Dawson Creek Forest District

Vegetation Resources Inventory Ground Sampling Plan Revised Final Report

Prepared for

Ministry of Forests
Resources Inventory Branch
Victoria BC

Project: MFI-401-033

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Vancouver – Kamloops BC

0Executive Summary

Background

This report outlines the sampling plan for Phase II of the Provincial Vegetation Resources Inventory (VRI), and sub-unit inventories, in the Dawson Creek Forest District in the Prince George Forest Region. This plan was developed through consultation with various stakeholders in the District who identified local inventory needs and priorities. These stakeholders included staff from: the Ministry of Forests (MOF) (Resources Inventory Branch, Prince George Forest Region, and Dawson Creek Forest District), and Canadian Forest Products Ltd. (TFL 48).

The stakeholders have approved an earlier version (31 March 1997) of this report. This revised version considers the MOF policy which reduces the minimum sampling error standard from 15% to 10% (95% probability), includes the issue of provincial monitoring of indicators of sustainable forest management, and conforms with the newer format for final reports of the sampling plans.

Inventory Unit

The inventory unit for the Dawson Creek VRI is the entire landbase within the administrative boundaries of the District. The District covers approximately 3 million ha and is located in the Prince George Forest Region, between the Continental Divide and the Alberta border. The area includes the Dawson Creek TSA, TFL 48, a portion of the Kakwa Recreational Area, Monkman Provincial Park, Gwillim Lake Provincial Park, Sukunka Falls Provincial Park, Federal land, Williston Lake, and private lands. Approximately one-third of the District is in TFL 48, of which approximately 60% is classed as productive. Approximately 74% of the District is considered productive forest land. The remaining areas include non-forest and non-productive land (approximately 26%), and land with no typing available (less than 1%). According to the most recent timber supply review, about 33% (758,609 ha) of the Timber Supply Area was considered available for timber production.

Inventory Issues

Priority forest management issues were identified during the recent timber supply reviews in the TSA. Specific inventory issues related to these management issues are:

- The 1995 Inventory Audit of the Dawson Creek TSA indicated mature timber volumes were under-estimated by approximately 19% on average.
- Information to assist in projection of wildlife habitat; wildlife tree and coarse woody debris inventory and recruitment; forest health status (in coniferous and deciduous stands); pathological rotation ages; and range forage assessment (in aspen and cottonwood stands).

- Information for SIBEC correlations.
- Data to support inventory projection of boreal mixed-wood stands.
- Taper equation bias is suspected in the high elevation balsam and spruce stands.
- Quality and piece size information on stands that will be delivered to the mill in the next 10-20 years.
- Merchantability of old-growth spruce/balsam balsam/spruce stands; mixed-wood deciduous stands; deciduous stands; and height class 2 pine stands.
- Provincial monitoring of the indicators of sustainable forest management, as defined by the Canadian Council of Forest Ministers (CCFM).
- Issues raised by the Forest Resources Commission in its 1991 report *The Future of Our Forests*, regarding the inadequacy of forest inventories in the province.

Inventory Objectives

The inventory objectives were formulated based on the discussion and synthesis of the inventory issues by the stakeholders. The first objective is to implement VRI Phase II ground sampling in the Dawson Creek Forest District. The purposes of this sampling are to: estimate overall vegetation totals and averages for the District; provide initial conditions for measuring indicators of sustainable management; and provide a framework for sub-unit inventories. The number of samples will aim to target a sampling error of ±10% (95% probability) for timber volume in the treed portion of the District, and allow for calculation of sampling errors for other VRI attributes. The VRI should cover the entire District including the timber harvesting landbase, inoperable landbase, TFL 48, ecological reserves, municipalities, parks, and private lands.

The second objective is to conduct supplemental decay sampling across the District to estimate merchantability (net volume and value) of specific old-growth forest types identified by the MOF and the licensee. These forest types include old-growth spruce/balsam balsam/spruce stands; mixed-wood deciduous stands; deciduous stands; and height class 2 pine stands. These stands constitute about 66% of the forest area in the District.

These objectives will be addressed using VRI ground sampling and sub-unit inventories, as described below.

VRI Ground Sampling

The VRI Phase II ground sampling addresses the concerns expressed by the Forest Resources Commission in its 1991 report *The Future of Our Forests*, regarding the inadequacy of forest inventories in the province. The VRI Phase II ground sampling will provide unbiased estimates of overall averages and totals for timber and non-timber vegetation resources in the District.

This will address the immediate need to improve the accuracy of timber volume inventory in the operable landbase. The new inventory will provide data to check District biodiversity guidelines. Additional information for non-timber resources will include plant lists to indicate where more intensive sampling could improve estimates for specific plants and other botanical products. The VRI plots will establish initial conditions and locations for measuring changes and trends of the indicators of sustainable forest management at the Provincial level. This monitoring information can be used to counter inaccurate information about BC's forestry practices, to protect our forest products markets, and to address public environmental concerns. The VRI plots will also provide a common sampling base for a variety of other resources and special projects, and for sub-unit inventories.

The VRI Phase II samples will not, however, provide more detailed polygon information than is available in the current inventory. Thus these samples may not help address some of the management issues that require this information. More detailed polygon information can be provided through improved Phase I estimates. It is recommended that new Phase I estimates be derived for polygons containing the Phase II samples. This additional data could be used to evaluate potential benefits of new Phase I estimates.

The VRI ground sampling should be implemented in a two-step process. Step 1 would install approximately 100 Phase II sample clusters in the first season over the entire District. This should give an unbiased stand-alone inventory. Step 2 would install additional plots in the second field season. Sampling in the first year would provide experience to refine the process for the second field season. This first year of sampling would also provide estimates of the coefficient of variation (CV) to estimate the remaining number of samples required to achieve the precision target of ±10% for timber volume.

We suggest a minimum total sample size of 350 Phase II plots for planning, training, and logistic considerations, 250 of these will be in the treed portion of the District. Planning should include sub-sampling plots with difficult access to reduce the high costs of sampling these areas. We also suggest that the sample polygons be photo interpreted before or after ground sampling. This information would help assess any improvements that could be achieved through newer Phase I estimates in the remaining polygons.

Other Ground Sampling Activities

A two-step approach is also suggested for the other ground sampling activities that support the VRI process: Net Volume Adjustment Factor (NVAF) sampling and Within Polygon Variation (WPV) sampling. A total of 200 sample trees in at least 30 sampling points is recommended initially for NVAF stem analysis in 1999. Additional stem analysis may be done in 2000, if needed. A minimum sample of 30 of the initial 100 polygons should be selected for intensive sampling for WPV starting in 1999. Additional polygons can be sampled after these are complete, if interim results suggest more are needed to achieve a desired precision.

Merchantability Sub-unit Inventory

One sub-unit was created within the Dawson Creek Forest District to address the second inventory objective. This sub-unit was specific to the merchantability (net volume and value) of old-growth spruce/balsam balsam/spruce stands; mixed-wood deciduous stands; deciduous stands; and height class 2 pine stands. These stands constitute about 66% of the forest area in the District. A total of 250 timber emphasis plots with stem analysis are recommended for sampling this sub-unit.

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3 1. ....INTRODUCTION

41.1 TERMS OF REFERENCE

This report was completed under contract to the Ministry of Forests (MOF) Resources Inventory Branch to develop sampling plans to implement the Vegetation Resources Inventory (VRI) in several Forest Districts. These reports are similar in presentation, but each contains specific recommendations for the target inventory unit to address local concerns. This sampling plan was designed by A.Y. Omule, *Ph.D., RPF*, Kim Iles, *Ph.D.*, and Jim Thrower, *Ph.D., RPF*. Drafts of this report were prepared by A.Y. Omule, Jim Thrower, and Fei Disbrow with assistance from other support staff.

51.2 BACKGROUND

This report is a revised final report of the sampling plan for the VRI Phase II in the Dawson Creek Forest District in the Prince George Forest Region. This report is a revised version of the earlier report (31 March 1997) that was approved by the stakeholders.[1] The earlier version of the report was revised to take into account: the MOF policy which reduces the minimum sampling error standard from 15% to 10% (95% probability); to include the provincial monitoring of indicators of sustainable forest management; and to conform with the newer format of the VRI sampling plans final reports.

This plan was developed through consultation with various stakeholders in the District who identified local inventory needs and priorities. These stakeholders included staff from the MOF (Resources Inventory Branch, Prince George Forest Region, and Dawson Creek Forest District), and Canadian Forest Products Ltd. (TFL 48). The consultation process included a conference call to discuss the process for developing a sampling plan; a Stakeholders meeting to identify local forest management and inventory issues, needs, priorities, and to develop inventory objectives; and a conference call to approve the final report.

The development of this plan followed the procedures outlined in the MOF Resources Inventory Branch draft procedures *"Vegetation Resources Inventory. Preparing a Sampling Plan for Ground Sampling"* (December 1996). This plan was developed in conjunction with the VRI sampling plan for the Lillooet Forest District.

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[1] ~~100 Mile House~~Dawson Creek Forest District. Vegetation Resources Inventory Ground Sampling Plan. 31 March 1997. Prepared by J.S. Thrower & Associates Ltd. 18 pp.

DOCUMENT OBJECTIVES

This report describes the sampling plan for the VRI Phase II ground sampling for the Dawson Creek District. The intent is that this revised report will be reviewed by the MOF and the other stakeholders in the District. A final sampling plan to be approved by the MOF District Manager, Regional Manager, the Director of the Resources Inventory Branch, and other stakeholders will be prepared by the MOF Resources Inventory Branch based upon this revised report.

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DAWSON CREEK FOREST DISTRICT

82.1 LANDBASE

The inventory unit is the Dawson Creek Forest District. The District covers approximately 3 million ha and is located in the Prince George Forest Region, between the Continental Divide and the Alberta border. The area includes the Dawson Creek TSA, TFL 48, the portion of the Kakwa Recreational Area within the District, Monkman Provincial Park, Gwillim Lake Provincial Park, Sukunka Falls Provincial Park, Federal land, and private lands (Figure 1). The District is a very diverse area rich in timber, oil and gas, wildlife, recreation, and agriculture.

Approximately one-third of the District is in TFL 48, of which about 60% is classed as productive. Williston Lake is the only significant water body included in the inventory unit boundary. Kakwa Recreational Area will be split at the District boundary for the purposes of this inventory.

About 74% of the District is considered productive forest land (Tables 1 and 2).[2] The remaining areas include non-forest and non-productive land (approximately 26%) and land with no typing available (less than 1%). About 33% (758,609 ha) of the TSA was considered available for timber production in the most recent Timber Supply Analysis.[3]

[2] BC Ministry of Forests. Provincial Summary Reporting System 4.0. Dawson Creek Forest District No. 34G. (Summary report provided by Gary Johansen, 24 March 1997).

[3] BC Ministry of Forests. Dawson Creek TSA Timber Supply Analysis. Timber Supply Branch, 1450 Government Street, Victoria, BC.

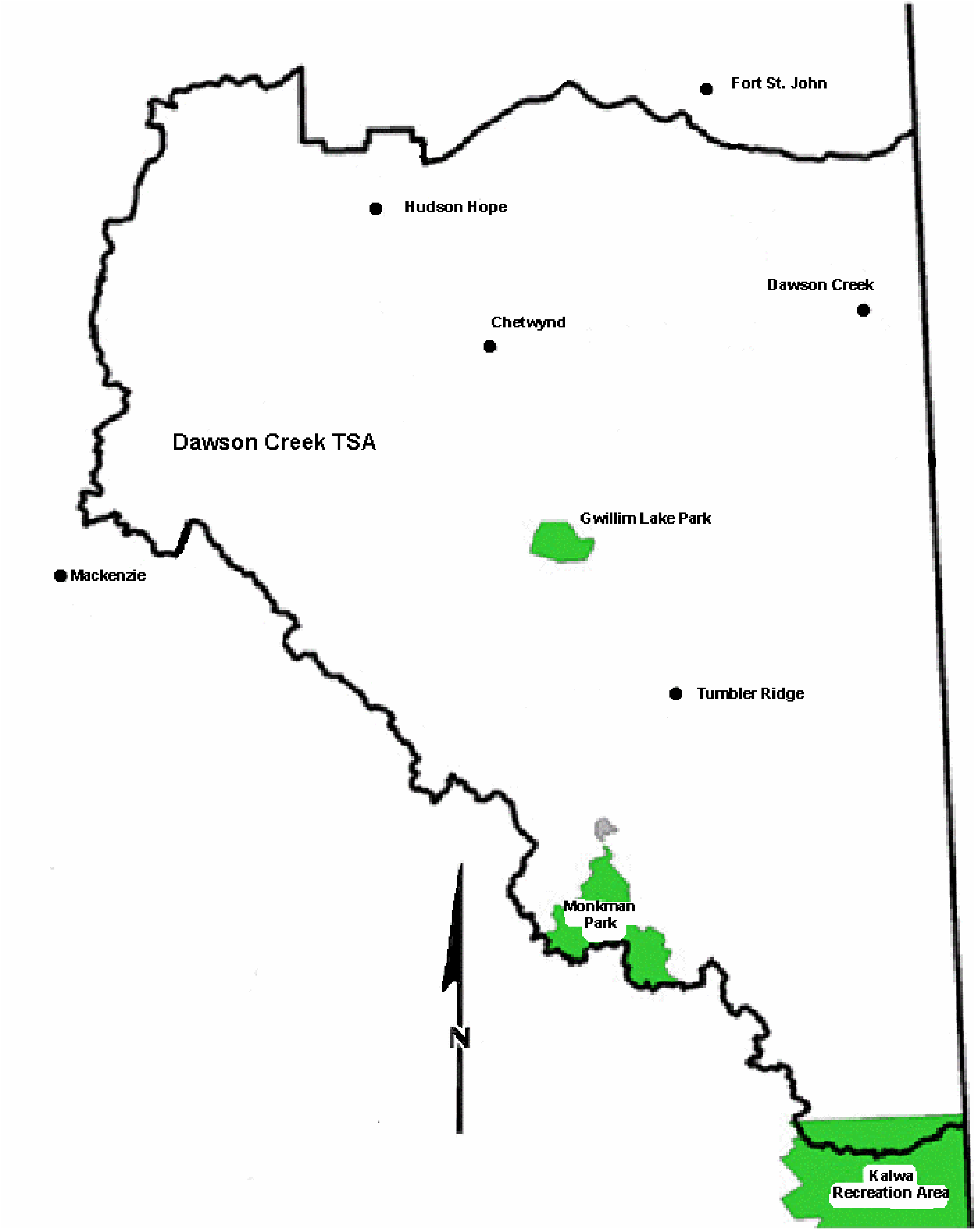

Figure 1. Map of the Dawson Creek Forest District.

Table 1. Area in the Forest District by ownership and administration class.[4]

Land Class	Total Area (ha)	Total Area (%)
Provincial Crown		
TSA	1,932,123	64.2
TFL 48	638,767	21.2
Parks	39,796	1.3
Federal (IR)	5,162	0.2
Private	392,262	13.0
Total	*3,008,110*	*100*

Table 2. Area by forest and non-forest land.

Land Classification	Total Area (ha)	Total Area (%)
Forest Land		
Productive	2,244,105	
Immature	(800,601)	(26.4)
Mature	1,226,596	40.5
Not Stocked	216,907	7.2
Non-Productive	147,101	4.9
Non-Forest Land	636,679	21.0
No Typing Available	799	0.0
Total	*3,028,684*	*100*

92.2 FORMER INVENTORIES

The most recent re-inventory in the Dawson Creek TSA was the standard re-inventory, which began in 1970/71 and ended in 1990/91. No new Phase I VRI has been carried out in the TSA since then. A new Phase I process (based on the old re-inventory standards) is currently underway in the TFL. A 1995 audit of the Dawson Creek TSA inventory showed significant under-estimation of timber volume (approximately 19%). No inventory audit has been completed in the TFL.

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[4] These statistics are intended to portray the relative areas in the different land tenure. They do not define the exact total areas to be sampled.

BUSINESS CONSIDERATIONS

113.1 STAKEHOLDERS

One of the first steps in developing the sampling plan was to identify stakeholders to be consulted for determining local inventory needs and priorities. The following stakeholders were contacted and provided with all the documentation developed throughout the process (some may not have been present at the stakeholders meeting and conference calls).

MOF Resources Inventory Branch	Mark Gillis Ken Richardson Sam Otukol
MOF Prince George Forest Region	Dick Nakatsu Matt Mackar
MOF Dawson Creek Forest District	Jeff Beale Rod Kronlachner
Canadian Forest Products (TFL 48)	Don Rosen Andrew deVries

123.2 FOREST MANAGEMENT ISSUES

The new VRI is important to planning and management in the District. Several priority forest management issues were identified during the recent timber supply review (Tables 3 and 4). An assessment of potential impacts of the VRI Phase II ground sampling on these management issues is also shown in these tables, but the relative importance of the various issues is not indicated. For example, a statistically accurate timber volume estimate may carry more weight than all other issues combined, in which case the contribution or impact of the VRI ground sampling would be highly significant.

Table 3. Forest management issues in the Dawson Creek TSA and the potential impact of the VRI Phase II ground sampling.

Issues[5]	Impact	Remarks
1. Slope and terrain mapping in the northeastern part of TSA.	No	Phase II data could be used by interpreters of slope and terrain mapping.
2. Clarify management goals for mixed-wood stands.	Partial	Phase II will provide information for planning supplemental decay sampling in the mixed – wood stands, which will provide base data for setting management goals for these stands.
3. Timber/vegetation inventory.	Yes	Improved District timber net volumes will be obtained by removing overall bias and net volume adjustment. Statistical statements of accuracy for the overall inventory will be

[5] Forest Management Issues Identified Through the AAC Determination Process. TSA/TFL Timber Supply Reviews: 1992-1996. 31 December 1996. Timber Supply Branch, BC Ministry of Forests, Victoria, BC. Pages 109-113.

	Issues[5]	Impact	Remarks
			provided. In addition, Phase II will provide overall District totals for non-timber vegetation such as coarse woody debris, stumps, potential wildlife trees, range forage, and plant lists for species diversity. This information can be used to check existing biodiversity guidelines, and provides a basis for additional sampling. There is a risk that precise estimates will not be obtained for these attributes.
4.	Growth and yield models for regenerated deciduous and mixed-wood stands.	Partial	Phase II will help check volume assignment of overall volumes for the District. Adjusted Phase I estimates provide polygon starting volumes for projection. Stem analysis of trees for net volume adjustment factor (NVAF) sampling can be used to check decay relationships.
5.	Regeneration/ regeneration delay.	No	
6.	Land-base: prescribed burn areas outside timber harvesting land-base.	No	
7.	Small diameter pine.	Yes	Phase II will help check the expected overall volumes in these stands for the District.
8.	Non-recoverable losses	Partial	The Phase II sampling will provide basis for subsequent augmentation sampling to quantify these losses. The NVAF sampling will provide information on decay losses.

Table 4. Forest management issues in TFL 48 and the potential impact of the VRI Phase II ground sampling.

	Issues[6]	Impact	Remarks
1.	Operability: impact of increased timber harvesting landbase on timber supply.	Yes	Phase II will check the overall TFL timber inventory volumes, which would be the basis for examining the impact of the expanded timber harvesting landbase on timber supply.
2.	Operability: harvest systems.	No	
3.	Timber/vegetation inventory.	Yes	Improved TFL timber net volumes will be obtained by removing overall bias and net volume adjustment. Statistical statements of accuracy for the overall inventory will be provided. In addition, Phase II will provide overall TFL totals for non-timber vegetation such as coarse woody debris, stumps,

[6] Forest Management Issues Identified Through the AAC Determination Process. TSA/TFL Timber Supply Reviews: 1992-1996. 31 December 1996. Timber Supply Branch, Ministry of Forests, Victoria, BC. Pages 267-269.

Issues[6]	Impact	Remarks
		potential wildlife trees, range forage, and plant lists for species diversity. This information can be used to check existing biodiversity guidelines, and provides a basis for additional sampling. There is a risk that precise estimates will not be obtained for these attributes. The Phase I work currently under way in the TFL will potentially improve the individual polygon estimates.
4. Regeneration delay.	No	
5. Estimates of areas in riparian reserves and management zones.	No	Potential impact possible with better Phase I estimates: assignment of "wetland" land classification to polygons in the Phase I will help identify wetlands and their associated riparian areas.
6. Areas of cultural or archaeological significance.	Partial	Plant lists from Phase II will provide incidence data for medicinal plants and other botanical products as a basis for additional sampling.

133.3 INVENTORY ISSUES

The most recent Timber Supply Review in the TSA and TFL and the Inventory Audit in the TSA identified specific issues and information to improve the timber inventory. Some of the issues and information identified by MOF Region and District staff and Canadian Forest Products Ltd. staff include:

- The 1995 Inventory Audit of the Dawson Creek TSA indicated mature timber volumes were under-estimated by approximately 19% on average. No inventory audit has been completed for the TFL.
- Information to assist in projection of wildlife habitat; wildlife tree and coarse woody debris inventory and recruitment; forest health status (in coniferous and deciduous stands); pathological rotation ages; and range forage assessment (in aspen and cottonwood stands).
- Information for SIBEC correlations.
- Data to support inventory projection of boreal mixed-wood stands.
- Taper equation bias is suspected in the high elevation balsam and spruce stands.
- Quality and piece size information on stands that will be delivered to the mill in the next 10-20 years.

- Merchantability of old-growth spruce/balsam balsam/spruce stands; mixed-wood deciduous stands; deciduous stands; and height class 2 pine stands.
- Provincial monitoring of the indicators of sustainable forest management, as defined by the Canadian Council of Forest Ministers (CCFM).[7] Monitoring would involve measuring changes and trends in some of these indicators, which include percent and extent of area by forest type and age class, and mean annual increment by forest type and age class.
- Issues raised by the Forest Resources Commission's 1991 report *The Future of Our Forests*, regarding the inadequacy of forest inventories in the province. These concerns included lack of statements of precision on the inventory, inadequate information on non-timber vegetation, and the narrow focus on commercial timber volume and the operable landbase.

143.4 Inventory Objectives

The following inventory objectives were formulated based on the discussion and synthesis of the inventory issues by the stakeholders:

1. The first objective is to implement VRI Phase II ground sampling in the Dawson Creek Forest District. The purposes of this sampling are to: estimate overall vegetation totals and averages for the District; improve the existing inventory in the TSA and TFL 48; provide initial conditions for measuring indicators of sustainable management; and provide a framework for sub-unit inventories. The number of samples will aim to give a sampling error of ±10% (95% probability) for timber volume in the treed portion of the District, and allow for calculation of sampling errors for other VRI attributes. The VRI will cover the entire District including the timber harvesting landbase, inoperable landbase, parks, ecological reserves, municipalities, and private lands.
2. The second objective is to conduct supplemental decay sampling across the District to estimate merchantability (net volume and value) of specific old-growth forest types identified by the MOF and the licensee. These forest types include old-growth spruce/balsam balsam/spruce stands; mixed-wood deciduous stands; deciduous stands; and height class 2 pine stands. These stands constitute about 66% of the forest area in the District.

These objectives are addressed using VRI ground sampling and sub-unit inventories, as described in the next section.

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[7] Canadian Council of Forest Ministers. 1995. Defining sustainable forest management. A Canadian Approach to Criteria and Indicators. Natural Resources Canada, Canadian Forest Service, Ottawa, Ontario. 22 pages.

153.5 DISCUSSION

The VRI Phase II ground sampling addresses the concerns expressed by the Forest Resources Commission in its 1991 report *The Future of Our Forests*, regarding the inadequacy of forest inventories in the province. These concerns included lack of statements on the precision of the inventory, inadequate information on non-timber vegetation, and the narrow focus on commercial timber volume and the operable landbase. To address these issues, the VRI Phase II ground sampling will provide unbiased estimates of overall averages and totals for timber and non-timber vegetation resources in the District. This will address the immediate need identified by the timber volume inventory audit. The new inventory will also provide data to check District biodiversity guidelines, VDYP assigned volume, site indices, limited information for site index-BEC correlations, and forage-tree attribute correlations. Additional information for non-timber resources will include plant lists to indicate where more intensive sampling could improve estimates for specific plants and other botanical products. The VRI will provide the initial conditions and locations for measuring changes and trends in the indicators of sustainable forest management. This monitoring information can be used to counter inaccurate information about BC's forestry practices, to protect BC forest products markets, and to address public environmental concerns. The VRI plots will also provide a common sampling base for a variety of other resources, special projects, and sub-unit inventories.

The VRI Phase II samples will not provide more detailed polygon information than is available in the current inventory. Thus these samples may not help address some of the management and inventory issues that require this information (Section 3). More detailed polygon information can be provided through improved Phase I estimates, which will be provided in the "second pass" of the inventory. However, we recommend that new Phase I estimates are derived for the polygons selected for the Phase II samples. This should be done using one photo interpreter to provide consistency among estimates. Existing polygon boundaries should be maintained, and the additional data could be used to evaluate potential benefits of new Phase I estimates.

One sub-unit inventory has been proposed to address the second inventory objective identified by stakeholders. This sub-unit was specific to the merchantability (net volume and value) of old-growth spruce/balsam balsam/spruce stands; mixed-wood deciduous stands; deciduous stands; and height class 2 pine stands. This timber sub-unit inventory can be done independently of the VRI ground sampling. However, it is important that the sampling design that will be implemented for these sub-unit inventories use the VRI definitions and measurement protocols as much as possible. This will allow for seamless integration of the data from this sub-unit inventory with the VRI ground sampling.

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VRI GROUND SAMPLING

174.1 OBJECTIVE

The objective of VRI ground sampling in the Dawson Creek Forest District is to provide overall totals and averages for timber and non-timber vegetation resources (such as forage range, medicinal plants, and other botanical forest products) in the District. This should help resolve some forest management issues in the District such as improved estimates of overall net timber volume inventory, biodiversity guidelines levels (e.g., coarse woody debris), site index estimates, and site index-BEC correlations. The VRI also provides a foundation for sub-unit inventories, and provides initial conditions and locations for monitoring (measuring changes and trends of the indicators of sustainable forest management at the District and Provincial levels). It also provides a sampling framework for a variety of other potential sampling needs.

The total number of VRI sample clusters will aim to achieve a ±10% sampling error (95% probability) for timber volume in the treed portion of the District,[8] TSA, and TFL, and to allow for calculation of sampling errors for other VRI attributes. The key attributes of interest in the Dawson Creek VRI are stand age, net volume by species, stand height, stand structure, and species composition. Information should be collected on all attributes, but the variability of identified key attributes should be used to set the sample size for the VRI.

184.2 TARGET POPULATION

The target population is the entire Dawson Creek Forest District landbase, both vegetated and non-vegetated. The VRI should cover the entire District including the timber harvesting landbase in the TSA and TFL, inoperable landbase, parks, recreational areas, ecological reserves, municipalities, and private lands.

194.3 SAMPLING UNIT

The sampling unit[9] for VRI Phase II ground sampling is a five-point cluster (Figure 1) consisting of a central sample point (the integrated plot) surrounded by four auxiliary points located 50 m at cardinal directions from the integrated plot. Plots of different configurations (e.g., fixed-area plots, prism plots, and line transects) are centered on the integrated point to collect various vegetation attributes. Measurements include tree attributes, plant lists and percent cover, ecological site description, soil description, old-growth designation, coarse woody debris, and range resources (Appendix A).

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[8] The 10% sampling error level is the provincial standard which was approved by the Chief Forester in June 1997 (Briefing Note to the Chief Forester of 7 May 1997 prepared by the MOF Resources Inventory Branch). This level was chosen based on consideration of the risks associated with misstating the inventory in timber supply analysis.

[9] A sampling unit is a portion of the population from which sample observations are made. Sampling units are non-overlapping subdivisions of the population for sampling purposes.

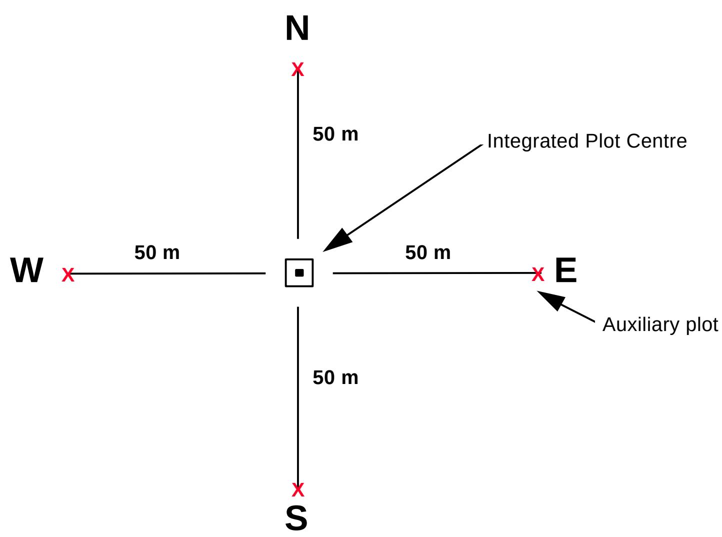

Figure 2. The five-point sample cluster for the Vegetation Resources Inventory.[10]

204.4 SAMPLE SELECTION

The sample polygons should be selected systematically from a sorted list that includes all polygons in the District. Polygons from the TSA should be compiled to create one sorted list.[11] The polygons in this list should be sorted by land type [BC Land Cover Classification Scheme (BCLCS)], and the treed polygons should be sorted further by leading tree species, age, and site index (Figure 2). Sorting the polygons should uniformly distribute the samples across the selected sorting criteria.

[10] BC Resources Inventory Committee. 1997. Vegetation Resources Inventory Ground Sampling Procedures (March 31), pages 3-1 to 3-2.

[11] We can create more than one sorted list from the population, and select an independent systematic sample from each list separately. Each list must be a valid subset of the entire population; that is, polygons should be allocated to the sorted lists randomly or systematically. This would enable direct estimation of sampling error using the systematic sampling formulae involving averages from each set (rather than assuming the simple random sampling formulae, which generally may over-estimate sampling error). In this case stratified random sampling formula can be used, whereby each list is considered a stratum.

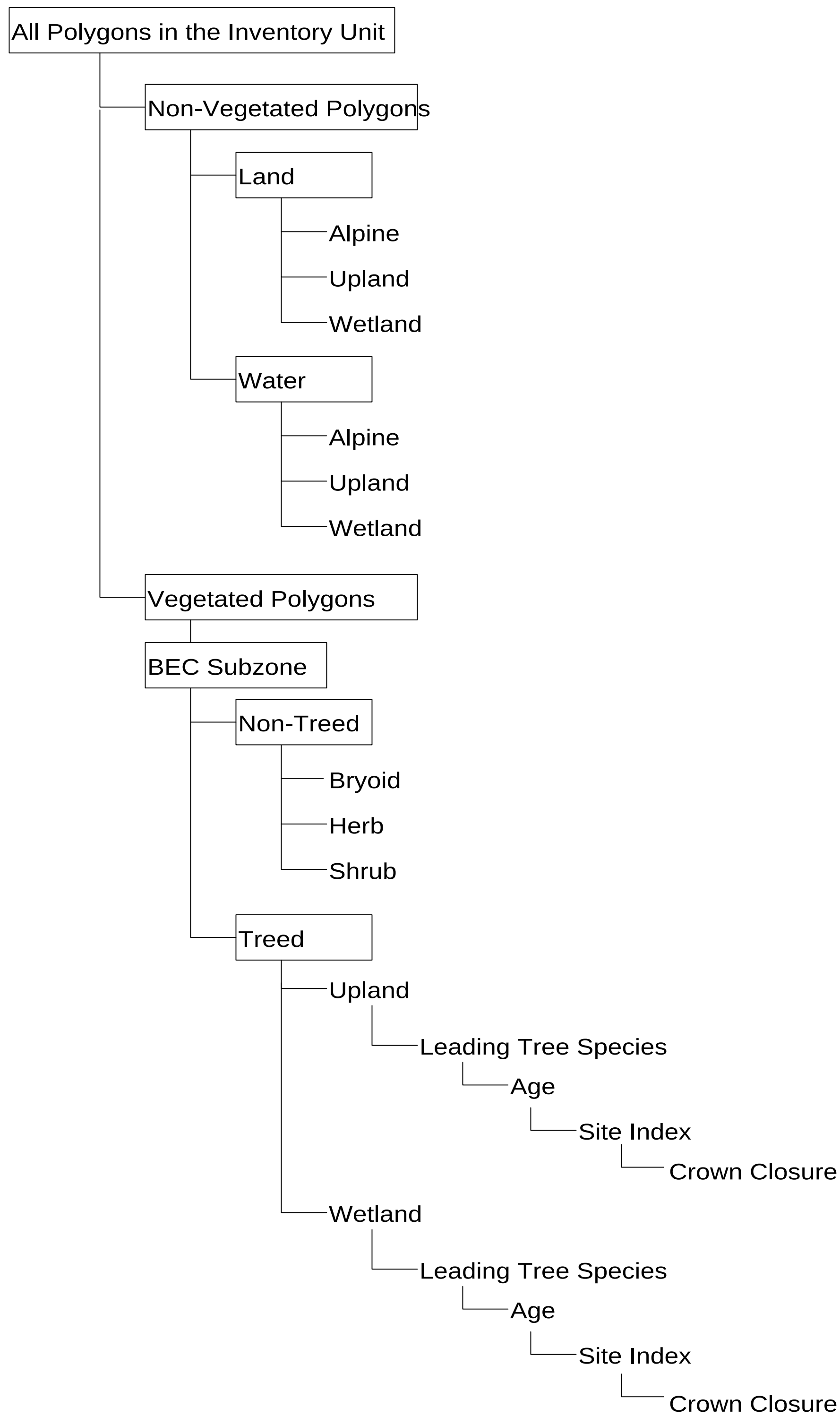

Figure 3. Polygon sort criteria for Vegetation Resources Inventory ground sampling.

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SAMPLE SIZE

The number of samples in an inventory generally depends on factors including theoretical considerations, available funds, available staff, timelines, and length of field season. Calculation of a theoretical target sample size requires:

- An estimate of variation in the key attributes of interest under the proposed sampling procedures [often expressed as the coefficient of variation (CV)]; and
- A statement of the precision desired in the attributes.

For example, assuming a CV of 40-80%, the sample size to estimate net timber volume in the treed portion of the landbase to a target precision of ±10% would be 60-250 sample clusters (Figure 4). We suggest a minimum total sample size of 350 Phase II sample clusters in the District for planning, training, and logistic considerations (Table 5).

Table 5. Sample size and distribution in the Dawson Creek Forest District.

Land Type[12]	Number of sample clusters – ALL VRI measurements	Number of sample clusters – Tree measurements only	Total number of sample clusters
Vegetated Treed	110	140	250
Remaining Area (Non-Vegetated; Vegetated Non-Treed)	100	-	100
Total	*210*	*140*	*350*

All measurements typically taken in the VRI should be made in 110 out of the 250 sample clusters in the treed area; and only tree information should be collected in the remaining 140 sample clusters. All measurements typically made in the VRI should be taken in all the 100 sample clusters in the non-vegetated and the vegetated non-treed landbase. The suggested total sample size in the treed landbase is based on the CV (the ratio of audit volume to map volume) computed from the inventory audit of the mature timber in the TSA. The calculated CV of the ratio was 63% but was inflated to 79%,[13] and used with Figure 4 to estimate the total number of plots to achieve a target sampling error of ±10% for net volume in the treed portion of the District. Note that for this CV (79%), increasing sample sizes beyond 250 does not significantly reduce sampling error (Figure 4), but increases costs (Figure 5).

This estimated total sample size (Table 5) would be adjusted since the inventory will be implemented in two steps (Section 4.7). The sampling in the first year will provide experience

[12] The vegetated treed landbase constitutes about 59% of the District landbase.

[13] The inventory audit CV was inflated by 25% to account for possible differences between the CV estimates based on the VRI design (a tight 5-plot cluster) and that based on the inventory audit (a well-distributed 9-plot cluster). We expect the CV based on the VRI to be higher because the number of plots per cluster is lower and the plots within a cluster are less widely distributed in the VRI design than in the inventory audit design.

to refine the process for the second field season. It would also provide information (such as CV) to estimate more precisely the remaining number of samples to meet the precision target of ±10% for net timber volume in the treed (BCLCS) polygons.

The sample planning should take into account the likely high cost of sub-sampling sites that are difficult to access and the matching of the inaccessible sites. It should also include the cost of photo interpretation of the sample polygons. This information would help assess improvements that may be achieved through better Phase I estimates (Appendix D).

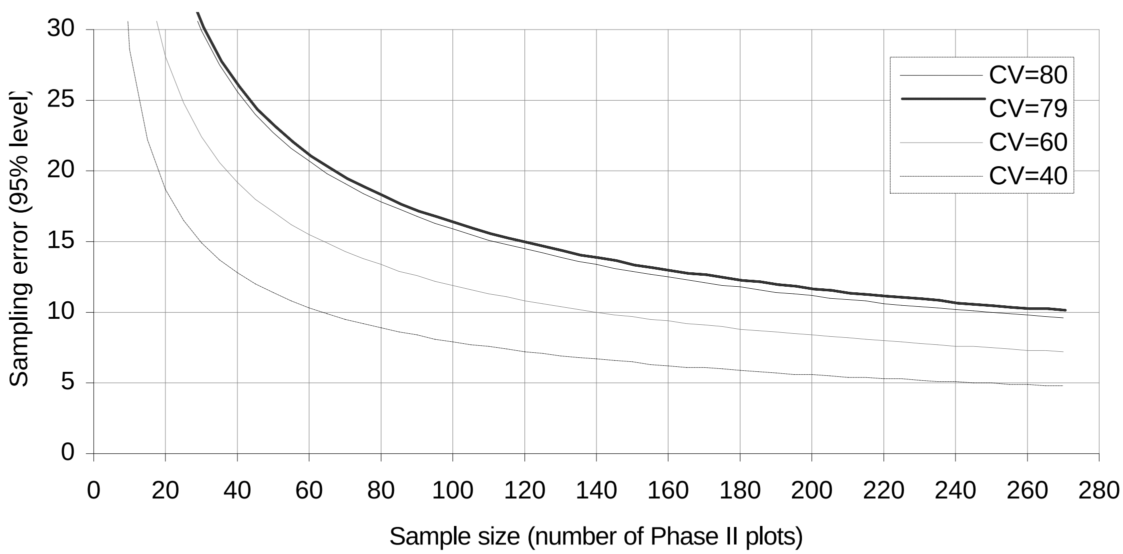

Figure 4. Decreasing sampling error (95%) as sample size increases.

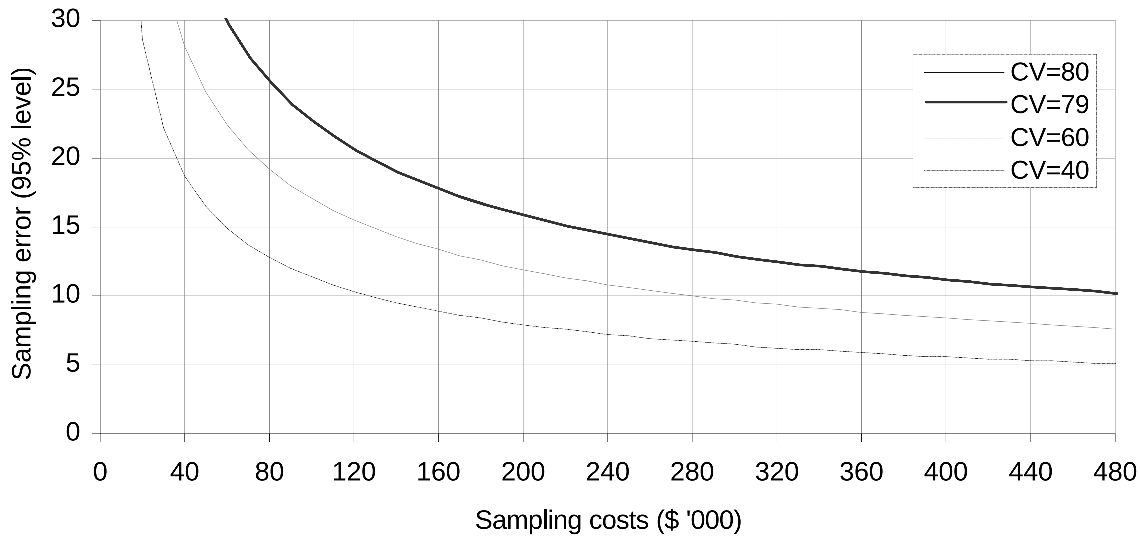

Figure 5. Decreasing sampling error (95%) as sampling costs increase ($2,000/plot).

224.6 SUPPORTING ACTIVITIES

234.6.1 Net Volume Adjustment Factor Sampling

244.6.1.1 Objective

The objective of Net Volume Adjustment Factor (NVAF) sampling is to improve estimates of tree net volume from the net factoring process. This is accomplished using stem analysis to provide local estimates of decay and tree taper. The data from stem analyses are used to develop a factor (NVAF) to adjust the net volume from the Phase II ground sampling (derived from the net factoring process and taper equations). The basis for the method to calculate the NVAF is the estimation of the actual net volume of felled trees.

254.6.1.2 Sampling Unit

The NVAF sampling unit is the tree. The attributes of interest are actual merchantable volume per tree and actual percent sound wood of the merchantable volume.

264.6.1.3 Sample Selection

Sample trees are selected at random, with varying (but known) selection probabilities from the cells of a 3-dimentional matrix defined by four tree diameter (dbh) classes, six severity groups, and two access classes. This matrix is populated with tree data from auxiliary plots of the sample clusters installed in the Phase II ground sampling (Section 4.2). The sample clusters for NVAF sampling should be selected at random from the Phase II sample clusters.[14]

[14] Alternatively, the sample clusters for NVAF may be selected systematically from a sorted list, independent of the Phase II sample selection (Appendix A, Section 7.2.1).

274.6.1.4 Sample Size

The MOF Resources Inventory Branch recommends a total of 200-250 sample trees for NVAF stem analysis. These samples can be selected from the first 100 sample clusters, and should be distribute over at least 30 sample clusters.[15] Twenty-eight of the 30 sample clusters should be selected from the treed (BCLCS) polygons and two from non-treed polygons.

284.6.2 Within Polygon Variation Sampling

294.6.2.1 Objective

The objective of Within Polygon Variation (WPV) sampling is to provide information for expressing the total inventory error and to indicate accuracy of individual polygon estimates. Sampling for WPV involves detailed sampling of individual polygons selected for the installation of Phase II sample clusters. Results from these detailed measurements should be assumed as the *true* values for the sampled polygons, and compared to the adjusted polygon values.

304.6.2.2 Sampling Unit

The WPV sampling unit is a polygon. Well-distributed clusters of plots are established within each sampled polygon to estimate tree attributes.

314.6.2.3 Sample Selection

The sample polygons should be selected with equal probability. The data should be weighted appropriately to account for differences in polygon size when calculating overall totals or averages. The selection should be made from the polygons picked in the Phase II sample clusters (Section 4.2).

324.6.2.4 Sample Size

The MOF Resources Inventory Branch recommends a minimum sample of 30 polygons be selected from the initial 100 polygons (picked for VRI ground sampling). Additional polygons can be sampled after these are complete if interim results suggest more are needed to achieve a desired precision.

334.7 IMPLEMENTATION

The VRI ground sampling should be implemented in a two-step process (Figure 6). Step 1 is to install approximately 100 Phase II sample clusters in the 1998 field seasons over the entire District. This would provide an unbiased stand-alone inventory, although the resulting sampling error may be higher than stated in the inventory objectives. Step 2 would involve the installation of additional plots in the 1999 field season.

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[15] The MOF Inventory Branch recommends a minimum of 30 sampling locations for NVAF sampling based on past experience with similar work done in the Queen Charlotte Islands and Boston Bar.

Text No.	Task Name
	VRI Ground Sampling Implementation
	Step One: First Field Season (1998)
1	Assemble all District polygons
2	Sort polygon list
3	Select 500 potential sampling points from list
4	Select 100 sampling points from list of 500
5	Randomly select 30 of the 100 for NVAF sampling
6	Begin planning for field sampling
7	Prepare field sampling plan with plot batches
7	Identify & sample NVAF sample points
8	Locate & measure Phase II sample clusters
9	Monitor quality assurance of field data & procedures
9	Check cruisers sample auxiliary plots of NVAF samples
10	Compile data from completed batches
	Step Two: Second Field Season (1999)
11	Prepare NVAF tree-sampling matrix
12	Estimate remaining number of samples
13	Select remaining sample clusters
14	Locate & measure remaining Phase II samples
14	Complete stem analysis of NVAF sample trees
15	Compile data & produce final inventory results
15	Begin planning WPV sampling

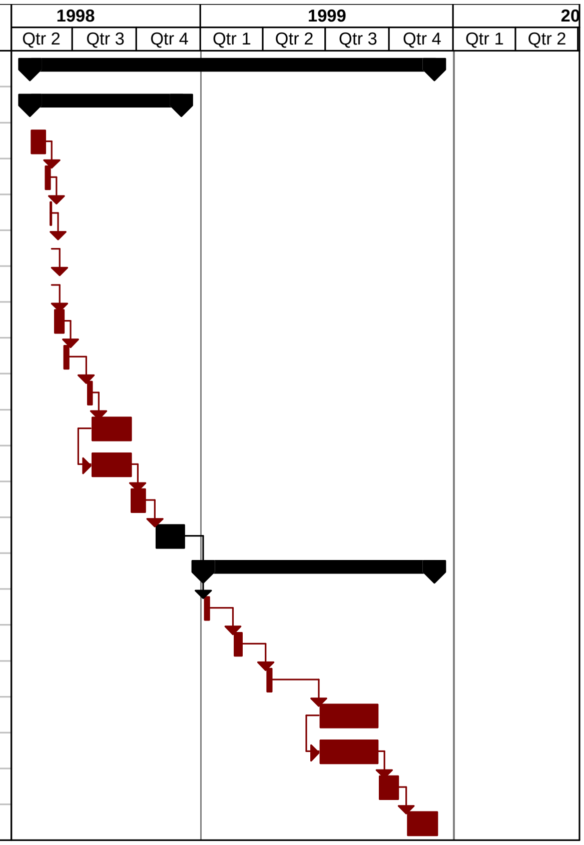

Figure 6. Gantt Chart of Two-Step Inventory Implementation Process in the Dawson Creek Forest District.

The NVAF work should be done over the entire District in 1999, and in 2000 if necessary. Sample trees for stem analysis should be selected from the 100 Phase II sample clusters done in the first field season. Additional stem analysis may be done in 2000, if needed.

The WPV sampling should start in 1999 and continue into 2000 if necessary. Sample polygons should be selected from those included in the Phase II sampling.

The two-step inventory implementation process could proceed as follows:

34Step 1 – 1998 Field Season

1. Assemble all polygons in the District into one list; check to ensure no areas are missing or double counted.
2. Sort the polygon list (Figure 3).
3. Select 500 potential sampling points from the sorted list. The locations of the 500 samples should be displayed on a map and available for other sub-unit inventories or for use by other groups. The sample selection process is described in the MOF Resources Inventory

Branch document *Vegetation Resources Inventory, Preparing a Sampling Plan for Ground Sampling*, pages 8-10 (31 March 1997).

4. Systematically select 100 sampling points from the list of 500. Three out of the proposed 200 Provincial monitoring plots are located in the District (two in the TFL and one in the TSA).[16]
5. Select a valid sub-sample of 30 polygons (28 Treed and 2 Non-Treed) for NVAF sampling from the 100 Phase II sample clusters. This selection should be done at this stage so that the NVAF activity can start early in the 1999 field season.
6. Begin planning for field sampling.
7. Prepare a field sampling plan that includes plot batches (e.g., two batches of 50 plots each), to ensure a complete unbiased sample is obtained at the end of the field season. Identify NVAF sample points and ensure they are sampled early in the field season. Monitor the area to ensure no logging of the sample plots occurs before the second season of sampling is complete.
8. Locate and measure Phase II sample clusters in the first two batches of the selected sampling points.
9. Carefully monitor quality assurance of field data and procedures during field sampling. Arrange for check cruisers to sample auxiliary plots of NVAF samples.
10. Compile the data from completed batches in winter 1998. This will include computing averages of timber volume, basal area, regression of photo estimated volume to ground sample volume, and the associated standard error of the regression.

Step 2 – 1999 Field Season

11. Prepare the NVAF tree-sampling matrix.
12. Prepare for the second step. This will include calculation of the CV based on the standard error of the regression. The remaining number of samples required to achieve the stated desired precision can then be accurately determined using standard procedures.
13. Systematically select the last batch of sample clusters from the remaining samples in the initial list of 500.
14. Locate and measure remaining Phase II sample clusters and the three provincial monitoring plots that fall in the District in 1999. Complete stem analysis of the NVAF sample trees.
15. Compile all data and produce final inventory results in fall 1999. Begin planning the WPV sampling.

[16] The MOF Resources Inventory Branch has selected at random 200 sample plots throughout the province. The purpose of these plots is to measure (monitor) changes and trends of the indicators of sustainable forest management as defined by the Canadian Council of Forest Ministers (CCFM).

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SUB-UNIT INVENTORY

365.1 OVERVIEW

Sub-units are separate populations created within the inventory unit (District) to control sampling error and sampling intensity for specific attributes. One sub-unit inventory was identified in the Dawson Creek Forest District to address the inventory issues raised by the stakeholders (Section 3). This sub-unit corresponds to the merchantability of specific vegetation including old-growth spruce/balsam balsam/spruce stands; mixed-wood deciduous stands; deciduous stands; and height class 2 pine stands. These stands constitute about 66% of the forest area in the District.

375.2 OBJECTIVE

The objective of this sub-unit is to estimate the merchantability of the old-growth spruce/balsam balsam/spruce stands; mixed-wood deciduous stands; deciduous stands; and height class 2 pine stands.

385.3 TARGET POPULATION

The target population is all spruce-balsam balsam-spruce stands; mixed-wood deciduous; deciduous stands; and height class 2 pine stands in the Dawson Creek Forest District.

395.4 SAMPLING UNIT

We recommend using timber emphasis plots (TEPs) based on the same five-point cluster design as the VRI plots (Section 4.3). These plots should focus on tree attributes to provide only the needed information for this sub-unit. This sampling should include call grading, net factoring, and sub-sampling trees for stem analysis, and should address only decay, not breakage and waste. These attributes are contained in VRI Card Types 8 and 11. Measurements of other vegetation characteristics taken on VRI plots should not be taken in these TEP plots. However, as with the VRI plots, these TEPs provide a sampling frame for any additional sampling that may be required in the future.

405.5 SAMPLE SELECTION

Sample polygons should be systematically selected from a sorted list of those in the target population. This list should include all the stands in the defined forest types in the District, and be sorted according to Figure 7.

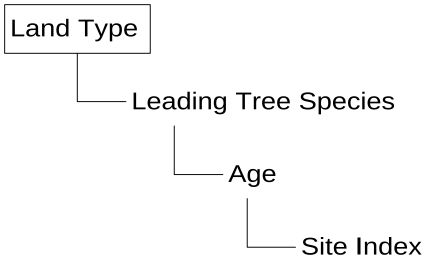

Figure 7. Polygon sort criteria for Spruce-balsam Balsam-spruce stands, Mixed-wood deciduous stands, Deciduous stands, and Height class 2 pine stands.

415.5.1 Sample Size

An estimated preliminary total of 250 sampling points are suggested for planning, training, and logistic considerations. Therefore, 85 timber emphasis plots are needed in addition to the full VRI plots. This sample size was based on an assumed CV of net volume of 80% and a target sampling error of 10% (95% probability). This large sample size should provide overall volume estimates with good precision, and strata volumes with reasonable sampling error. This estimated total sample size should also be adjusted using the results of the analyses of the first VRI samples.

425.5.2 Implementation

We recommend that this sub-unit inventory should be implemented in the same two-step process as the District VRI. This sampling should take place after the first field season of VRI ground sampling. The inventory should be implemented as follows: Step 1 should install a large number of additional timber emphasis plots (e.g., 60) over all defined forest types measuring *only some* tree attributes. This should occur in the first field season after VRI ground sampling over the entire sub-unit. Approximately 80% of sample clusters should be installed in the treed (BCLCS) operable landbase and 20% in the remainder of the sub-unit landbase. Step 2 should install additional plots in the second field season, in the same proportion, if needed.

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DISCUSSION

446.1 VRI GROUND SAMPLING

The VRI Phase II ground sampling will give unbiased estimates of overall averages and totals for timber and non-timber vegetation resources in the District. This will address the immediate need identified by the timber volume inventory audit. The new inventory will also provide data to check District biodiversity guidelines, VDYP assigned volume, site indices, limited information for site index-BEC correlations, and forage-tree attribute correlations. Additional information for non-timber resources will include plant lists to indicate where more intensive sampling could improve estimates for specific plants and other botanical products. The VRI will provide the initial conditions and locations for measuring changes and trends in the indicators of sustainable forest management. The VRI plots will also provide a common sampling base for a variety of other resources, special projects, and sub-unit inventories.

The VRI Phase II samples will not provide more detailed polygon information than is available in the current inventory. Thus these samples may not help address some of the management and inventory issues that require this information (Section 3). More detailed polygon information can be provided through improved Phase I estimates, which will be provided in the "second pass" of the inventory. However, we recommend that new Phase I estimates are derived for the polygons selected for the Phase II samples. This should be done using one photo interpreter to provide consistency among estimates. Existing polygon boundaries would be maintained, and the additional data would be used to evaluate potential benefits of new Phase I estimates.

456.2 SUB-UNIT INVENTORY

One sub-unit inventory has been proposed to address a specific objective identified by stakeholders. This sub-unit inventory should improve the timber inventories of the various forest components in preparation for the next Timber Supply Review. This merchantability sub-unit inventory can be done independently of the VRI ground sampling. However, it is important that the sampling design that is implemented for these sub-unit inventories use the VRI definitions and measurement protocols as much as possible. This will allow for seamless integration of the data from this sub-unit inventory with the VRI ground sampling.

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APPENDIX A – OVERVIEW OF THE VRI

477.1 INVENTORY DESIGN

The VRI inventory design is an equal-probability-sampling system implemented in two phases. Phase I is the subjective delineation of polygons and the estimation of attributes for all polygons in an inventory unit. Medium scale aerial photographs (usually 1:15 000) are most often used in Phase I. However, other sources of data can be used for polygon delineation and attribute estimation. Phase II is ground sampling that involves measuring attributes of trees and other vegetation from a sample of the polygons delineated in Phase I (Figure 8). Ground sampling points are selected systematically with equal probability. The selection is from a sorted list (sorted by attribute estimates) and accumulated polygon areas.

The photo-interpreted polygon areas and attribute estimates facilitate the selection of sampling points and the estimation of population and polygon totals. The attribute estimates, if consistent, improve the precision of the estimates of the overall and polygon-specific totals or averages. Ground sampling provides the means for making an unbiased estimation of the population totals, or averages, and for adjusting the individual polygon photo estimates. The adjustments are based on the relationships, estimated by ratio or regression techniques, comparing the photo attribute estimates and the ground observations. This adjustment process results in overall inventory unit totals and individual polygon adjusted values that form the district-level VRI database. Ground sampling also provides the means to make statements of precision for overall district totals.

487.2 SUPPORTING ACTIVITIES

Two other ground sampling activities support the VRI process: 1) Net Volume Adjustment Factor (NVAF) sampling; and 2) Within Polygon Variation (WPV) sampling. NVAF sampling provides factors to adjust net tree volume from the Phase II ground sampling (derived from the net factoring process and taper equations) to account for hidden decay and possible taper equation bias. This involves detailed stem analysis of sample trees to calculate actual net volume, and to compare this with the net volume estimated in the VRI net factoring process and the taper equations. WPV sampling provides information to estimate the individual polygon true error, assessed as the difference between the adjusted polygon value and the “true” value for that polygon.

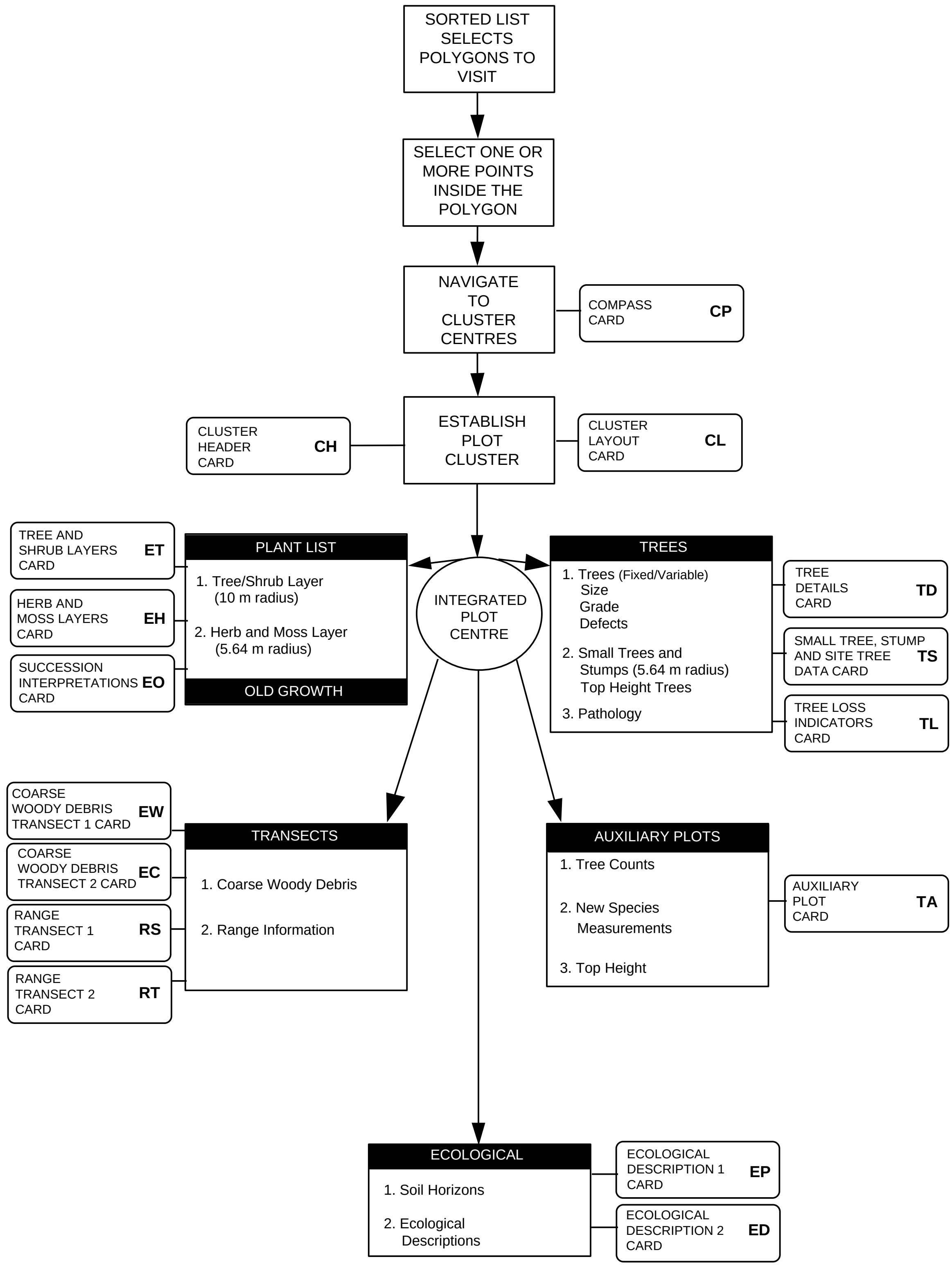

Figure 8. Major ground sampling activities.[17]

[17] BC Resources Inventory Committee. 1997. Vegetation Resources Inventory ground sampling procedures (March 31), page 1-4~~, page 3-2~~.

497.2.1 NVAF Sampling

The purpose of NVAF sampling is to estimate the net volume adjustment factor (NVAF) for an inventory unit. The NVAF is used to adjust the estimated net volume, which is based on the inventory net factoring process and the existing tree taper equations. We expect the net factoring process (corrected with the NVAF) to be better than the risk-group based approach, since net factoring is done based on rule-based deduction.

Estimation of the *actual* net volume of felled trees is the basis of the method to calculate the NVAF. Therefore, the sampling unit is the tree. The attributes of interest are *actual* merchantable tree volume and *actual* percent sound of the merchantable volume.

Trees are selected at random, with varying but known selection probabilities. These selection probabilities are used to weight the data. The sample trees are selected from polygons already sampled as part of Phase II ground sampling. Alternatively, the sample tree selection process could proceed as follows:[18]

1. Define the inventory unit.
2. Create a list of all the sample polygons (accessible and inaccessible) selected and measured in the inventory unit as part of the regular VRI process.
3. Delete the *non-treed* polygons from the list (non-treed as defined in the regular inventory).
4. Sort the remaining *treed* sample polygons using the following criteria and order:

   Leading species

   Age class (1-79 yr., 80-149 yr., 150-249 yr., and 250+)

   Merchantable volume/tree (merchantable volume per ha divided by number of stems per ha).

   If the Inaccessible polygons were subsampled at a different rate, attach appropriate weights to the data. For example, if a sample polygon in the inaccessible category represented four polygons, this polygon would have a weight of four. Data for sorting is obtained from the *Integrated Plot* (Figure 2) in the regular inventory. Decide beforehand if stratification will be done.
5. Select 30 polygons from the sorted list by accumulating polygon areas, in the usual manner.

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[18] Sampling for net volume adjustment factor. 1996. Resources Inventory Branch, Ministry of Forests, Victoria, BC.

6. For each polygon, decide how many auxiliary plots (up to four) to sample; and select a sample at random from the possible four. The total number of auxiliary plots to select per polygon will be determined such that the polygon can be cruised in half a day or one full day.

7. Re-cruise all the selected auxiliary plots in all the 30 sample polygons, using an experienced check-cruiser. The check cruiser should be experienced, familiar with the NVAF process, and preferably from outside the MOF.

8. Pool the tree lists from all the auxiliary plots in all the re-cruised sample polygons. To distribute the sample of trees, create a three-dimensional matrix based on Dbh, NF Severity Group, and Access. There will be four Dbh classes, with the class intervals varying depending on the range of diameters in the population. There will be six Severity Groups as follows:

   - Dead trees with visible decay (conk/blind conk).
   - Dead trees with visible decay (other indicators).
   - Dead trees with no visible decay.
   - Live trees with visible decay (conk/blind conk).
   - Live trees with visible decay (other indicators).
   - Live trees with no visible decay.

   There will be two Access classes: "difficult" and "easy," defined on the basis of slope severity; all this information is available from the regular inventory. Trees can also be grouped by species decadence classes if applicable.

9. Select sample trees in each of the matrix cells, uniformly across the matrix cells. The total sample should be 200-250 trees. Vary the selection by Access classes. Difficult Access cells will be sampled at less intensity than the Easy Access cells; the actual frequencies will depend on the relative cost and proportion of the inventory unit of the two Access classes. Decide the approximate relative allocation of the sample trees between the two classes. For example, this decision could be based on the following formula:

$$\frac{p\sqrt{\frac{c_2}{c_1}}}{\left(p\sqrt{\frac{c_2}{c_1}}\right)+(1-p)}$$

   where p = proportion of landbase in difficult access
   c_1 = unit cost of sampling in difficult access
   c_2 = unit cost of sampling in easy access

For example if p=60%, c_1=4 and c_2=1, then 43% of the sample trees should fall into the difficult access cells. This formula is based on the usual stratified sampling optimum allocation, with the Access classes as strata having equal variance.

507.2.2 WPV Sampling

Within Polygon Variation (WPV) sampling enables the estimation of the individual polygon true error, assessed as the difference between the adjusted polygon value and the "true" value for that polygon. The adjustment process (regression) in the VRI only measures the variation between the photo estimates and the sample cluster estimates (not the true value). Therefore, to assess the polygon true error, a relation is needed to measure the variation between the photo estimates of polygon totals and the actual polygon totals. This is attained in the VRI process through WPV sampling, which provides more detailed sampling of some of the polygons selected for the Phase II ground sampling. The observed polygon value from these detailed measurements will be assumed the "true" values for the entire polygon. This is not strictly the "true" value of the polygon, but only an estimate that improves as more sample clusters are established in the polygon.

The purpose of intensive sampling of polygons is to obtain an unbiased distribution of sample plots across the polygon to obtain a representative and precise sample of tree characteristics of the polygon.[19] For this reason, the sample plots will be dispersed within the polygon as widely as possible, using a grid of plots. At present, a fixed number of plots (16) should be located in each target polygon; the grid interval will vary depending on the area of a given polygon. In the future however, the number of plots per polygon should be varied, such that measurements in a sample polygon can be completed in one or two days.

The distance between grid points can be determined using the equation:

$$D = \sqrt{\frac{10000 * A}{n}}$$

where: D = interval between grid points in meters
A = area of polygon in hectares
n = number of plots to be established within a polygon (presently 16)

A plot will be established at each grid intersection and measurements of tree attributes taken. All field procedures must conform to the VRI procedures and standards as specified in the official Procedures and Standards manual. Generally, there will be two major variations to the principal VRI procedures:

[19] Interim procedures for intensive sampling within polygons. 1997. Resources Inventory Branch, Ministry of Forests, Victoria, BC.

1. The general lay out of plots will be different from the five-point cluster which is used for the regular VRI Phase II data collection. Instead, there should be 16 plots within a target polygon. Two of the plots will be full measure plots and 14 should be count plots.
2. Top height should be measured at the two full measure plots and at six of the 14 count plots.

For very small polygons, other sampling approaches such as 3P sampling could be employed.

517.3 IMPLEMENTATION

Implementation of the VRI that started in 1996 is based on a two-pass strategy proposed by the MOF Resources Inventory Branch. Pass One involves sampling the existing Phase I database (current inventory maps and database) and establishing Phase II ground samples at the District level. The result of Pass One is a District-level vegetation inventory covering the entire landbase. Pass Two involves strategic improvements to the precision of specified domains of the district-level inventory to achieve specific inventory objectives. These improvements are driven by regional priorities, business needs, and inventory audit results, and are achieved through sub-unit inventories. Sub-unit inventories may involve better Phase I estimation or additional ground sampling for specific attributes. They can be scheduled independently of the District-level VRI implementation and can use different sampling or plot designs. However, these special inventories should, as much as possible, use the VRI definitions and field procedures.

527.4 UNAVAILABLE SITES

Some selected sampling locations will not be available for sampling for a variety of reasons, such as safety (e.g., located on steep cliffs). However, it is important that sites with similar characteristics be located and sampled for all, or a subset of such sites. A process is in place for deciding whether the site is unavailable, and for matching the sites.[20]

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547.5 DIFFICULT ACCESS SITES

Some potentially available sampling locations may be difficult to access due to unsafe access routes or unreasonably long access distances. The decision to designate a sampling point as difficult access should be made by the project manager. These sampling sites should be sub-sampled using specialized crews at a frequency of at least 10%. For example, if 20 sampling

[20] Procedures for finding matching sites for these unavailable sites are described in the report *Preliminary report on unavailable Phase II samples* by H.C.K. Forestry Ltd. (August 31, 1996). Resources Inventory Branch, BC Ministry of Forests, Victoria, BC. For additional information on handling unavailable sites please see the following contract reports prepared for the Resources Inventory Branch, BC Ministry of Forests, by Margaret Penner (1996)*: Alternative procedures for handling unavailable sample sites in the Resources Inventory Program. Phase I – Review of the literature*, and *Alternative procedures for handling unavailable sample sites in the Resources Inventory Program. Phase II – Evaluation of alternatives for the British Columbia Vegetation Inventory.*

points are difficult to access, then at least two sampling locations should be selected at random and sampled. Data from the sub-samples will have to be weighted appropriately during analysis. Sub-sampling of difficult access sites should be planned in advance to reduce the high cost of such areas.

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APPENDIX B – IMPLEMENTATION OPTIONS

568.1 OPTION 1 – SINGLE STEP IMPLEMENTATION

578.1.1 Process

This option would implement the VRI in a single step, and complete all fieldwork in a single field season. Planning and integration of all VRI components would be required before commencing field operations. Data compilation could proceed after field sampling is complete and results could be available the following spring. Supplementary sampling for Net Volume Adjustment Factor (NVAF) or Within Polygon Variation (WPV) could proceed in the second year.

588.1.2 Advantages

The major advantage of this option is that results from the inventory would be available as soon as possible. Another advantage is the reduction in the per-plot cost of the travelling component of field sampling.

598.1.3 Disadvantages

The greatest disadvantage of this option is the risk of attempting to complete all components of a full-scale VRI without the opportunity for interim review. The results of an aborted partial project would be biased for the inventory unit. In contrast, the two-step option has opportunity for review of procedures and results at a mid-point in the process, thus providing the option to modify operations and sample size.

Without interim review, there is a risk of over-sampling if actual sampling precision is higher than expected. This would result in a higher than necessary project cost to achieve a given level of overall sampling precision. This single step option also requires knowledge of appropriate population coefficients of variation (CVs) in advance of sampling; such information is not usually known, or is known without adequate precision.

608.2 OPTION 2 – TWO STEP IMPLEMENTATION

618.2.1 Process

This approach would implement the VRI in a two-step process and complete all fieldwork in two field seasons. This option would complete a certain number (e.g., approximately one-half) of the expected total number of plots in the first year. These initial plots would be distributed throughout the District. They would be a valid stand-alone inventory, in case the project is cancelled or stopped. Successful completion of the first step will provide an opportunity to review procedures and results, and modify sample requirements accordingly. The remaining samples would be installed in the second year. These plots would also constitute a valid independent sample. This process would also provide unbiased estimates in the first year. Supplementary sampling for NVAF, and detailed polygon sampling could proceed in the second and third years.

628.2.2 Advantages

The major advantage of this option is the increased probability of completing the VRI in the most efficient and cost-effective manner through the opportunity to review the process after approximately one-half of sampling is complete. This will provide an opportunity to detect and resolve problems before they compromise completion of the overall objectives.

Another major advantage of this option is the potential to increase sampling efficiency and thereby reduce the overall cost. This can be achieved by analyzing the data after the first field season. This will provide information on actual variation in ground sample plots to compute precisely the number of additional plots (established in the second field season) needed to achieve the target precision. Another advantage is that this method does not require precise estimates of the population CVs prior to ground sampling.

638.2.3 Disadvantages

The major disadvantage of this option is the additional year before final results become available. Another disadvantage is that overall travel costs will be higher than in the single-step implementation as crews may have to access the same area in each step. However, this increase in cost is probably much less than the cost of over-sampling likely to occur in the single-step option. This method also requires a data compilation program be in place to compile and analyze data quickly, to provide feedback for planning the second field season sampling.

648.3 RECOMMENDATION

Given the risk associated with the single-step option, and the potential benefits of this two-step option, we have recommended that the District VRI be implemented using Option 2 - Two Step Process. The two-step approach can be implemented in one or more field seasons.

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APPENDIX C – SAMPLING CONCEPTS

669.1 PRE-STRATIFICATION

Stratification of an inventory unit into sub-populations (strata) is the process of dividing the area into mutually exclusive components of the total area. The primary purpose of stratification is generally to provide estimates for specific areas (strata), or to increase the confidence in the overall estimates by considering the special characteristics of each stratum.

Previous forest inventories in BC (e.g., 1961-1977) defined potential strata and allocated samples to each. These strata were often based on stand age, height, and stocking class within an Inventory Type Group (forest types of similar species composition).[21] There is no stratification in the VRI in the traditional sense as used in past inventories. Instead, increased precision of population estimates is achieved through Phase I delineation and regression. A good distribution of the samples (useful for examining the regression relationships between Phase I estimates and Phase II measurements) is achieved through selection of samples from a sorted list of all polygons in the District database [forest inventory / planning (FIP) file]. Lacking the VRI Phase I, the FIP file will be converted to the BC Land Classification Scheme (BCLCS), based on a defined conversion process before the list is compiled.[22] For example, a *lake* in the FIP file will be classified in the BCLCS as *NWW__LA* (non-treed, water, wetland, lake), and *NPBr* will become *VN_ST__* (vegetated, non-treed, tall shrub).[23]

679.2 POST-STRATIFICATION

Post-stratification is a sampling system that divides polygons in the inventory unit into strata *after* ground sampling has been completed, and based on the polygon Phase I estimates. Samples that fall in each post-stratum are analyzed separately and results are applied to the corresponding population post-strata. Post-stratification is a powerful analytical tool to improve the precision of the inventory's overall averages and totals. There are opportunities for stratification of the data after sampling in the VRI. For example, separate regression relationships can be developed for separate strata (e.g., parks) if it is seen that the photo estimate—ground measurement relationships are sufficiently distinct among the strata. This can be achieved by displaying the paired sample data on graphs and examining the scatter patterns.

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[21] J.S. Thrower. 1992. An historical summary of forest inventory sampling designs in British Columbia. A report to the BC Ministry of Forests, Inventory Branch, Victoria, BC. Pages 4-5.

[22] Resources Inventory Branch. Vegetation Resources Inventory. Forest Inventory / Planning (FIP) file conversion to the BC Land Classification Scheme (BCLCS). Resources Inventory Branch, Ministry of Forests, Victoria, BC. 2 pages. (Contact: Laurence Bowdige)

[23] Blanks in the BCLCS labels indicate no information is available in the current database to assign a BCLCS label at that level.

689.3 SUB-UNIT INVENTORIES

Although there is no formal pre-stratification in the VRI, separate populations (sub-units) can be created within the inventory unit to control the sampling error or sampling intensity of a specific sub-unit. A sub-unit could be, for example, specific geographic areas (e.g., operable land-base) or land type (e.g., excluded forest types). Greater precision can be achieved by adding samples into these populations. This should generally be done after the initial VRI is complete. In this case, totals for sub-units will probably change somewhat from estimates in the regular inventory. If the total for that portion of the population (sub-unit) is changed, the remainder of the inventory outside the sub-unit must also change by a compensating amount to retain an unbiased estimate for the entire area. An alternative is to plan the sub-unit inventory before implementation of the larger scale inventory - in effect conducting a separate inventory in each area. This is not recommended because it defeats some of the original intents of the VRI to obtain unbiased estimates for large units and provide a framework for more detailed sampling of sub-units.

Another way to improve final results of the inventory would be to improve estimates on which the sampling process is based. This could be done before or after the initial ground sampling is done. It is probably more efficient to improve estimates and update polygon boundaries before ground sampling. One could use a recent inventory of the area, for instance, instead of the old map values or photo estimates. *Ground calls* - plots established subjectively in what the photo interpreter considers "representative" of the stand - could be used to provide better estimates, but not used as ground-measured samples. During adjustment, such better estimates would not be adjusted as much as the estimates from a less reliable source.

699.4 TARGET PRECISION

The number of samples included in an inventory generally depends on several factors including theoretical considerations, available funds, available staff, timelines, and length of field season. Calculation of a theoretical target sample size as reported in most sampling textbooks is simple when the statistician has two necessary components of information:

- An estimate of variation in the key attributes of interest under the proposed sampling procedures [often expressed as the coefficient of variation (CV)]; and
- A statement of the precision desired in these attributes.

However, in practice this process is generally not straightforward because most agencies do not and cannot make a meaningful statement about the degree of precision needed in the attributes of interest for management decisions. Generally, statements of precision are associated with feelings of comfort based on historical trends, past experiences, and previous projects. In practice, actual sample sizes are more affected by available budgets, time requirements for inventory results, length of field season, and availability of crews.

709.5 Sample Size

The formal process for determining the minimum number of samples to be established in the inventory unit is to anticipate the results (e.g., target sampling error for volume) and then determine the approximate sample size corresponding to this desired result. For example:

1. Set the target overall inventory unit accuracy to 7.5% (one) standard error (SE) for timber volume. That is, the number of samples should be adequate to ensure at least ±15% sampling error (at 95% probability), and allow for calculation of sampling errors for other VRI attributes.
2. Estimate the CV of this attribute. This CV is defined as a relative measure of the average difference between a polygon ground measurement (assumed the true value) and its corresponding adjusted estimate. The CV is calculated from previous inventories of the same or similar populations as:

   $$CV = SE'\% * \sqrt{n}$$

   where *CV* is the estimated coefficient of variation, *SE'%* is the calculated standard error of the regression of the photo estimates and ground samples, and *n* is the sample size corresponding to *SE'%*.
3. Calculate the required sample size based on this information:

   $$n_0 = [\frac{CV}{SE\ \%}]^2$$

   where n_0 is the number of samples, *CV* is the population coefficient of variation (in percent) of the attribute, and *SE*% is the anticipated precision (in percent) of the inventory unit attribute total. For example, if the *CV* is 100% and the expected one standard error (*SE%*) is 7.5% then the estimated number of samples n_0= 10,000/56.25 = 178.

719.6 Use of Inventory Audit Data for Sample Planning

An estimate of the variation among sample plots (CV) is needed to estimate the sample size to achieve a target precision. The CV depends on the plot design and the attribute of interest. The best source of information to estimate CV is a preliminary VRI sample from the target population or similar area. However, in many cases this is not feasible. Other potential sources of data to estimate CVs are:

1. Operational cruise samples
2. Inventory audit samples

The VRI Phase II sampling system is based on a cluster of prism plots and estimates of polygons averages from air photos.

Estimates of CVs from operational cruising can provide estimates for one source of variation in the VRI Phase II sampling system. However, the additional source of variation needed to compute sample size is not addressed from operational cruise-based estimates.

Estimates of CVs from the inventory audits can provide estimates for both sources of variation in the VRI Phase II sampling system. However, the inventory audit plot cluster design is different from the VRI. The inventory audit is based on a well-distributed cluster of 9 plots, whereas the VRI is based on a tight cluster of 5 plots. Additional source of variation needed to compute sample size is not addressed from operational cruise-based estimates. The inventory audit data, if available, is probably the best available information to estimate CV.

We used the CV of the ratio between ground volume and map label volume in the inventory audits. This is also the CV of the adjusted volume. This CV was arbitrarily inflated by 25% to account for the possible impact on the CV of the differences in the cluster design.[24] We postulated that the CV based on the VRI would be higher since the VRI cluster has a tighter cluster with fewer plots. The inflated CVs were then applied to the steps outlined in Section 5 of this Appendix to estimate the sample size for planning purposes. For example, in the Fraser TSA, the calculated CV of the ratio was 44%. This ratio was inflated to 55%, and entered into Figure 5 (Section 4.4, in the main text) to determine the total number of plots (122) corresponding to a target sampling error of ±10% for net volume in the TSA. In this example, the minimum total sample size for planning purposes was set at 120.

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24 Another approach to estimate the CV would be to sub-sample the inventory audit cluster (e.g., pick 1 full measure plot and 4 count plots ar random) to mimick the VRI cluster, and re-compile the data. However, this would not eliminate the difference due to plot spacing among the inventory audit and VRI clusters, and we would still need an inflation factor to account for this.

APPENDIX D – PHOTO-TYPING SAMPLE POLYGONS

A new Phase I may be required to improve attribute accuracy of the inventory at the individual polygon level. This, according to the VRI implementation strategy proposed by the MOF Resources Inventory Branch, will be done strategically during the "Pass Two" inventory in the district. However, we recommend new Phase I estimates be derived for polygons in which Phase II samples fall. This should be done using one photo interpreter to provide consistency among estimates. Existing polygon boundaries would be maintained. The additional data would be used to evaluate potential benefits of new Phase I estimates. The process would also help Region and District staff and licensee staff develop more familiarity with the area and maintain photo interpretation expertise in the province. This process of obtaining new estimates for a subset of polygons should be made standard procedure for the VRI process.

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