume removal	Low
Stocked by residual overstory, value removal moderately exceeded volume removal	Medium
Not fully stocked by residual overstory, high level of poor quality timber retained	Low
Not fully stocked by residual overstory, low level of poor quality timber retained, high level of seedling and sapling stocking	High
Not fully stocked by residual overstory, low level of poor quality timber retained, low level of seedling and sapling stocking	Low
Not fully stocked by residual overstory, low level of poor quality timber retained, medium level of seedling and sapling stocking	Medium

STEP 8: Judgements on the adequacy of the result

Last, in forming a judgement on the adequacy of the result, bring in considerations of context, such as the management objectives and constraints applicable to the evaluated location. Consider the modifiers and their potential impact on the interpretation of the base classification. Consider guidance, policies, and common practice in-place at the time of the partial harvest. Assess whether, in your opinion, the evaluation result (in terms of the FRPA timber goal) is reasonable given the applicable management objectives and constraints. Consider whether, in your opinion, the objectives that necessitated the partial harvest could have been satisfied with another pattern of harvest and reforestation that would have scored higher in terms of the government's objectives for timber.

Pre-Evaluation Information Collection

The following materials and information will help you complete the field measurements, assess the modifiers, and judge the adequacy of the classified condition.

- Site plan
- Mapped NAR and accepted local definition of NAR
- Site plan p + a species
- Management objectives
- Seedlot and GW of planted trees
- Species planted
- RESULTS report
- Previous root disease surveys

Step 2 Worksheet

1. **Estimate basal area by species for both stumps and standing trees.**
   - In the vicinity of the sample center point, select the BAF prism that will pick up 8-10 trees plus stumps.
   - Sweep around the sample center with the prism. Identify trees that are "in." Check all trees that appear borderline in the prism. Count the number of "in" trees by species.
   - Complete a second full sweep around the sample center point, checking for "in" stumps with the prism. To do this, find stumps that might be in (based on their diameter and distance from the sample point), measure stump diameter, and from measured stump diameter estimate dbh. Determine whether the stump is in or out using the borderline tree procedure based on the measured distance from the sample point to the stump center and the estimated dbh. Count the number of "in" stumps by species.
   - For stumps and for trees, by species, multiply the number "in" by the BAF to get an estimate of the basal area. Enter the values in Table 1.

Table A7-1. Basal area and relative value of standing trees

Component	Species	Basal area (m^2/ha)	Relative value	Basal area X relative value
Standing trees				
	Sub-total standing		**XXXXXXXXX**	
Stumps				
	Sub-total stumps	C	**XXXXXXXXX**	**A**
	Grand total (standing plus stumps)	D	**XXXXXXXXX**	**B**

2. **Compute relative value by species.**

For each component (standing trees and stumps), by species, enter into Table A3-2 the basal area, relative value (from Table A3-3), and basal area times relative value. Sum basal area and basal area times relative value for both the standing trees and the stumps. Calculate totals.

3. **Compute percent value removed, percent basal area removed, and the ratio:**

- Percent of pre-cut value removed = 100*(A/ B) =
- Percent of pre-cut basal area removed = 100*(C/D) =
- % value removed / % basal area removed =

Enter these values on the main evaluation form at Step 2.

Table A7-2 Timber value by species group.

Species	Average Price[1] ($/m^3)	Relative Value[2]
SPF (spruce, lodgepole pine, and abies)	56.87	1
Douglas-fir and western larch	72.91	1.3
Hemlock	51.60	0.9
Cedar	95.53	1.7
White pine	85.00	1.5
Yellow pine	71.95	1.3
Deciduous[3]	0.00	0

1 BC Interior Log Market report for March, 2006 published by Revenue Branch, MoFR.

2 Average price divided by average price for SFP.

3 Relative value assumed zero for Cranbrook.

DFP Table

DFP by understory (layer 2-4) tree density and overstory (layer 1) basal area.

OS basal area	Well-spaced trees in plot*								
(m^2/ ha)	0	1	2	3	4	5	6	7	8
0	1.00	0.76	0.52	0.34	0.22	0.13	0.07	0.03	0.00
1	0.98	0.74	0.51	0.34	0.21	0.13	0.07	0.03	0.00
2	0.96	0.73	0.50	0.33	0.21	0.13	0.07	0.03	0.00
3	0.93	0.71	0.49	0.32	0.20	0.12	0.07	0.03	0.00
4	0.90	0.68	0.47	0.31	0.20	0.12	0.06	0.03	0.00
5	0.86	0.65	0.45	0.30	0.19	0.11	0.06	0.02	0.00
6	0.82	0.62	0.43	0.28	0.18	0.11	0.06	0.02	0.00
7	0.77	0.58	0.40	0.27	0.17	0.10	0.05	0.02	0.00
8	0.72	0.55	0.38	0.25	0.16	0.09	0.05	0.02	0.00
9	0.67	0.51	0.35	0.23	0.15	0.09	0.05	0.02	0.00
10	0.62	0.47	0.32	0.21	0.14	0.08	0.04	0.02	0.00
11	0.57	0.43	0.30	0.20	0.12	0.07	0.04	0.02	0.00
12	0.52	0.39	0.27	0.18	0.11	0.07	0.04	0.01	0.00
13	0.47	0.35	0.24	0.16	0.10	0.06	0.03	0.01	0.00
14	0.42	0.32	0.22	0.15	0.09	0.05	0.03	0.01	0.00
15	0.38	0.28	0.20	0.13	0.08	0.05	0.03	0.01	0.00
16	0.33	0.25	0.17	0.11	0.07	0.04	0.02	0.01	0.00
17	0.29	0.22	0.15	0.10	0.06	0.04	0.02	0.01	0.00
18	0.26	0.19	0.13	0.09	0.06	0.03	0.02	0.01	0.00
19	0.22	0.17	0.12	0.08	0.05	0.03	0.02	0.01	0.00
20	0.19	0.14	0.10	0.07	0.04	0.02	0.01	0.01	0.00
21	0.16	0.12	0.08	0.06	0.04	0.02	0.01	0.00	0.00
22	0.13	0.10	0.07	0.05	0.03	0.02	0.01	0.00	0.00
23	0.11	0.08	0.06	0.04	0.02	0.01	0.01	0.00	0.00
24	0.09	0.07	0.05	0.03	0.02	0.01	0.01	0.00	0.00
25	0.07	0.05	0.04	0.02	0.02	0.01	0.00	0.00	0.00
26	0.05	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.00
27	0.04	0.03	0.02	0.01	0.01	0.00	0.00	0.00	0.00
28	0.02	0.02	0.01	0.01	0.01	0.00	0.00	0.00	0.00
29	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

* total number of well-spaced trees in a 0.005 hectare plot at minimum inter-tree distances of 1.5 to 2.0 m.

Appendix 8. Compiled Data by Sample

Sample number	Density of small trees (trees/ha) Good condition	Poor condition	Total	Mean height of small trees (m) Good condition	Poor condition	Total	Height difference (m) Mean height poor minus mean height good
1	16240	812	17052	0.9	1.6	0.9	0.7
2	3999	8997	12996	1.8	1.5	1.5	-0.3
3	8932	0	8932	0.8	0	0.8	-0.8
4	18303	1592	19894	0.4	0.5	0.4	0.1
5	5598	1000	6598	0.9	1.9	1.1	1
6	22282	11937	34218	1.5	2.4	1.8	0.9
7	17507	0	17507	0.6	0	0.6	-0.6
8	7798	3999	11797	0.5	1.7	0.9	1.2
9	600	800	1400	11	6.8	8.6	-4.2
10	4999	200	5199	0.5	2.5	0.6	2
11	7958	7958	15916	11.7	10.1	10.9	-1.6
12	4872	5278	10150	2.3	2.3	2.3	0
13	9744	2436	12180	0.4	0.4	0.4	0
14	5398	2399	7798	1.3	1.8	1.5	0.5
15	16795	3799	20594	1	2.5	1.3	1.5
16	3999	9597	13596	1	1.3	1.2	0.3
17	17507	5570	23077	0.7	1.2	0.8	0.5
18	400	3599	3999	8.1	7.4	7.5	-0.7
19	4199	3199	7398	3.3	3	3.2	-0.3
20	7598	800	8398	2.1	1.2	2	-0.9
21	15022	2842	17864	0.8	0.3	0.7	-0.5
22	12992	406	13398	1.1	0.5	1.1	-0.6
23	6398	800	7198	0.5	0.4	0.5	-0.1
24	12596	600	13196	0.6	1.1	0.6	0.5
25	15022	4872	19894	1	0.8	1	-0.2
Mean	9870	3340	13210	2	2	2	-0.06
Std Dev	6091	3308	7160	3	2	3	1.19
Std Error	1218	662	1432	1	0	1	0.24
Std error in percent	12	20	11	29	23	26	372

Sample number	Basal area of large trees (m^2/ha) Good condition	Poor condition	Total	Multi-layer well-spaced density (trees/ha) All layers	Layers 2-4	DFP	Dead or down merch volume (m^3/ha)
1	7	0	7	1200	1400	0.02	0
2	19	5	24	1067	867	0.02	10
3	5	0	5	1133	1133	0.08	0
4	21	3	24	1200	867	0.02	43
5	15	0	15	1133	867	0.07	30
6	14	0	14	1067	867	0.08	25
7	1	0	1	867	800	0.21	0
8	5	1	6	1200	1067	0.09	57
9	32	0	32	700	400	0.00	0
10	3	0	3	1200	1200	0.07	12
11	22	7	28	933	333	0.01	0
12	8	4	12	1200	800	0.11	0
13	17	0	17	1200	1000	0.04	8
14	3	1	4	667	600	0.31	0
15	18	0	18	1200	867	0.05	10
16	5	1	6	1133	1000	0.11	15
17	9	2	11	1000	800	0.12	0
18	25	3	28	733	133	0.02	0
19	30	2	32	1067	667	0.00	8
20	5	0	5	800	733	0.22	8
21	19	0	19	1200	1133	0.02	27
22	21	0	21	867	467	0.07	27
23	0	0	0	1200	1200	0.07	22
24	17	0	17	1200	1067	0.03	10
25	9	0	9	1200	867	0.12	0
Mean	13	1	14	1055	845	0.08	12
Std Dev	9	2	10	181	295	0.08	15
Std Error	2	0	2	36	59	0.02	3
Std error %	14	32	14	3	7	19	24

Sample number	Estimate of pre-harvest condition (current plus cut) Merch volume (m^3/ha)	Value ($)	Cut Merch volume (m^3/ha)	Value ($)	Current Merch volume (m^3/ha)	Value ($)	Cut volume as a percent of pre-harvest volume	Cut value as a percent of pre-harvest value
1	705	46343	642	41721	63	4621	91	90
2	293	19521	94	5539	199	13983	32	28
3	257	14629	200	11375	57	3253	78	78
4	414	23549	177	10043	238	13507	43	43
5	889	53763	751	44180	138	9582	84	82
6	235	13304	142	8099	92	5205	61	61
7	232	13210	226	12855	6	355	97	97
8	613	34834	575	32712	37	2122	94	94
9	401	28237	149	9864	252	18373	37	35
10	532	30268	517	29401	15	867	97	97
11	270	15585	93	5578	177	10007	34	36
12	483	28503	403	23245	80	5258	83	82
13	360	23591	208	12533	152	11057	58	53
14	132	7511	109	6171	23	1340	82	82
15	429	24415	270	15352	159	9063	63	63
16	759	43228	716	40841	43	2387	94	94
17	458	28795	376	22755	82	6041	82	79
18	369	23494	190	10782	180	12712	51	46
19	567	32231	155	8816	412	23415	27	27
20	350	24755	296	20966	54	3789	85	85
21	625	40408	464	28629	162	11779	74	71
22	528	30008	237	13472	291	16536	45	45
23	538	30782	538	30782	0	0	100	100
24	534	30392	335	19754	200	10637	63	65
25	218	12372	170	9641	48	2732	78	78
Mean	448	26949	321	19004	126	7945	69	68
Std Dev	185	11242	201	11973	102	6215	23	23
Std Error	37	2248	40	2395	20	1243	5	5
Std error %	8	8	13	13	16	16	7	7

Sample number	Standing, live lodgepole pine merch volume (m^3/ha)	Harvested non-pine (excludes Xc) m^3/ha
1	0	326
2	10	10
3	26	95
4	0	177
5	0	254
6	47	66
7	0	143
8	0	539
9	0	88
10	0	0
11	15	26
12	37	20
13	0	44
14	0	0
15	11	160
16	0	9
17	0	86
18	25	0
19	332	0
20	0	257
21	0	140
22	272	5
23	0	265
24	0	256
25	0	170
Mean	31	125
Std Dev	83	133
Std Error	17	27
Std error %	54	21

Appendix 9. Photographs and Orthophoto Images of Sample Locations

figure A9-1 **Sample Location #1**

figure A9-2 **Sample Location #2**

figure A9-3 **Sample Location #3**

figure A9-4 **Sample Location #4**

figure A9-5 **Sample Location #5**

figure A9-7 **Sample Location #7**

figure A9-8 ***Sample Location #8***

figure A9-11 ***Sample Location #11***

figure A9-9 ***Sample Location #9***

figure A9-12 ***Sample Location #12***

figure A9-10 ***Sample Location #10***

figure A9-13 ***Sample Location #13***

figure A9-14 ***Sample Location #14***

figure A9-17 ***Sample Location #17***

figure A9-15 ***Sample Location #15***

figure A9-18 ***Sample Location #18***

figure A9-16 ***Sample Location #16***

figure A9-19 ***Sample Location #19***

figure A9-20 ***Sample Location #20***

figure A9-23 ***Sample Location #23***

figure A9-21 ***Sample Location #21***

figure A9-24 ***Sample Location #24***

figure A9-22 ***Sample Location #22***

figure A9-25 ***Sample Location #25***

figure A9 - 26 **Partial Cut - Sample 2, Block 14**

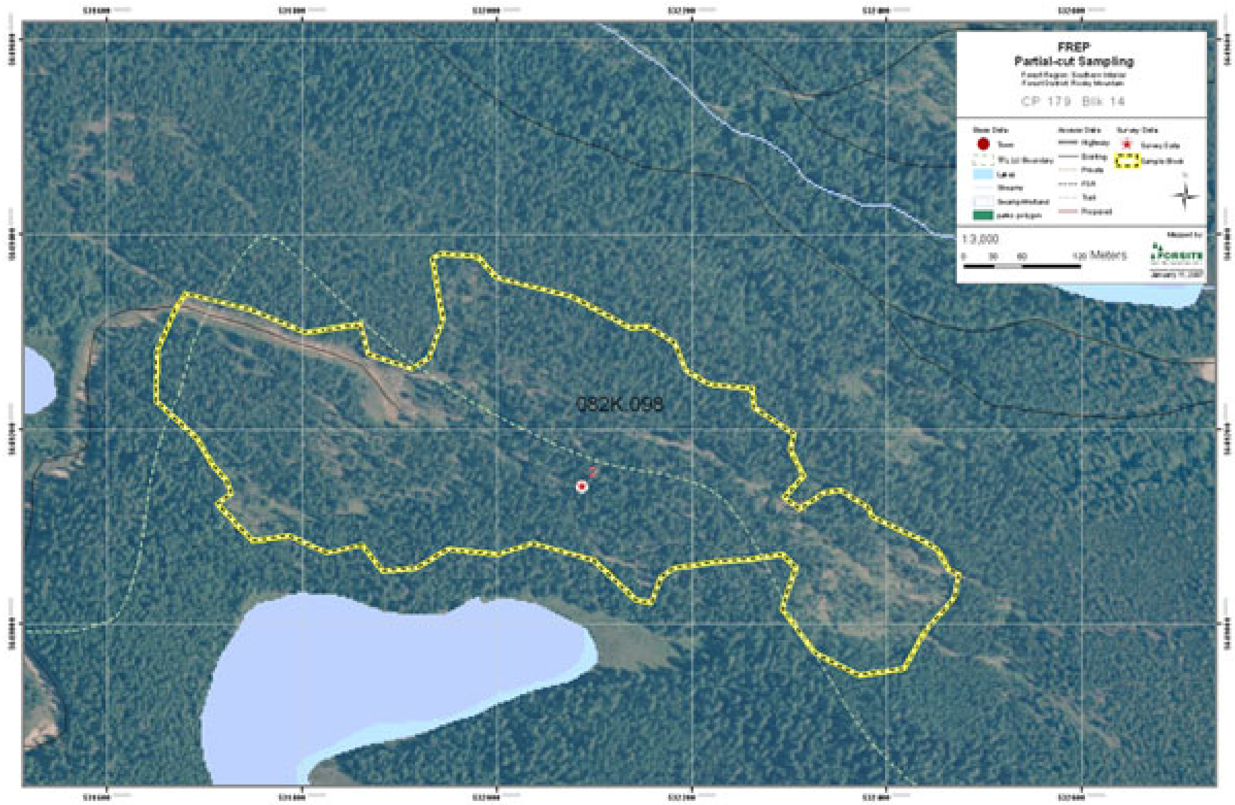

figure A9 - 27 **Partial Cut - Sample 3 & 7, Block 235**

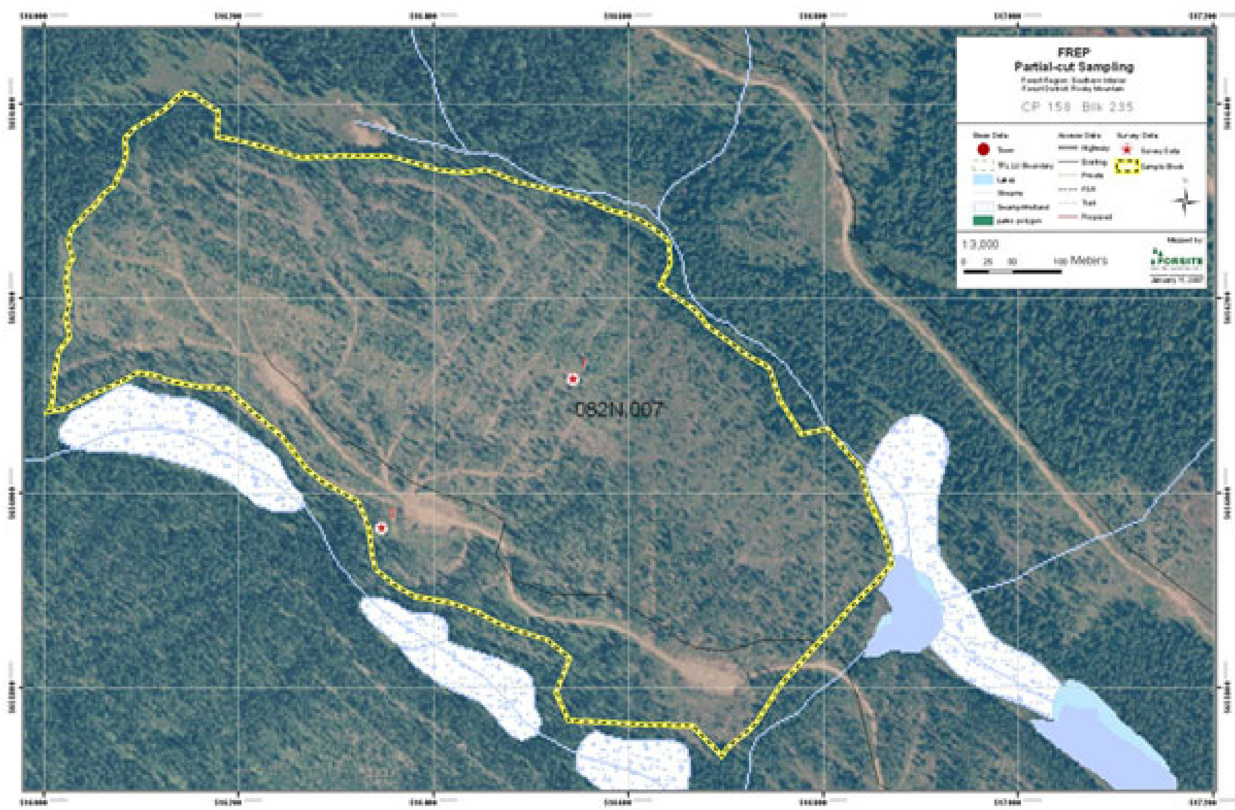

figure A9 - 28 ***Partial Cut - Sample 5, Block 20***

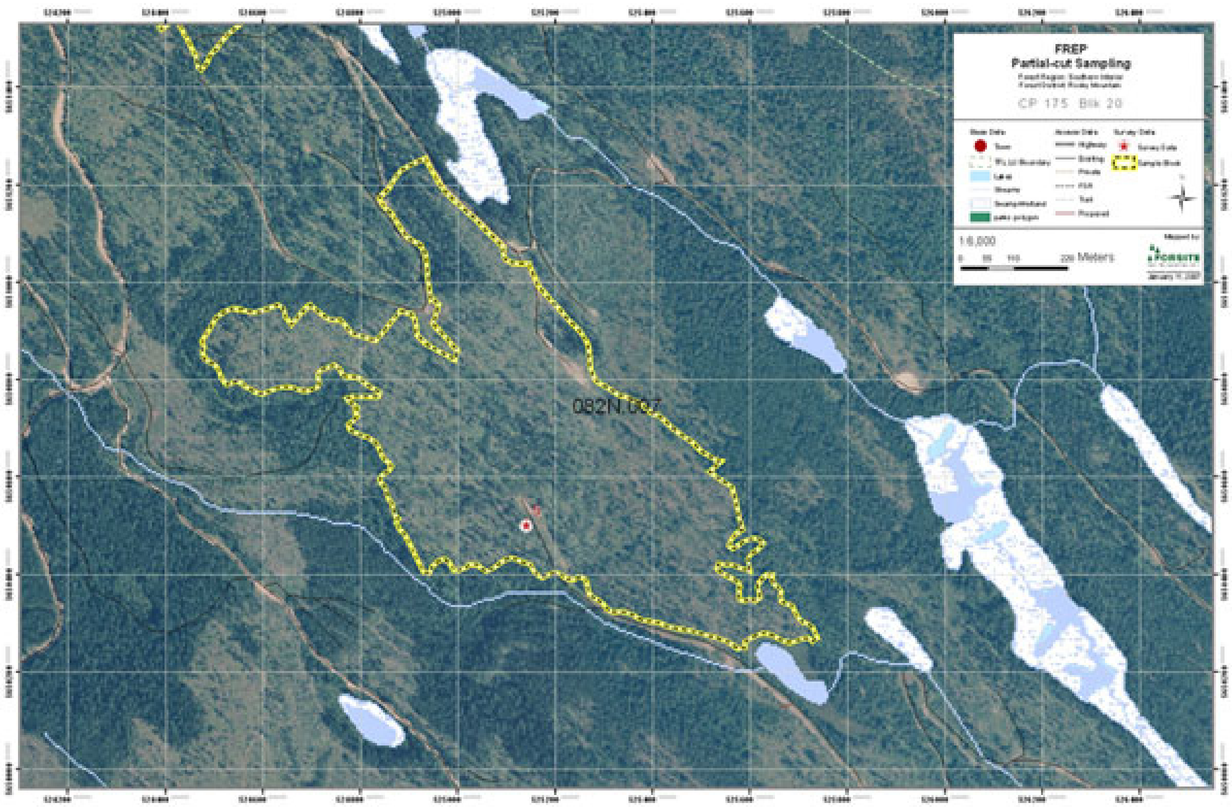

figure A9 - 29 ***Partial Cut - Sample 6, Block 16***

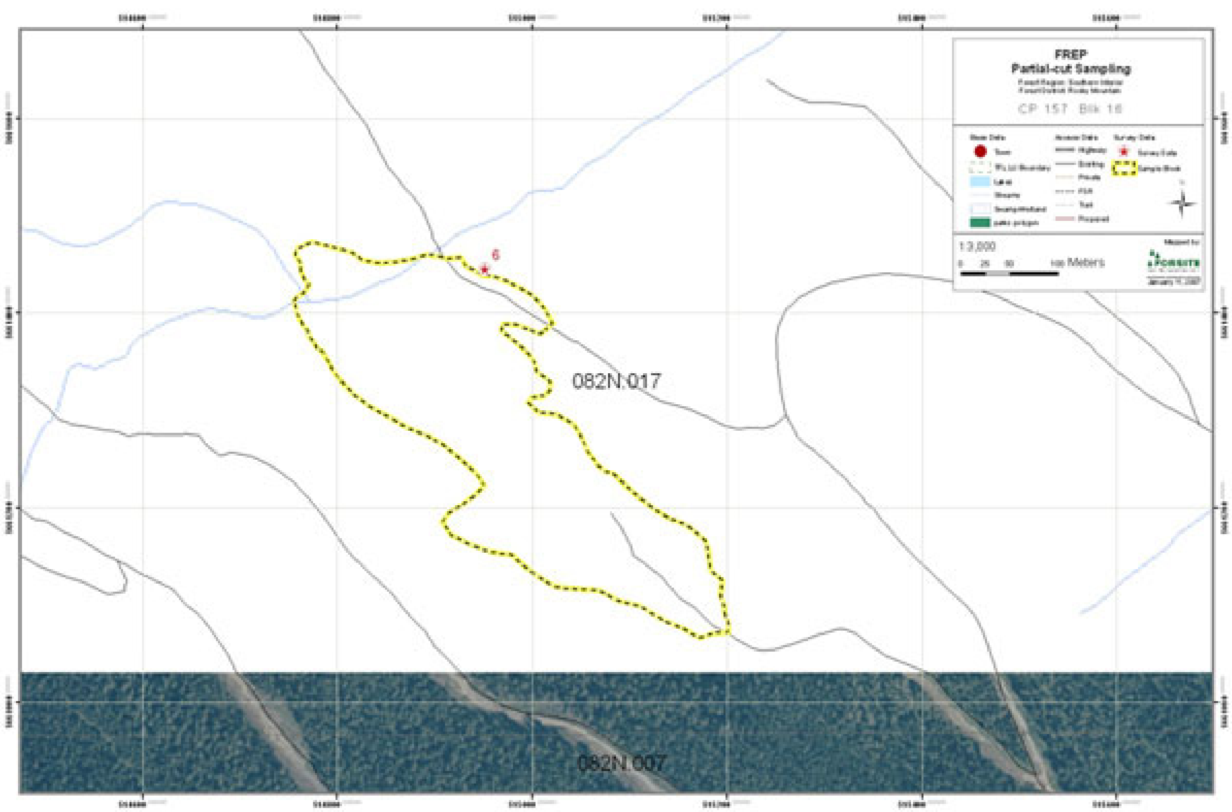

figure A9 - 30 ***Partial Cut - Sample 9 & 11, Block 7***

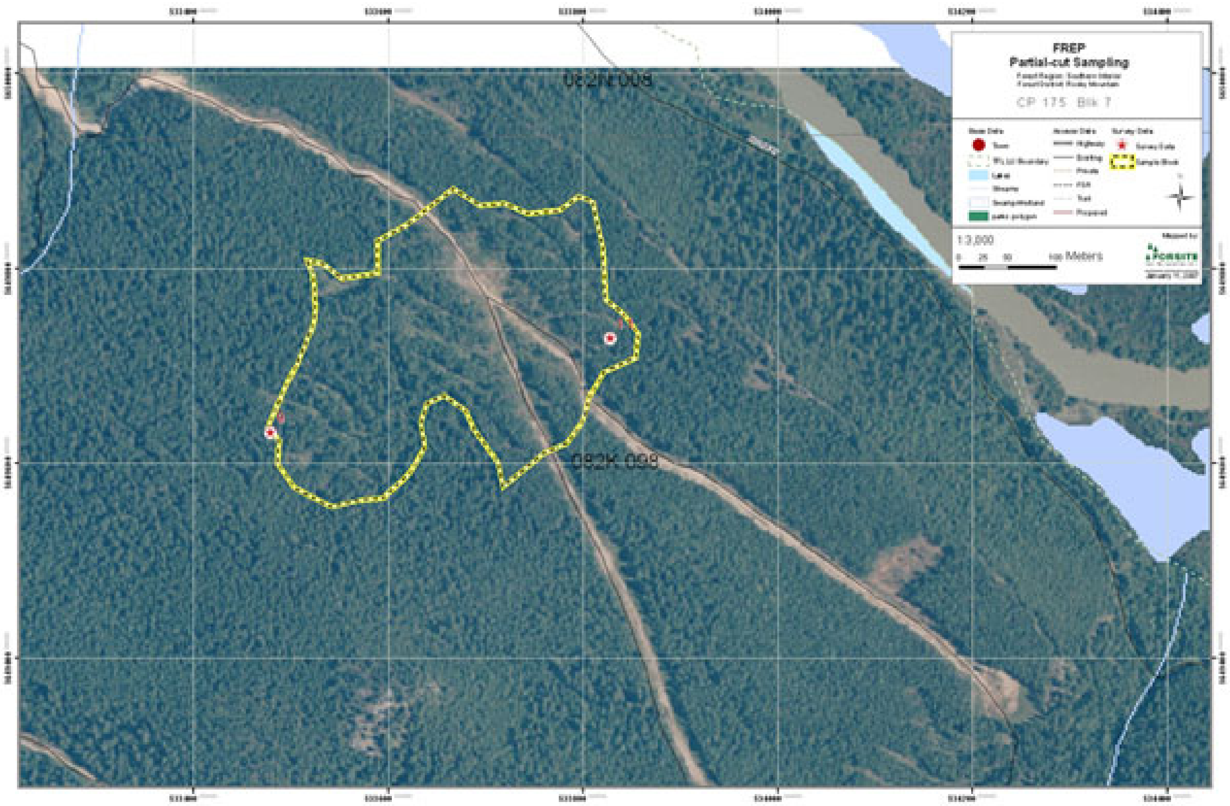

figure A9 - 31 ***Partial Cut - Sample 13 & 21, Block 19***

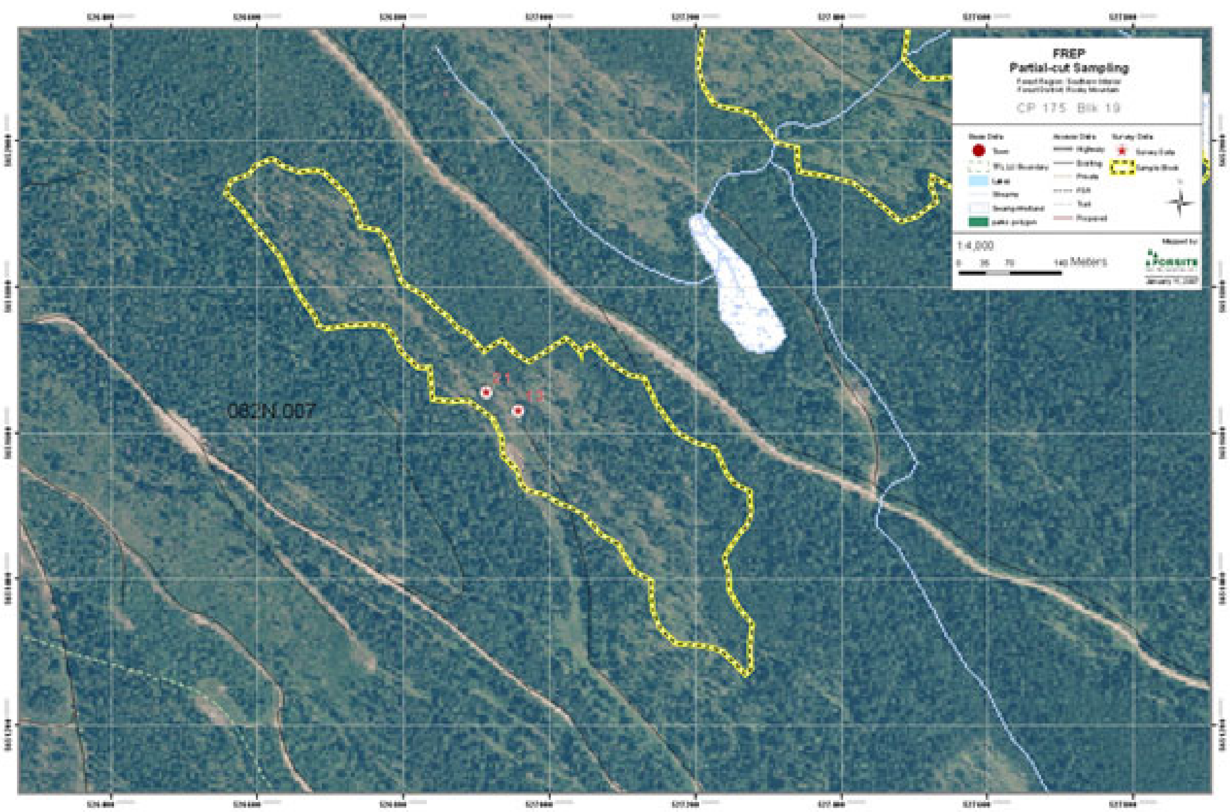

figure A9 - 32 ***Partial Cut - Sample 15, 19 & 22, Block 118***

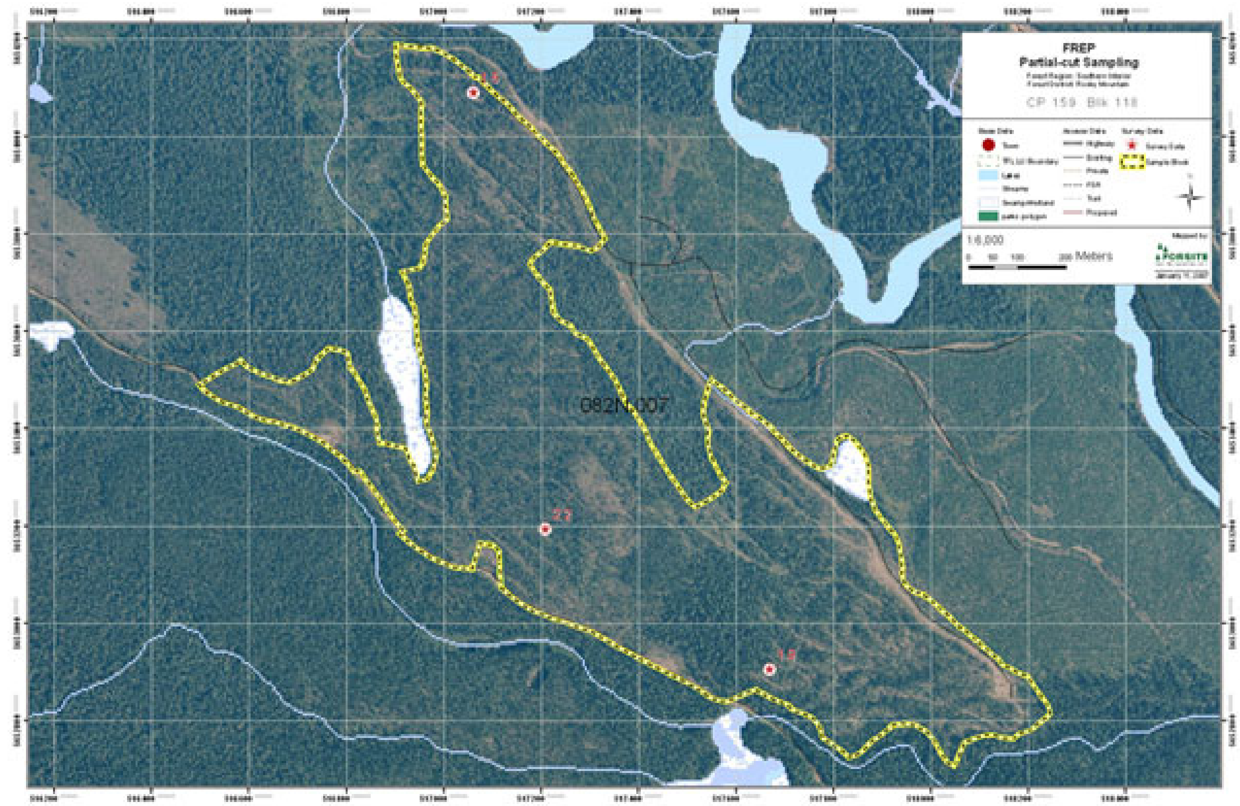

figure A9 - 33 ***Partial Cut - Sample 16, Block 13***

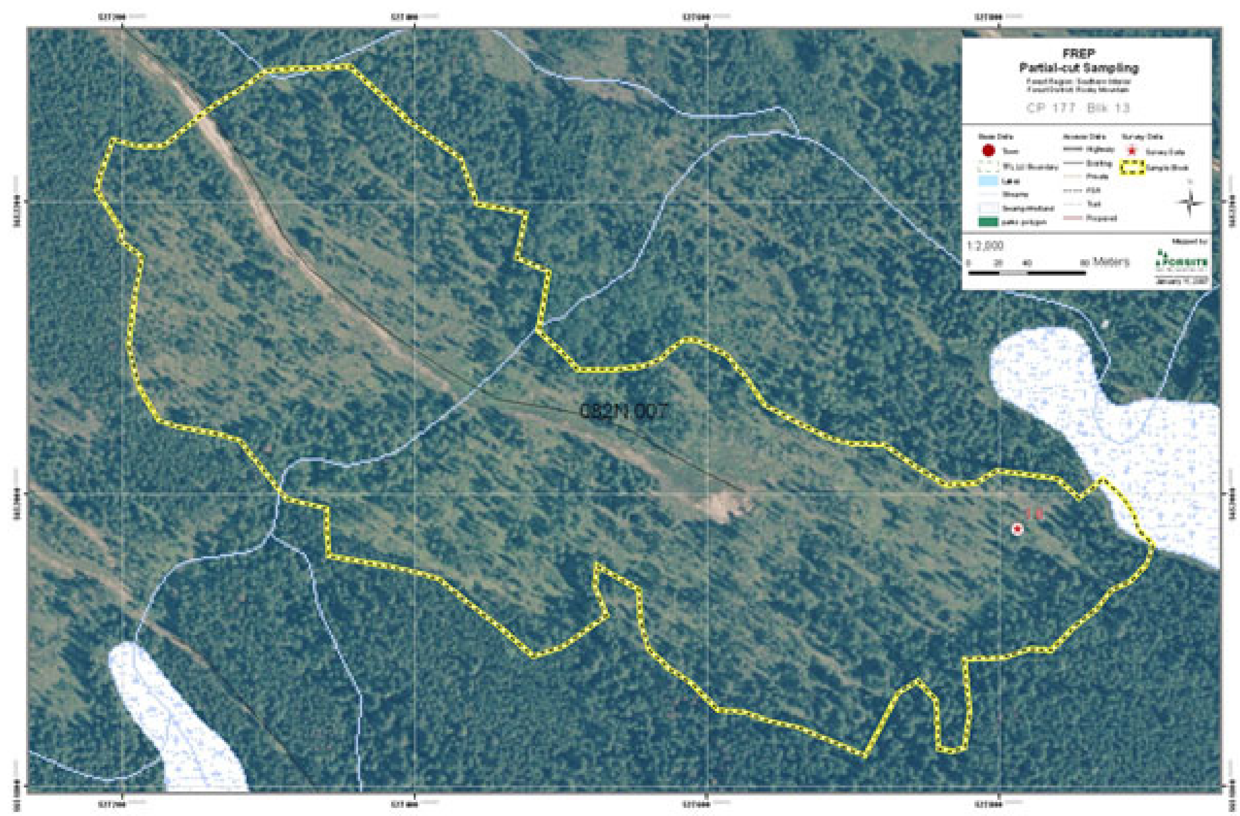

figure A9 - 34 **Partial Cut - Sample 18, Block 4**

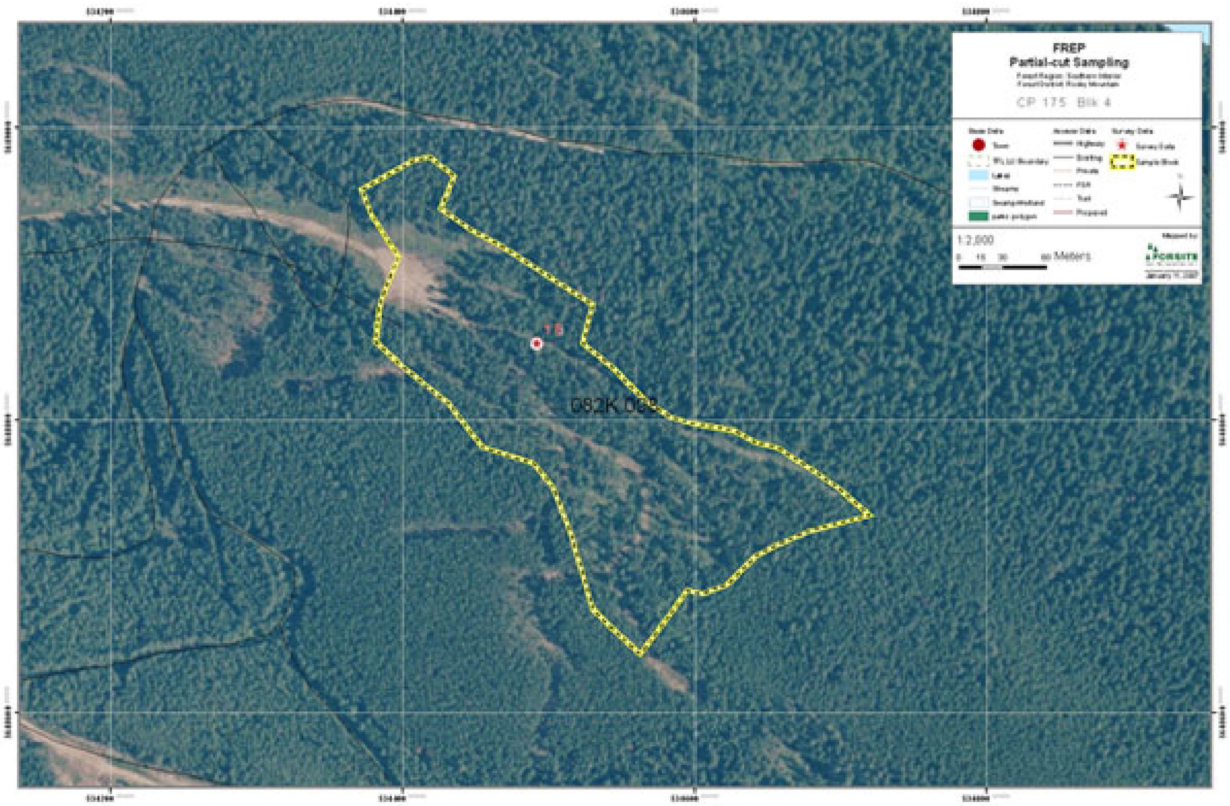

figure A9 - 35 **Partial Cut - Sample 23, Block 15**

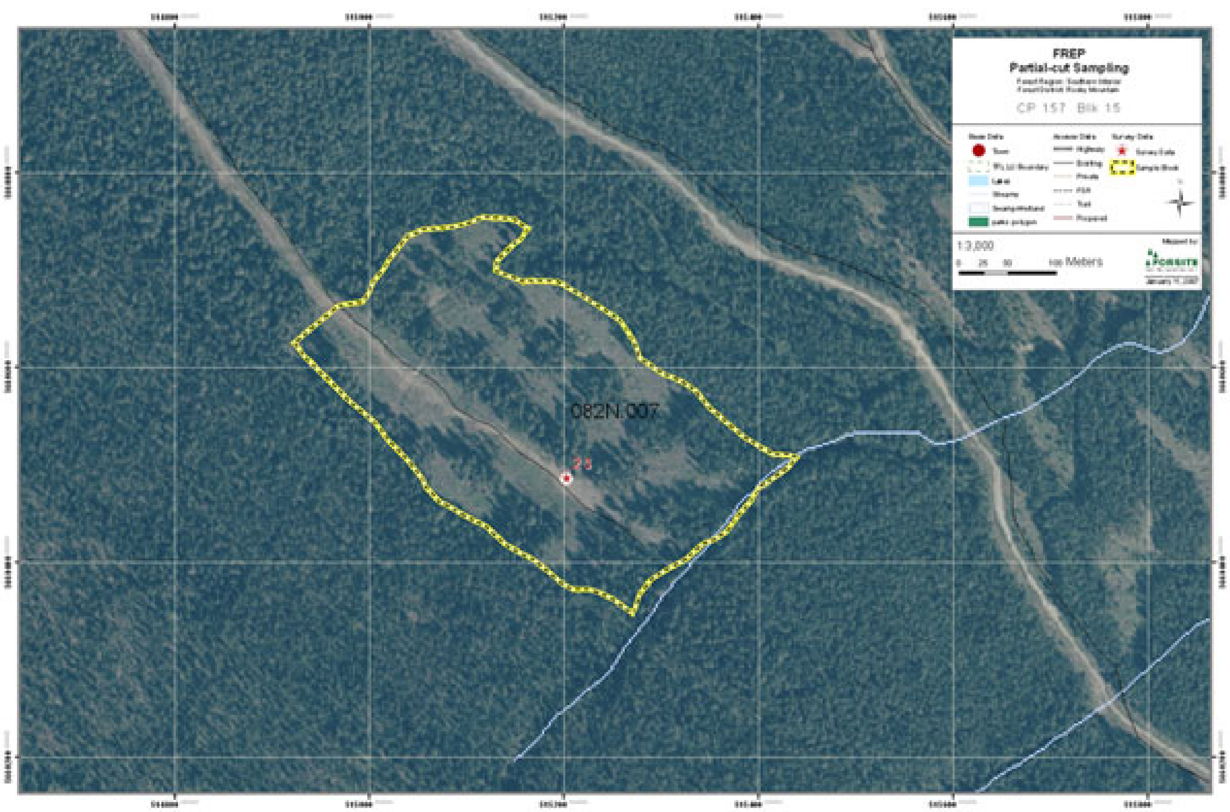

figure A9 - 36 ***Partial Cut - Sample 24, Block 3***

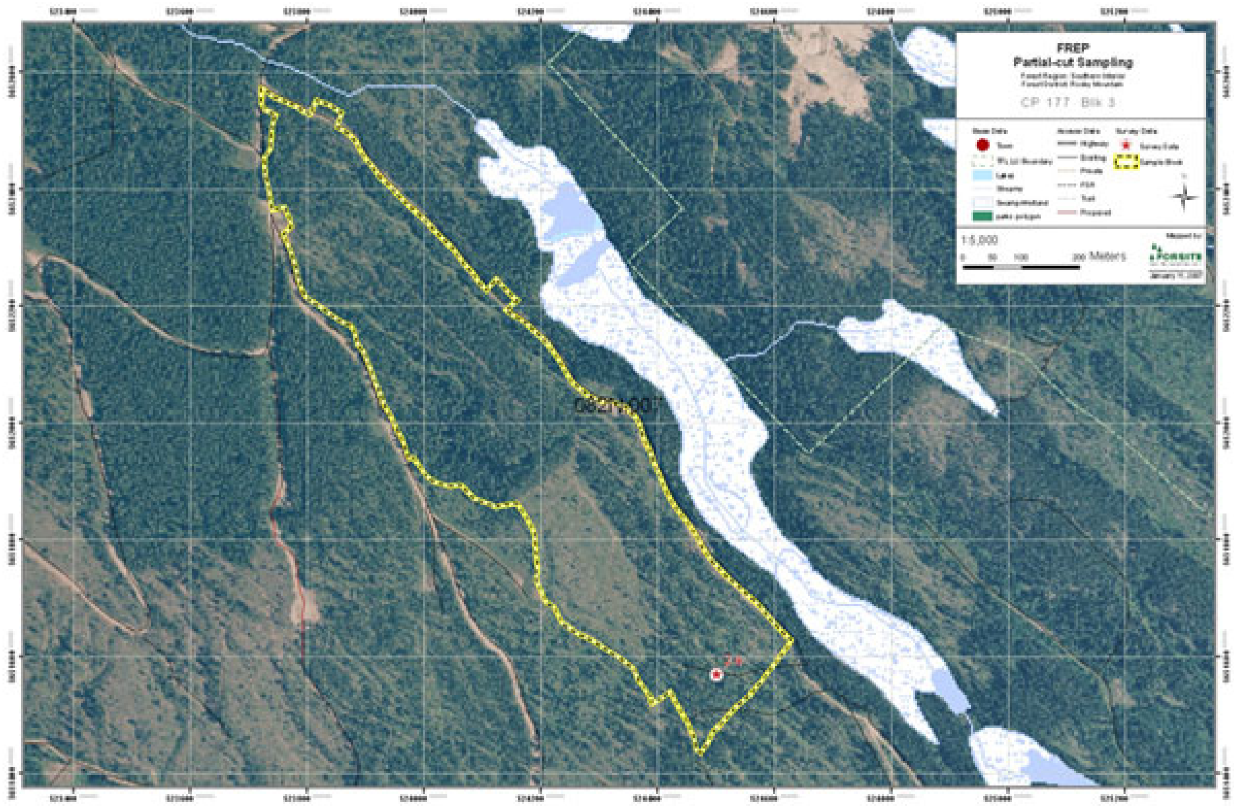

figure A9 - 37 ***Partial Cut - Sample 25, Block 109***