Tree Farm Licence 52
Vegetation Resources Inventory
Statistical Adjustment
Preliminary Report

Prepared for

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Executive Summary

In 1997, West Fraser Mills Ltd (West Fraser) initiated a Vegetation Resources Inventory (VRI) project on Tree Farm Licence (TFL) 52. This initiative will update the TFL forest cover inventory to current Ministry of Sustainable Resources Management (MSRM) standards.

West Fraser completed the Phase I in 2000, and installed 54 Phase II timber emphasis plots in 2002. NVAF is planned for completion in 2003. This report presents a preliminary (pre-NVAF) statistical adjustment of the TFL's vegetated polygons (154,937 ha).

Following adjustment, inventory height decreased 4% while inventory age increased 3%. This created a 7% decrease in average site index, which was consistent across all species groups.

Net merchantable volume (12.5 cm for lodgepole pine leading stands, 17.5 cm otherwise) increased 16% after adjustment. This increase did not include NVAF correction. Assuming an NVAF reduction of 3 to 5%, the volume increase would be 11 to 13%.

Species Group	Area (ha)	Site Index (m)			Net Merch. Volume (m³/ha)		
		Unadjusted	Adjusted	Difference (%)	Unadjusted	Adjusted	Difference (%)
Sx	78,160	15	14	-8	254	302	19
Pl	41,195	18	17	-6	269	302	12
Bl	26,095	11	11	-7	145	158	9
Others	9,487	16	15	-5	143	165	15
All	*154,937*	*15*	*14*	*-7*	*233*	*270*	*16*

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1. INTRODUCTION

1.1 BACKGROUND

In 1997, West Fraser Mills Ltd (West Fraser) initiated a Vegetation Resources Inventory (VRI) project on Timber Forest Licence (TFL) 52. The Phase I was finalized in 2000 and Phase II timber emphasis sampling began in 2002, with the intention of completing data collection in 2003. The VRI adjustment will be finalized when the NVAF sampling data is collected and analyzed (expected to occur in 2003). Until then, only a preliminary adjustment can be completed. Once completed, this initiative will update the TFL forest cover inventory to current Ministry of Sustainable Resource Management (MSRM) standards.

The VRI program includes the following four phases (Figure 1):

1. Phase I (unadjusted inventory data) – Polygon attributes are estimated using photo-interpretation.
2. Phase II (ground plot data) – Measurements are taken from randomly located ground samples.
3. Net Volume Adjustment Factor (NVAF) Sampling – Trees are selected for stem-analysis studies to develop adjustment ratios to correct taper and decay estimation bias.
4. Adjustment Phase – The Phase I estimates are adjusted using the NVAF adjusted Phase II ground samples to give an adjusted unbiased estimate of forest inventory attributes. The final product is an adjusted VRI database.
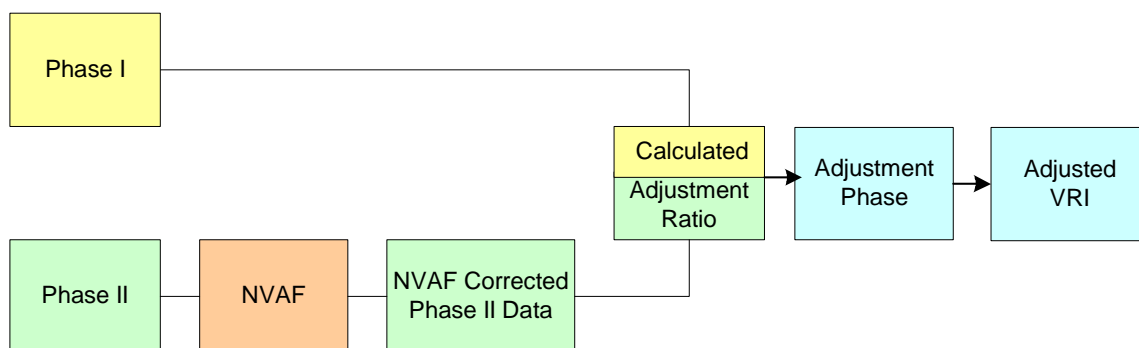
Figure 1. VRI program.

The VRI program complements the Change Monitoring Inventory (CMI) program also underway on TFL 52. Under the CMI program, 78 permanent sample plots, located in stands 15 to 40 years old (as of January 2000), will be established by the end of the 2003 season. The CMI program measures growth and yield attributes and compares the collected ground data to the yield table estimates used for TFL 52 timber supply analysis. To date, 52 CMI plots have been installed under a separate project.[1] However, this project focuses on stands older than 40 years and provides unbiased height, age, and volume estimates.

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[1] J.S. Thrower & Associates. 2003. Tree Farm Licence 52 change monitoring inventory pilot project: second year results. March 31, 2003. Unpublished Report, Project No. WFQ-030. 11 pp.

1.2 PROJECT OBJECTIVES

West Fraser's primary objectives were to:

- Develop statistically unbiased volume estimates for stands greater than 40 years on TFL 52.
- Install enough sample plots to produce a sample error that satisfies timber supply analysis requirements.[2]

West Fraser's secondary goals are to:

- Improve the accuracy of volume estimates for interior spruce (Sx) and subalpine fir (Bl) leading polygons.
- Check Site Index Adjustment (SIA) derived site index estimates[3] for areas outside the CMI sample population (15 to 40 years).
- Collect Mountain Pine Beetle (MPB) attack data.
- Collect coarse woody debris (CWD) data.
- Collect data to calculate decay and waste estimates and correct taper equation bias.

1.3 REPORT OBJECTIVES

The report objectives were to:

- Provide descriptive statistics for Phase I (unadjusted inventory data).
- Provide descriptive statistics for Phase II (ground plot data).
- Provide a preliminary adjustment of the inventory database.
- Estimate the sample size required to meet different precision standards.

This is a preliminary report, and addresses only primary objectives. West Fraser's secondary objectives will be addressed in the final report due next year.

1.4 TERMS OF REFERENCE

JS Thrower & Associates Ltd (JST) completed this VRI statistical adjustment for Earl Spielman, *RPF* (West Fraser). The JST team included Hamish Robertson, *RPF* (project manager), Mike Ciccotelli, *DoT* (field operations), and Guillaume Thérien, *PhD (*senior analyst). Field work was completed by VRI-certified field crews from JST and Timberline Forest Inventory Consultants Ltd in the summer of 2002. Auditing was done with the support of Nona Phillips, *RPF* of the MSRM, Prince George Region.

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[2] West Fraser will not commit to a sampling error until changes to provincial inventory requirements are defined. A target sampling error will be identified and discussed with the MSRM prior to the 2003 field season.

[3] J.S. Thrower & Associates Ltd. 2000. Potential Site Indices for Major Commercial Tree Species on TFL 52. March 15, 2000. Unpublished report, Project No. WFQ-101-018. 17 pp.

2. VRI DATA

2.1 STUDY AREA

TFL 52 is located northeast of Quesnel and west of Bowron Lake Provincial Park and covers a total of 259,095 ha (Table 1, Figure 2). The population sampled for the VRI were all polygons in the TFL, excluding the AT biogeoclimatic (BGC) zone, the ESSFwc3 and ESSFwcp3 BGC subzones, non-vegetated polygons, and polygons less than 40 years as of January 2000. The VRI sampled population covered 154,937 ha (60% of the TFL).

Table 1. TFL 52 VRI sample population net down.

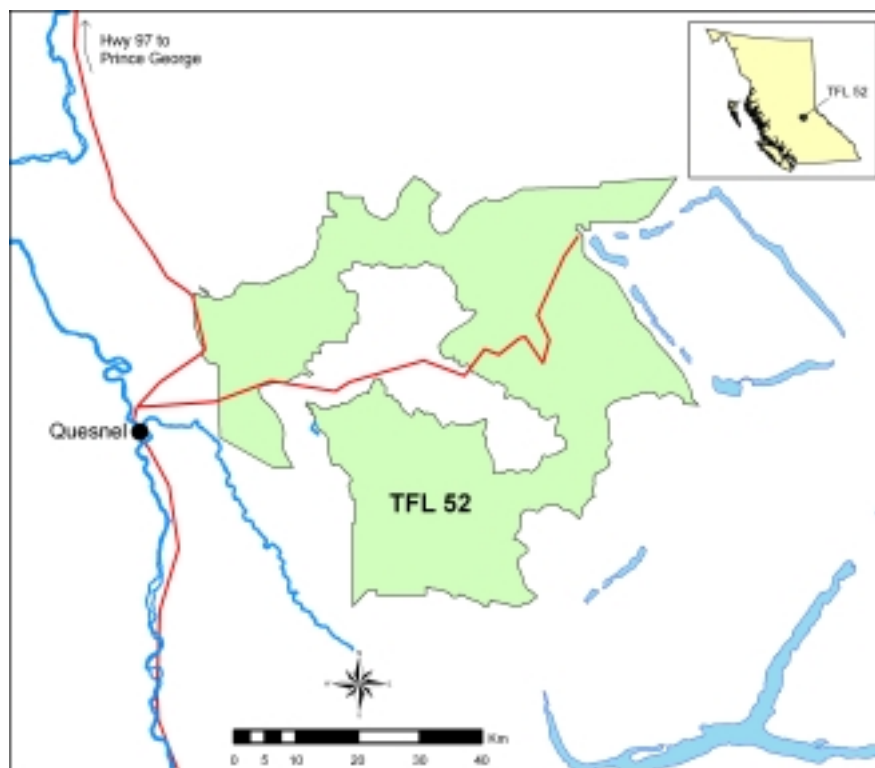| Landbase	Area (ha)	Area (%)
TFL 52	259,095	100
AT and ESSFwc3	37,053	14
Non-Vegetated	5,643	2
CMI Sample Population	21,618	8
<15 years Total Age	39,849	15
VRI Sampled Population	*154,937*	*60*

Figure 2. Location of TFL 52.

2.2 PHASE I (UNADJUSTED INVENTORY DATA)

The average height of all species was 25.3 m with an average age of 135.9 years and site index of 15.4 m. Average volume[4] was 232.6 m³/ha (Table 2). Sx and lodgepole pine (Pl) leading stands had significantly more volume than Bl-leading stands or stands with Other species leading.

Table 2. Unadjusted inventory statistics for TFL 52 target population.

Ldg Spp	Area (ha)	Height (m)	Age (yrs)	Site Index (m)	Volume (m³/ha)
Sx	78,160	28.1	155.3	15.1	253.6
Pl	41,195	24.7	114.1	18.4	268.9
Bl	26,095	18.8	122.2	11.4	145.2
Others	9,487	22.6	108.9	15.9	142.9
All	*154,937*	*25.3*	*135.9*	*15.4*	*232.6*

2.3 PHASE II (GROUND PLOT DATA)

Fifty-four (54) timber emphasis plots were established in the sample population. In some cases, the species collected in the field did not match the leading species on the Phase I, one plot lacked valid age information and three other plots lacked valid height information. Statistics from the ground sampling data included an average height of 24.2 m, age of approximately 142.6 years, and site index of 14.4 m. Average volume[5] was 268.3 m³/ha (Table 3).

Table 3. Phase II ground sampling statistics for TFL 52 target population.

Leading Species	Sample Size	Height (m) Avg.	Height (m) 95% CI	Age (yrs) Avg.	Age (yrs) 95% CI	Site Index (m) Avg.	Site Index (m) 95% CI	Volume (m³/ha) Avg.	Volume (m³/ha) 95% CI
Sx	27	25.5	[23.0, 2 8.0]	161.2	[135.3, 187.1]	13.7	[11.9, 15.5]	284.1	[234.9, 333.3]
Pl	14	23.8	[21.6, 26.1]	110.1	[87.8, 132.5]	17.4	[15.2, 19.6]	293.8	[238.2, 349.3]
Bl	10	23.1	[20.7, 25.4]	149.9	[112.5, 187.3]	12.3	[10.1, 14.4]	222.0	[136.2, 307.8]
Others	3	19.6	[0.0, 39.5]	108.9	[96.9, 121.0]	12.6	[0.0, 26.8]	162.6	[0.0, 590.0]
All	*54*	*24.2*	*[22.7, 25.7]*	*142.6*	*[126.7, 158.6]*	*14.4*	*[13.1, 15.6]*	*268.3*	*[235.2, 301.5]*

Note: CI = confidence interval.

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[4] Inventory volume is net merchantable volume at a utilization level of 12.5 cm for lodgepole pine leading stands, and 17.5 cm for all other stands.

[5] Ground volume refers to live whole-stem volume less top, stump, cruiser-called decay, waste, and breakage. The volume was not NVAF corrected. Utilization levels are 12.5 cm if the corresponding volume is based on a 12.5 cm utilization level or 17.5 cm otherwise.

3. METHODS

3.1 NET VOLUME ADJUSTMENT FACTOR

NVAF sampling may be completed during the 2003 field season. NVAF sampling is a VRI requirement and should be completed prior to West Fraser's next Management Plan. Anecdotal evidence suggests that uncorrected volumes may be overestimated by 3 to 5%.

3.2 STATISTICAL ADJUSTMENT

The statistical adjustment followed MSRM attribute adjustment procedures.[6] Since this adjustment is preliminary, only adjustment methods recommended by the MSRM were used. Different methods may be used in the final adjustment.

The MSRM adjustment process assumes the unadjusted (Phase I) inventory volume is biased because of two sources of error: an attribute bias associated with the photo-interpreted height and age and a model bias inherent to the growth and yield model used to estimate volume (*VDYP version 6.6d*). This process assumes that the errors from other attributes used by *VDYP* (species composition, stocking class, and crown closure) are marginal.

The attribute adjustment procedure is a two-step process detailed in Figure 3 and described as follows:

- In the first step, Phase I height and age bias are corrected using an adjustment ratio calculated from the Phase I data (unadjusted inventory data) and the Phase II data (ground plot data). An attribute-adjusted volume is then calculated using adjusted height and age with *VDYP*.

- In the second step, an adjustment ratio is calculated from the attribute-adjusted volume and the Phase II (ground plot data) volume, and this ratio is used to correct the model bias in the attribute-adjusted volume.
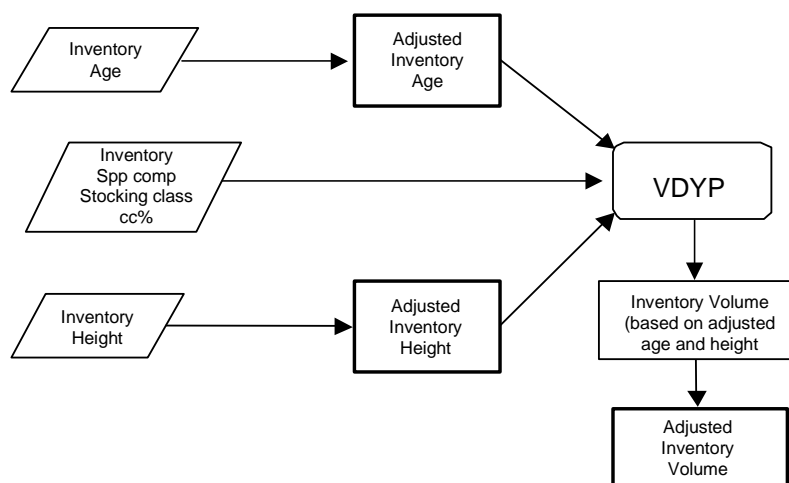

Figure 3. VRI statistical adjustment process.[6]

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[6] Ministry of Sustainable Resources Management. 2002. Vegetation resources inventory attribute adjustment procedures. Draft Version 4.4. 37 pp.

3.3 SAMPLE SIZE ESTIMATION

One of the primary objectives of this project was to calculate a sample size that meets MSRM precision standards for inventories. Sample size is a function of the confidence level required for the adjusted estimates (reflected in the t-value), population variability (measured by the coefficient of variation, or CV), and the desired precision (measured by the relative sampling error, or E%). Sample size (n) is estimated using the following formula:

$$n = \frac{t^2 \times CV^2}{E\%^2}$$

where t is the t-value, which is a constant proportional to the level of confidence desired.[7]

Sample size is proportional to the confidence level. If one wants to reduce the uncertainty around the information provided by a sample, the sample size must increase. For instance, going from a 95 to a 99% confidence level (for the same CV and E) will require a 70% increase in sample size. Therefore, the forest manager can influence the sample size by changing the confidence level.

Sample size is also proportional to the population variability. If a population has a CV twice as large as another population, then a sample size four times larger will be required to achieve the same confidence level and same sampling error. The forest manager has no influence on the CV.

Sample size is inversely proportional to the sampling error. More samples are required to achieve a smaller sampling error. Therefore, the forest manager can influence the sample size by selecting a different sampling error.

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[7] The t-value is approximately 2 for a 95% confidence level or 1.7 for a 90% confidence level.

4. RESULTS AND DISCUSSION

4.1 HEIGHT AND AGE ADJUSTMENT

Height and age were adjusted using the ratio of means (ROM) adjustment method to estimate the adjustment ratio. Height decreased 3.8%, while age increased 2.8% (Table 4, Figure 4, and Figure 5). The sampling errors were less than 10%, indicating precise average estimates for both height and age.

Table 4. Height and age adjustment statistics for TFL 52 target population.

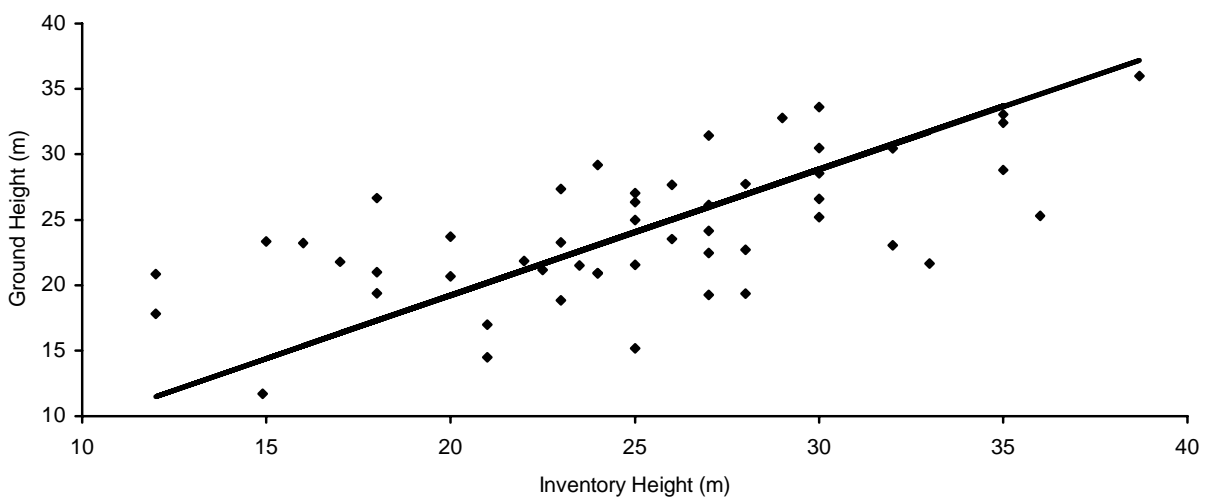| Attribute	Pop. Inv. Avg.	Sample Size	Sample Ground Avg.	Sample Inv. Avg.	Sample ROM	Sample R^2	Population Adj. Avg.	Population E	Population E%
Height (m)	25.3	51	24.2	25.2	0.962	39%	24.2	1.4	5.9
Age (yrs)	135.9	53	142.6	138.7	1.028	61%	139.4	10.3	7.4

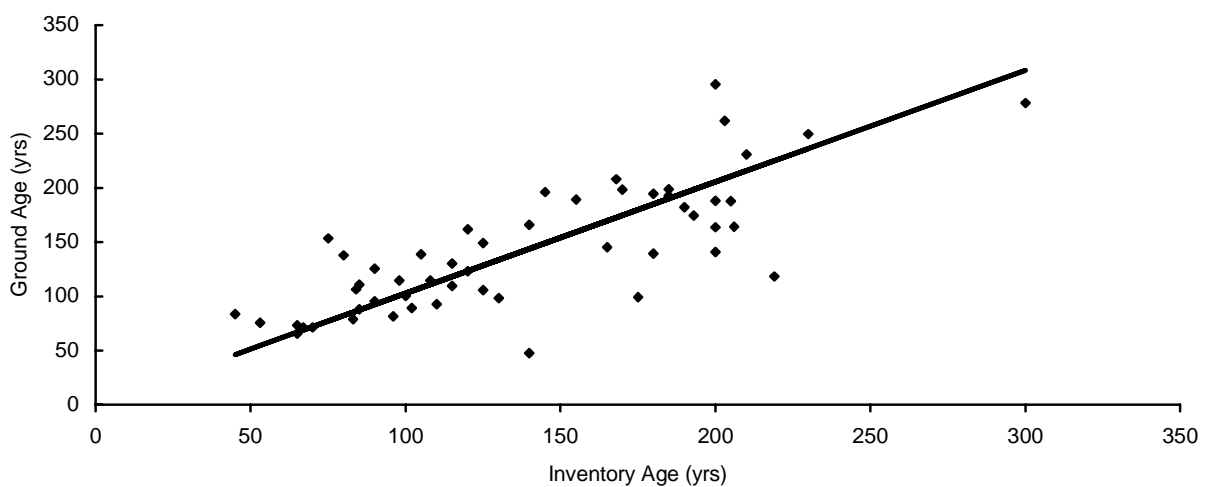Figure 4. Ground vs. unadjusted inventory height.

Figure 5. Ground vs. unadjusted inventory age.

4.2 ATTRIBUTE-ADJUSTED VOLUME

Following height and age adjustment, a new attribute-adjusted volume, free of photo-interpretation induced height and age bias, was generated using *VDYP*. Volume increased 2% after adjusting height and age (Table 5). However, the attribute-adjusted volume is a by-product of the MSRM procedures for statistical adjustment and has no practical interest since it still includes some bias.

Table 5. Unadjusted and attribute-adjusted volume for TFL 52 target population.

Ldg Spp	Area (ha)	Unadjusted Volume (m^3/ha)	Attribute-Adjusted Volume (m^3/ha)	Difference (%)
Sx	78,160	253.6	267.2	+5
Pl	41,195	268.9	266.6	-1
Bl	26,095	145.2	139.8	-4
Others	9,487	142.9	145.7	+2
All	*154,937*	*232.6*	*238.1*	*+2*

4.3 VOLUME ADJUSTMENT

The next step uses the *VDYP* attribute-adjusted volume (Section 4.2) and Phase II ground data volume to correct the growth and yield model (*VDYP*) bias. Attribute-adjusted volume increased approximately 13% (from 238.1 to 269.5 m^3/ha, Figure 6, Table 6) after adjustment. The sampling error was less than 15%, which is the recommended MSRM precision for VRI statistical adjustment.

Table 6. Volume adjustment statistics for TFL 52 target population.

	Population		Sample					Adjusted Population		
Attribute	Area (ha)	Avg.	Size	Grnd. Avg.	Attr. Avg.	ROM	R^2	Avg.	E	E%
Volume (m^3/ha)	154,937	238.1	54	268.3	237.1	1.132	15%	269.5	35.0	13.1

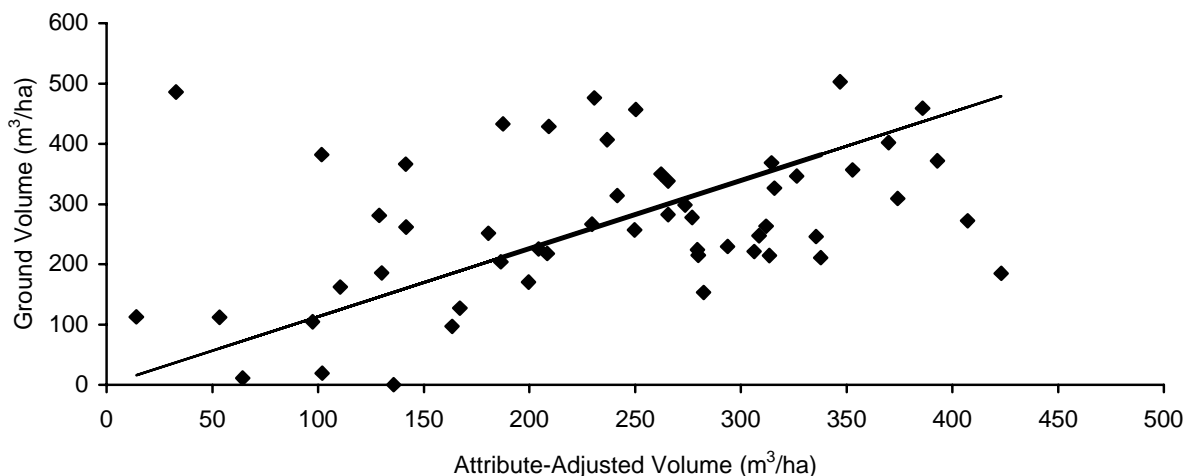Note: Attr. Avg. is the attribute-adjusted volume.

Figure 6. Ground volume vs. attribute-adjusted volume.

4.4 ADJUSTED INVENTORY

After adjustment, average age increased 3% and average height decreased 4%. These two adjustments led to a 7% decrease in inventory site index. The height and age photo-interpretation adjustments had a positive impact of 2% on volume (attribute-adjusted impact, Section 4.2), and the adjustment based on ground data volume had a 13% impact (model correction, Section 4.3), for an overall increase of 16%

(Table 7). However, this adjustment was not NVAF corrected. Assuming a NVAF of 3 to 5%, the true volume adjustment would be an increase of 11 to 13%.

Table 7. Adjusted inventory statistics for TFL 52 target population.

Spp Grp	Area (ha)	Height (m)			Age (yrs)			Site Index (m)			Volume (m³/ha)		
		Unadj.	Adj.	Diff. %	Unadj.	Adj.	Diff. %	Unadj.	Adj.	Diff. %	Unadj.	Adj.	Diff. %
Sx	78,160	28.1	27.0	-4	155.3	159.7	+3	15.1	13.8	-8	253.6	302.4	+19
Pl	41,195	24.7	23.8	-4	114.1	117.3	+3	18.4	17.3	-6	268.9	301.7	+12
Bl	26,095	18.8	18.0	-4	122.2	125.7	+3	11.4	10.6	-7	145.2	158.2	+9
Others	9,487	22.6	21.7	-4	108.9	112.0	+3	15.9	15.0	-5	142.9	164.9	+15
All	*154,937*	*25.3*	*24.3*	*-4*	*135.9*	*139.8*	*+3*	*15.4*	*14.3*	*-7*	*232.6*	*269.5*	*+16*

4.5 SAMPLE SIZE DETERMINATION

4.5.1 Overview

The CV of the volume adjustment ratio for the TFL 52 VRI sample was 48%. Figure 7 shows the relationship between sample size, relative error, and confidence levels for a CV of 48%. The figure shows the sample size required to achieve a desired error level increases dramatically if the confidence level increases from 95 to 99%. Similarly, the sample size must increase considerably for a given confidence level increase when the sampling error is below 8%.
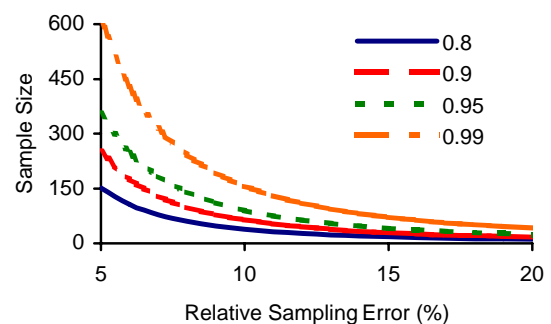

Figure 7. Estimated sample size for a relative error and confidence level with a CV of 48%.

4.5.2 Project Sample Size

With 54 samples, a sampling error of 13.1% (at a confidence level of 95%) has been achieved. This sampling error satisfies MSRM Timber Supply Review standard. To achieve the same sampling error with a 99% confidence level, 38 additional samples are required. To achieve a 10% sampling error with a 95% confidence level, 36 additional samples are required.

Selecting the appropriate sampling error and confidence level is a function of the timber harvest flow variability under different scenarios in a timber supply analysis. If the timber harvest flow is sensitive to a small variation in the volume adjustment ratio, additional samples are required to calculate a more precise inventory volume. If this sensitivity is negligible, then the current sample size is adequate.

5. CONCLUSION

West Fraser should review the results of this preliminary adjustment and decide if more VRI plots are needed to increase the confidence in the volume adjustment. If West Fraser is satisfied with the current level of confidence, then we recommend that:

NVAF sampling is completed in the 2003 field season.