Tree Farm Licence 48
Vegetation Resources Inventory
Statistical Adjustment

Prepared for

Don Rosen
Canadian Forest Products Ltd.
Peace Operations
Chetwynd, BC

Project: CFC-012

March 16, 2005

J.S. Thrower & Associates Ltd. *Consulting Foresters*
Vancouver – Kamloops, BC

Executive Summary

Canadian Forest Products Ltd. – Peace Operations (Canfor) initiated a Vegetation Resources Inventory (VRI) program on Tree Farm Licence (TFL) 48 in 1997. The Phase I (photo-interpretation) was completed in time for the second timber supply review (TSR) in 2001, while the Phase II (ground sampling) and Net Volume Adjustment Factor (NVAF) sampling were completed in 2002 and 2004, respectively. The statistical adjustment was the last component required to complete the VRI program and make the adjusted VRI available for TSR III.

While TFL 48 covers 643,248 ha, only Vegetated Treed polygons, regenerated before 1971 and not under a shelterwood silvicultural system (517,587 ha, 81% of the TFL) were statistically adjusted in this project. One hundred and twenty-eight (128) VRI Phase II plots, established in the target population, were used for the statistical adjustment.

Forty-four (44) trees were sampled in the NVAF component of the VRI program. The NVAF results showed that taper equations and net factor rules under-estimated the true net merchantable volume by 6 to 9% for all species except mature spruce (1% under-estimation).

The target population was stratified into three priority areas: High, Moderate, and Low. The High priority stratum covered areas most likely to be included in the timber harvesting land base (THLB) for Management Plan (MP) 4. Moderate and Low priority strata covered areas less likely to be included in the THLB.

Height, age, and net merchantable volume were the only attributes adjusted in this project. The TSR volume was derived from the adjusted net merchantable volume. TSR volume is defined as the net merchantable volume at the 12.5 cm+ utilization level in lodgepole pine-leading stands and the 17.5 cm+ level in all other stands. After adjustment, the average height increased by 5%, age decreased by 7%, and TSR volume increased by 34%. The TSR volume increased by 18% in the High priority areas.

	Area	Height (m)			Age (yrs)			TSR Volume (m^3/ha/yr)		
Priority	(ha)	Phase I	Adjusted	Diff.	Phase I	Adjusted	Diff.	Phase I	Adjusted	Diff.
High	257,583	22.9	23.2	1%	128	121	-6%	219.2	259.7	18%
Moderate	50,549	13.2	13.8	5%	52	59	16%	54.1	93.8	73%
Low	209,454	14.2	15.9	12%	149	133	-10%	87.6	152.6	74%
All	*517586*	*18.5*	*19.3*	*5%*	*129*	*120*	*-7%*	*149.8*	*200.1*	*34%*

Site index was not directly adjusted, but rather derived from adjusted height and age. Site index increased from 11.4 to 12.4 m, on average, after adjustment; however, the site index obtained after adjustment is probably still a poor indicator of potential site productivity, especially for future managed stands. Canfor should investigate methods to improve site productivity estimates for TSR III.

The adjusted VRI database represents the state of the inventory as of 2000. The inventory must be projected to 2005 to be used in TSR III.

This page was intentionally left blank.

Table of Contents

List of Tables

List of Figures

1. INTRODUCTION

1.1 BACKGROUND

1.1.1 Vegetation Resources Inventory Overview

The Vegetation Resources Inventory (VRI) is the Ministry of Sustainable Resource Management's (MSRM) forest inventory standard for public lands in BC. Forest licensees should use the VRI standard in their data package when submitting an application for an allowable annual cut (AAC) determination to the Ministry of Forests (MOF).

The VRI is a four-step process (Figure 1):

1. Phase I (unadjusted inventory data) – Polygon attributes are estimated, generally using photo-interpretation.
2. Phase II (ground sample data) – Measurements are taken from randomly located ground samples.
3. Net Volume Adjustment Factor (NVAF) sampling – Random trees are selected from the Phase II ground samples for stem-analysis studies to develop adjustment ratios that correct volume for taper and decay estimation bias.
4. Adjustment Phase – The Phase I estimates are adjusted using the NVAF-corrected Phase II ground samples to provide an adjusted unbiased estimate of forest inventory attributes. The final product is an adjusted VRI database.

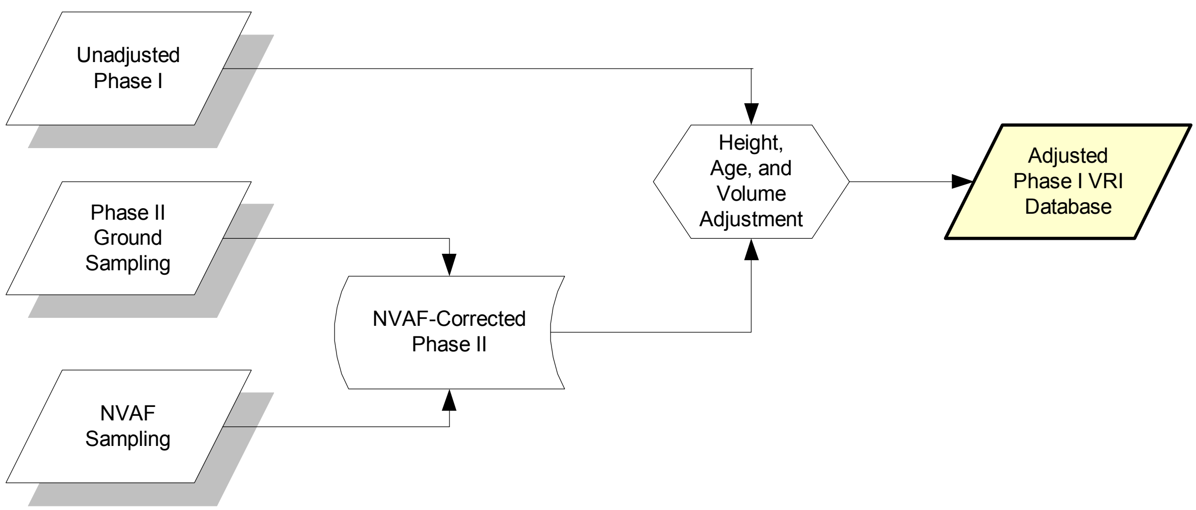

Figure 1. VRI flowchart.

1.1.2 TFL 48 VRI Program

Canadian Forest Products Ltd. – Peace Operations (Canfor) initiated a VRI program on Tree Farm Licence (TFL) 48 in 1997, in response to the Chief Forester's request in the 1996 rationale for AAC determination.[1] Canfor completed Phase I in time for the second timber supply review (TSR),[2] and

[1] Pedersen, L. 1996. Tree Farm Licence 48 Canadian Forest Products Ltd. Rationale for Allowable Annual Cut Determination. December 31, 1996. 37 pp. + app.

intends to complete the entire VRI program in time for TSR III, due in 2006. Phase II ground sampling was completed between 1998 and 2002, and the NVAF program was completed in 2004. The VRI statistical adjustment is, therefore, the last component to finalize the VRI program on TFL 48.

1.2 Project Objectives

The project objectives were to:

1. *Estimate the total and average height, age, net merchantable volume at the 12.5 cm+ utilization level (volume 12.5+), and net merchantable volume at the 17.5 cm+ utilization level (volume 17.5+) by priority area for the Vegetated Treed (VT) polygons.*
2. *Achieve a 95% sampling error of ±10% in net merchantable volume in the High and Moderate priority areas.*
3. *Distribute the estimated total of each attribute of interest among all the polygons within the target population.*

1.3 Document Objectives

The objectives of this document were to:

1. *Summarize the VRI activities implemented on TFL 48 since 1997.*
2. *Document assumptions and analytical methods used to adjust the VRI database.*
3. *Present the VRI statistical adjustment results.*
4. *Discuss the risks and uncertainties related to the TFL 48 VRI statistical adjustment for the upcoming TSR.*

J.S. Thrower & Associates Ltd. (JST) completed an interim VRI statistical adjustment of TFL 48 in March 2003.[3] The present document supersedes the 2003 report.

1.4 Terms of Reference

This VRI statistical adjustment report was prepared for Don Rosen of Canfor. Guillaume Thérien, *PhD* (JST) completed the analysis and report writing. This report was prepared as an internal document for Canfor.

---

[2] Baker, K. 2001. Tree Farm Licence 48 Canadian Forest Products Ltd. Rationale for Allowable Annual Cut (AAC) Determination. September 20, 2001. 42 pp. + app.

[3] J.S. Thrower & Associates Ltd. 2003. Tree Farm Licence 48 Vegetation Resources Inventory Statistical Adjustment. Unpublished Report, Contract No. CFC-007, March 31, 2003. 14 pp.

2. METHODS

2.1 LANDBASE

TFL 48 is located around the town of Chetwynd in the Dawson Creek Forest District of the Northern Interior Forest Region (Figure 2). The total area of the TFL has changed since the last TSR in 2001, as some areas have been added while others have been removed. The new total area of the TFL is 643,238 ha.

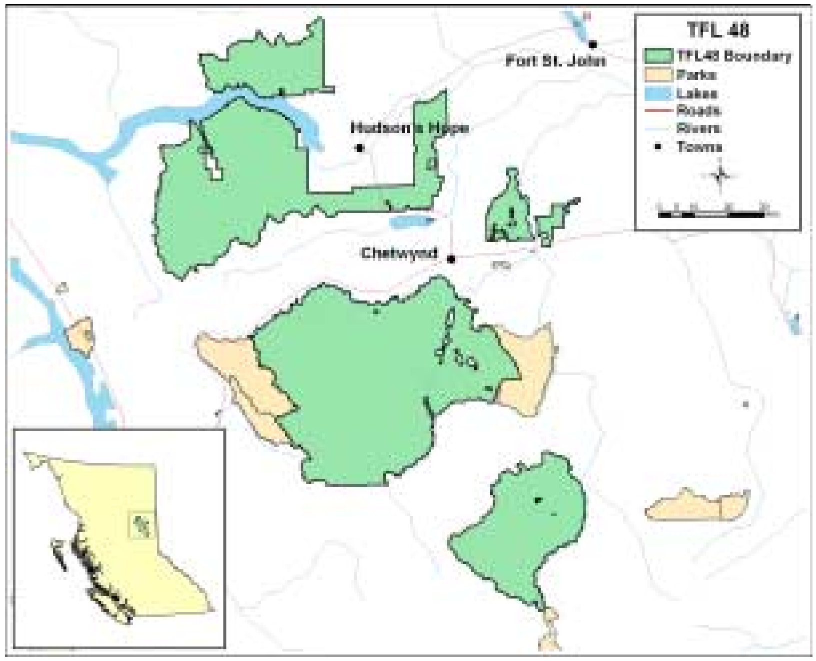

Figure 2. TFL 48 location.

The TFL lies within the Engelmann Spruce-Subalpine Fir (ESSF), Sub-Boreal Spruce (SBS), Boreal White and Black Spruce (BWBS), and Alpine Tundra (AT) biogeoclimatic zones. The main stand types are pure lodgepole pine (Pl) and balsam fir (Bl) stands, and mixed Bl-spruce (Sx) and Pl-Sx stands. The TFL area is evenly distributed among immature, mature, and over-mature stands.

2.2 TARGET POPULATION

The total area of the TFL where Phase I was completed as of January 1, 2005 totaled 641,462 ha (Table 1). A small area around Stewart Lake (1,776 ha) has not been inventoried because it was just recently added to the TFL.

The target population for the VRI adjustment excludes non-VT areas, stands that were established after 1970 (<30 years in 2000), and stands under the shelterwood silvicultural system. The target population for the VRI adjustment represented 517,586 ha (81% of the entire TFL).

Table 1. Target population net-down.

Land Class	Area (ha)	(%)
Total TFL	643,238	100%
Stewart Lake	1,776	0%
Inventoried areas	641,462	100%
Non-VT areas	76,701	12%
VT areas	564,761	88%
Below 30 years old	46,170	7%
30 years old+	518,591	81%
Shelterwood	1,004	0%
Target Population	*517,586*	*81%*

2.3 Stratification

The target population was stratified to reflect the likelihood of a polygon being included in the timber harvesting landbase (THLB) in the next TSR (Table 2). High priority areas include polygons most likely to be included in the THLB and represented 50% of the target population. Moderate priority areas (10% of the target population) were polygons that might also be included in the THLB, whereas Low priority areas were polygons that will probably not be included in the THLB.

Table 2. Target population area by priority class.

	Area (ha)	(%)
High	257,583	50%
Moderate	50,549	10%
Low	209,454	40%
Total	*517,586*	*100%*

2.4 Phase I

2.4.1 Update and Projections

Canfor completed the Phase I using aerial photography taken between 1993 and 1997. The Phase I data were updated for depletion to 2005 and projected for growth to January 1, 2000 (Figure 3).[4] The statistical adjustment presented in this report was completed on the 2000 population. Thus, report statistics indicate the state of the 2000 population. The adjusted Phase I data should be projected to January 1, 2005 for inclusion in TSR III.[5]

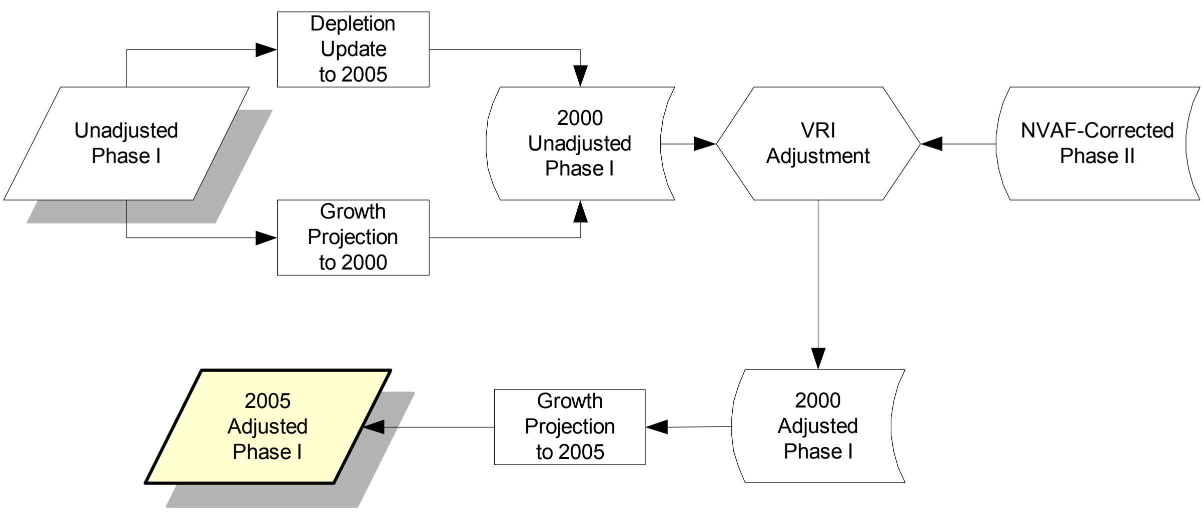

Figure 3. Update, adjustment, and projection of the TFL 48 Phase I inventory.

2.4.2 Statistics

The average Phase I volume 12.5+[6] in the High priority areas was approximately 227 m^3/ha while the average site index was 14.0 m (Table 3). The average mean annual increment (MAI) 12.5+, computed as the average volume divided by the average age, was approximately 1.8 m^3/ha/year. In the Moderate

[4] Year 2000 was selected because it represented the median year among the measurement dates of all the Phase II sample plots.

[5] This could be done with the VDYP7 growth model when it becomes available.

[6] Phase I volumes presented in this report were merchantable volume less decay, waste, and breakage as estimated by *VDYP version 6.6d.*

priority areas (mostly younger stands), the average site index was higher than in the High priority areas (15.4 m), while the average MAI was 1.2 m^3/ha/year (at 52 years).

Table 3. Phase I statistics by priority class for the target population.

Priority Class	Area (ha)	Height (m)	Age (yrs)	SI (m)	Vol. 12.5+ (m^3/ha)	Vol. 17.5+ (m^3/ha)
High	257,583	22.9	128	14.0	226.7	209.1
Moderate	50,549	13.2	52	15.4	62.6	41.6
Low	209,454	14.2	149	7.0	99.7	83.6
Total	*517,586*	*18.5*	*129*	*11.3*	*159.3*	*142.0*

2.5 PHASE II GROUND SAMPLING

2.5.1 History

The Phase II ground sampling was completed in four different projects (Table 4). One hundred and fifty-four (154) plots were established on TFL 48 over four years. The Phase II projects used different sample selection procedures, different target populations, and different inventories.

Table 4. Number of Phase II plots by year and project.

Year	Project				Total
	4741	4742	DDCA	DDCB	
1998	65		4	6	75
1999			7		7
2001		71			71
2002		1			1
Total	*65*	*72*	*11*	*6*	*154*

In 1998, prior to the new Phase I, Canfor established 65 Phase II ground plots in mature polygons for inventory audit purposes (project 4741).[7] These plots were selected systematically using a sorted list based on the previous mature forest inventory. These plots were revisited after the new Phase I was completed to determine which auxiliary plots were located in the new polygons.

In 1998, the MOF started to implement a VRI program across the Dawson Creek Forest District (projects DDCA and DDCB).[8,9] Seventeen (17) plots were established on TFL 48 before the stakeholders re-assessed their business needs and decided to sample only crown lands outside of the TFL.[10] These MOF plots were systematically selected from a random list based on the previous inventory. These plots were not revisited after the new Phase I was completed; however, to make these plots compatible with the new Phase I, auxiliary plot locations were checked using a Geographic Information System (GIS). Auxiliary plots not in the same polygon as the Integrated Plot Centre were deleted. Three auxiliary plots outside of an originally sampled polygon (and therefore not sampled) were located within a new polygon. The data for these plots were considered missing (or a non-response) and, therefore, represented a small potential bias.

[7] Canadian Forest Products Ltd. 1998. Dawson Creek Forest District Vegetation Resources Inventory Ground Sampling Plan TFL 48 Management Unit Inventory. Unpublished Report, November 6 1998, Amended March 15, 1999. 11 pp.

[8] J.S. Thrower & Associates Ltd. 1997. Dawson Creek Forest District Vegetation Resources Inventory Ground Sampling Plan Revised Final Report. Unpublished Report, Contract No. MFI-401-033, October 8, 1997. 37 pp.

[9] J.S. Thrower & Associates Ltd. 1997. Dawson Creek Forest District Vegetation Resources Inventory Ground Sampling Plan Revised Final Report Addendum. Unpublished Report, Contract No. MFI-401-033, October 20, 1997. 3 pp.

[10] Matt Makar, personal communication, November 2, 2004.

In 2001, Canfor implemented another VRI ground sampling program on the TFL to increase the sample size in specific areas of interest (project 4742).[11] Seventy-two (72) plots were selected across the entire landbase using probability proportional to size with replacement (PPSWR) based on the new Phase I.

Table 5. Number of Phase II plots by year and project used for analysis.

Year	4741	4742	DDCA	DDCB	Total
1998	61		1	6	68
1999			6		6
2001		53			53
2002		1			1
Total	*61*	*54*	*7*	*6*	*128*

2.5.2 Sample Size

While 154 Phase II ground plots were established on the TFL, only 128 of these were used in the analysis (Table 5). Two plots were no longer in the TFL, 12 plots were located in non-VT polygons, one plot was located in a partially-harvested stand, and 11 plots were located in stands established after 1970. The sample plots were geographically distributed across the entire target population (Figure 4).

2.5.3 Sampling Weight

Approximately 60% of the 128 plots used in the analysis were selected systematically from a sorted list based on the previous forest inventory (projects 4741, DDCA, and DDCB). The remaining 40% were selected using PPSWR based on the new Phase I inventory. To simplify the analysis, we assumed that all plots were selected using PPSWR with the same stratification used in project 4742,[12] where polygons were stratified by priority class and leading species.

The sampling weights were computed using the total area of the stratum divided by the number of plots in that stratum used for analysis (Table 6). In the High and Moderate priority areas, Bl and Sx leading stands were combined in the Others species group. In the Low priority areas, deciduous stands were grouped with Sx stands in Others. Finally, larch (Lw) leading stands in the Low priority areas were combined with the Pl group. Stands in the Moderate priority areas were sampled with the highest sampling intensity (approximately 2,300 ha/plot). Each plot in the High priority areas represented approximately 3,000 ha, while plots in the Low priority areas represented over 10,000 ha each.

Table 6. Sampling weight by species group and priority class.

Species	High			Moderate			Low		
Group	Area (ha)	Plots	Area/Plot	Area (ha)	Plots	Area/Plot	Area (ha)	Plots	Area/Plot
Deciduous	48,801	10	4,880	9,738	4	2,435			
Bl							107,023	8	13,378
Pl	99,808	39	2,559	24,094	11	2,190	32,161	7	4,594
Sx									
Others	108,974	37	2,945	16,716	7	2,388	70,270	5	14,054
Total	*257,583*	*86*	*2,995*	*50,549*	*22*	*2,298*	*209,454*	*20*	*10,473*

[11] J.S. Thrower & Associates Ltd. 2000. Vegetation Resources Inventory Sampling Plan. Canadian Forest Products Ltd. Tree Farm Licence 48. Unpublished Report, Contract No. CFC-012-002, August 22, 2000. 18 pp.

[12] Sam, Otukol, *PhD* (MSRM – Resource Information Branch), personal communication, November 16, 2004.

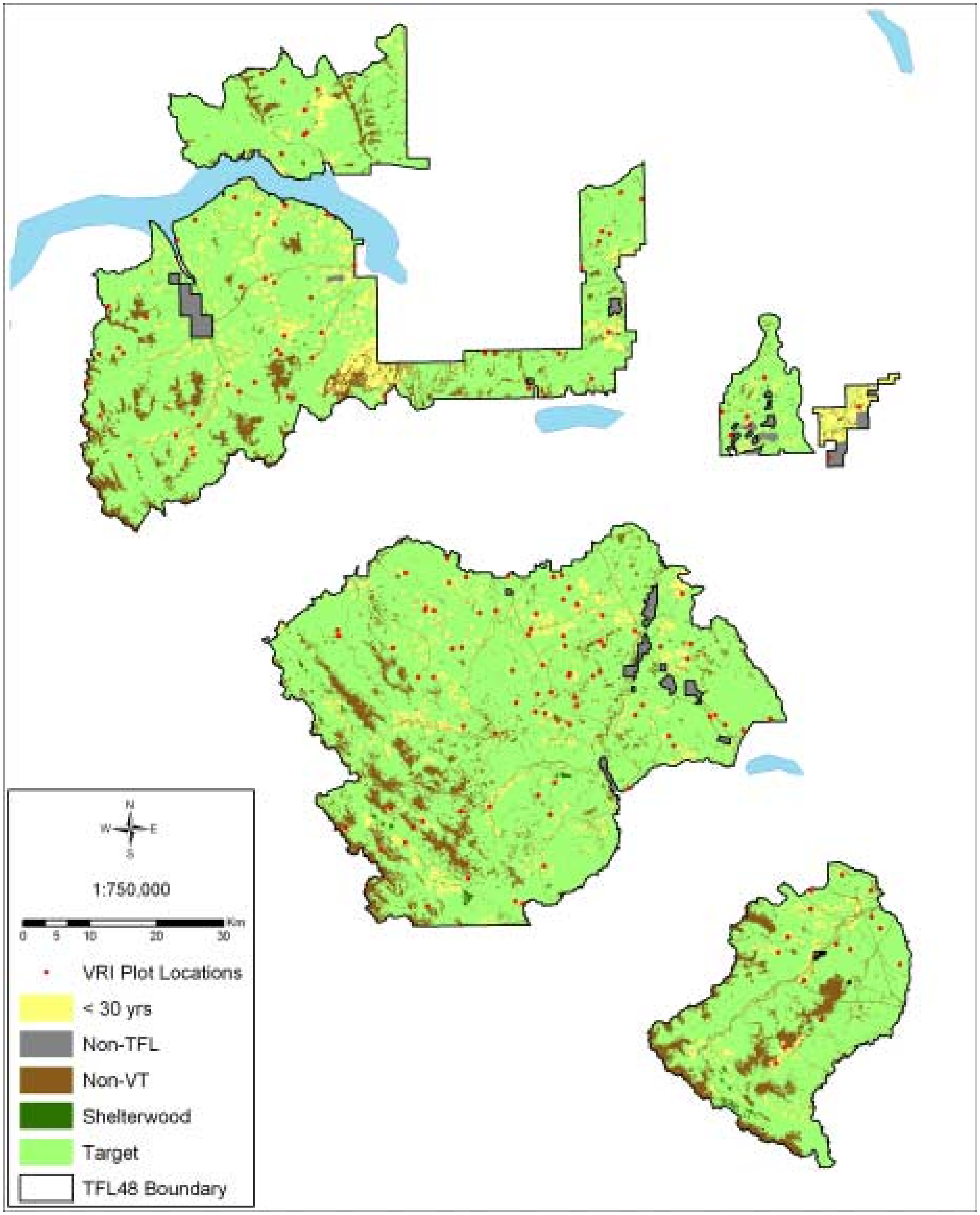

Figure 4. Phase II plot locations.

2.6 NVAF SAMPLING

2.6.1 Stratification

Forty-four (44) NVAF sample trees were selected by maturity class and species group from the Phase II ground sample.[13] Deciduous-leading polygons were considered immature if established in or after 1920 (≤80 years in 2000), and mature if established before 1920. Conifer-leading polygons established in or after 1880 (≤120 years in 2000) were immature, and mature otherwise. Species groups included Pl, Sx, and Others.

2.6.2 Ratio Estimation Algorithm

The NVAF ratios were computed using the model-based approach recommended by the MSRM.[14] The NVAF compiler provided by the MSRM on August 13, 2004 was used to compute the NVAF ratios.

2.6.3 NVAF Ratios and 95% Sampling Error

Most maturity class/species group combinations had similar NVAF ratios, around 1.07 (Table 7, Appendix I). Only mature Sx showed an NVAF ratio of 1.01. Thus, the net merchantable volume of trees in the immature, mature Pl, and mature Others strata were under-estimated by 6-9% by the taper equations and net factors. The under-estimation was 1% in mature Sx. The 95% relative sampling error was below 7% for all strata.

Table 7. NVAF adjustment ratios.

Maturity Class	Species Group	Sample Size	NVAF Ratio	95% E%
Immature	All	10	1.087	6.9
Mature	Pl	10	1.067	5.9
	Sx	12	1.008	2.7
	Others	12	1.060	6.8

2.7 PHASE II DATA COMPILATION

The Phase II ground data were summarized using the data provided by the MSRM on October 19, 2004. The sampled polygons were identified using the most recent version of the unadjusted Phase I and the plot locations. JST did not have access to the Phase II plot cards; hence, quality control for the data entry was the MSRM's responsibility. Measured height and net factoring from enhanced trees were used when available. The NVAF ratios were applied to the tree-level whole-stem volume less top, stump, cruiser-called decay, waste, and breakage, and these NVAF-corrected volumes were used for the VRI statistical adjustment.

Average volume 12.5+ was higher in the High priority areas than in the Moderate priority areas because these stands were older (Table 8). Average site index was also slightly higher in the High priority areas compared to Moderate priority areas. An opposite site index relationship occurred between the two priority areas in the Phase I data (Table 3).

Table 8. Phase II ground sampling statistics by priority class for the target population.

Priority Class	Sample Size	Height (m)	Age (yrs)	SI (m)	Vol. 12.5+ (m^3/ha)	Vol. 17.5+ (m^3/ha)
High	86	23.5	119	15.3	281.0	268.1
Moderate	22	15.2	70	14.1	118.5	79.0
Low	20	17.5	136	9.6	190.4	168.6
Total	*128*	*20.2*	*122*	*12.9*	*228.5*	*209.4*

[13] J.S. Thrower & Associates Ltd. 2004. Tree Farm Licence 48 Net Volume Adjustment Factor Sample Plan. Unpublished Report, Contract No. CFC-010, July 16, 2004. 7 pp.

[14] Will Smith, *RPF* (MSRM – Terrestrial Information Branch), personal communication, August 8, 2004.

This indicated that Phase I site index was poorly correlated with the actual ground site index. The average MAI 12.5+ was approximately 2.4 and 1.7 m^3/ha/year in the High and Moderate priority areas, respectively.

2.8 ADJUSTMENT PROCEDURE

The most recent MSRM VRI statistical adjustment standards were used for this project.[15] The MSRM adjustment process assumes that the Phase I volume is biased due to two sources of error:

1. An attribute bias associated with the photo-interpreted height and age; and
2. A model bias inherent to the growth and yield model used to estimate volume (*VDYP version 6.6d*).

Three attributes required for volume prediction are not directly adjusted. A new stocking class is derived by VDYP using adjusted age, while the MSRM has not developed methods to adjust species composition and crown closure. Leaving these attributes unadjusted is assumed to create a negligible bias.

The attribute adjustment procedure is a two-step process called the Fraser Method (Figure 5) and can be described as follows:

- In the first step, the biases in the Phase I height and age are corrected using adjustment ratios calculated from the Phase I and Phase II data. An attribute-adjusted volume can then be estimated using *VDYP* with the adjusted height and age.
- In the second step, an adjustment ratio estimated from the attribute-adjusted volume and the Phase II volume is calculated, and this ratio is used to correct the model bias in the attribute-adjusted volume.

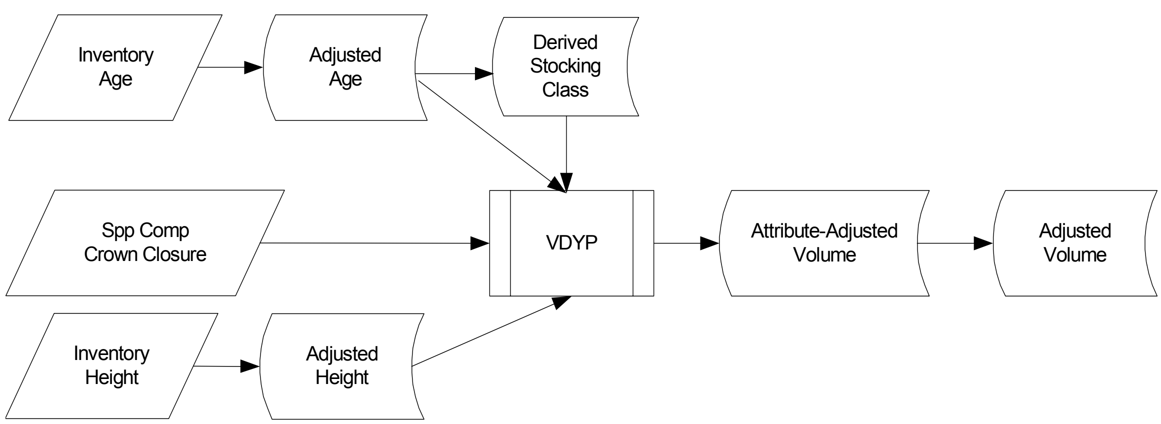

Figure 5. Fraser Method.

Post-stratification is a common technique used to improve the precision of the estimates. However, post-stratification was not attempted for this analysis since the sample selection was already based on a detailed pre-stratification.

---

15 Ministry of Sustainable Resource Management. 2004. Vegetation Resources Inventory Procedures and Standards for Data Analysis Attribute Adjustment and Implementation of Adjustment in a Corporate Database. Unpublished Report, March 2004. 77 pp.

Height and age were adjusted using the ratio of means (ROM) method and the confidence index.[16] The confidence index is used to better distribute the adjusted average. For each individual stand, a confidence coefficient (k) can be computed for height or age using the confidence index for the stand (CI) and the average confidence index for all stands within the stratum ($\overline{CI}$) (Table 9):

Table 9. Average confidence index by stratum.

Priority Class	Confidence Index Height	Confidence Index Age
High	5.23	5.21
Moderate	5.54	5.65
Low	5.20	5.14

$$k = \frac{9 - CI}{9 - \overline{CI}}$$

The equation used to compute the adjusted Phase I is then:

$$\text{Adj. Phase I} = \text{Phase I} \times \left[(1-k) + (ROM \times k)\right]$$

If the confidence index for a stand is equal to the average index for the stratum, k is 1 and the adjusted Phase I estimate is equal to the unadjusted Phase I multiplied by the ROM. If the confidence index is 9, the Phase I estimate is assumed to be known without error. The coefficient k is therefore 0, and the adjusted Phase I estimate is equal to the unadjusted Phase I.

There is no confidence index for volume in the VRI Phase I. Therefore, volume was adjusted using only the ROM.

[16] Using confidence index is not part of the statistical adjustment standards. However Sam Otukol, PhD (MSRM biometrician) authorized a variance on February 18, 2005, as allowed by the standards.

3. RESULTS

3.1 HEIGHT

Height for the leading ground species was not always available or suitable for height adjustment. In two cases, species between Phase I and Phase II data could not be matched; in 13 cases, suitable Phase II heights were not available; and in one case, the height measured on the ground belonged to a different layer than the main Phase I layer (project 4741, sample no. 110). When Phase II height was unavailable for the site trees, we tried to obtain a match using the additional trees measured on the plot (X and O trees); however, no additional matches were found. Therefore, 112 height observations were left for analysis.

Height in the High priority areas was slightly under-estimated (by approximately 1%) in the Phase I data (Table 10, Appendix II). The ROM estimator was very precise in this stratum with a 95% sampling error of less than 4%. All species groups in the High priority areas showed similar relationships between Phase II and Phase I data. In the Moderate priority areas, height was under-estimated by approximately 4% on average; however, the under-estimation varied among species group. The among-species variation could be due to the small sample size used for each species group. The 95% sampling error in the Moderate priority areas was 10%. When the entire target population was considered, average Phase I height was under-estimated by 5%.

Table 10. Height adjustment statistics by priority class and leading species.

Priority Class	Spp.	Area (ha)	Sample Size	Height (m)			ROM	Adj. Pop (m)	95% E	
				Pop Avg.	Sample Avg. Ground	Sample Avg. Map			(m)	%
High	Decid.	48,801	9	23.9	24.1	23.9	1.006			
	Pl	99,808	35	21.0	22.7	22.1	1.028			
	Others	108,974	31	24.2	24.4	24.3	1.004			
	All	*257,583*	*75*	*22.9*	*23.7*	*23.4*	*1.013*	*23.2*	*0.8*	*3.6*
Moderate	Decid.	9,738	3	15.9	19.6	17.6	1.112			
	Pl	24,094	10	13.7	14.3	14.7	0.974			
	Others	16,716	6	11.0	11.9	10.6	1.126			
	All	*50,549*	*19*	*13.2*	*14.5*	*13.9*	*1.044*	*13.8*	*1.4*	*10*
Low	Bl	107,023	7	11.7	16.3	13.2	1.233			
	Pl	32,161	6	13.3	15.3	13.0	1.174			
	Others	70,270	5	18.5	20.0	20.0	1.001			
	All	*209,454*	*18*	*14.2*	*17.5*	*15.7*	*1.117*	*15.9*	*2.9*	*18.2*
All	*All*	*517,586*	*112*	*18.5*	*20.3*	*19.3*	*1.048*	*19.3*	*1.5*	*7.6*

3.2 AGE

Age for the leading ground species was not always available or suitable for age adjustment. In two cases, species between Phase I and Phase II data could not be matched; in nine cases, suitable Phase II ages were not available; and sample no. 110 from project 4741 was also deleted for the age adjustment. When Phase II age was unavailable for site trees, we tried to obtain a match using the additional trees measured on the plot (X and O trees); however, no additional matches were found. Therefore, 116 age observations were left for analysis.

In the High priority areas, Phase I age was over-estimated by approximately 6%, on average (Table 11, Appendix III). The 95% sampling error in this stratum was very small relative to the other strata (5.8%). The over-estimation was consistent among all species groups in the High priority areas. In the Moderate areas, Phase I age was under-estimated by approximately 16%. The 95% sampling error was relatively high at 15%. When the entire target population was considered, the average Phase I age was over-estimated by approximately 7%.

Table 11. Age adjustment statistics by priority class and leading species.

Priority Class	Spp.	Area (ha)	Sample Size	Age (yrs)			ROM	Adj. Pop (yrs)	95% E	
				Pop Avg.	Sample Avg.				(yrs)	%
					Ground	Map				
High	Decid.	48,801	9	103	94	106	0.887			
	Pl	99,808	36	122	117	125	0.940			
	Others	108,974	32	145	137	143	0.959			
	All	*257,583*	*77*	*128*	*121*	*129*	*0.940*	*121*	*7.0*	*5.8*
Moderate	Decid.	9,738	3	46	60	51	1.172			
	Pl	24,094	10	54	59	55	1.070			
	Others	16,716	6	52	79	62	1.281			
	All	*50,549*	*19*	*52*	*66*	*57*	*1.155*	*60*	*9.0*	*15.0*
Low	Bl	107,023	8	140	107	144	0.744			
	Pl	32,161	7	117	119	107	1.116			
	Others	70,270	5	177	187	182	1.024			
	All	*209,454*	*20*	*149*	*136*	*151*	*0.897*	*133*	*28.4*	*21.3*
All	*All*	*517,586*	*116*	*129*	*123*	*131*	*0.929*	*120*	*10.3*	*8.6*

3.3 VOLUME

3.3.1 Attribute-Adjusted Volume

Volume 12.5+ increased by 7%, on average, after height and age adjustment (Table 12). This increase in volume was due to removing the bias in the growth model input. The age bias had little impact on the volume estimation since age decreased by 7% on average while volume increased by 7%. We can conclude that the volume bias was influenced more by the height than age bias.

Table 12. Change in volume 12.5+ due to height and age adjustment.

Priority Class	Area (ha)	Unadjusted Phase I (m^3/ha)	Attribute Adjusted (m^3/ha)	Diff. (%)
High	257,583	226.7	231.0	2%
Moderate	50,549	62.6	68.5	9%
Low	209,454	99.7	120.7	21%
Total	*517,586*	*159.3*	*170.5*	*7%*

3.3.2 Net Merchantable Volume

Sample 110 from project 4741 was again rejected, leaving 127 plots for analysis. Volume 12.5+ increased by more than 16% over the attribute-adjusted volume in the High priority areas (Table 13, Appendix IV). The 95% sampling error achieved in this stratum was slightly less than 11%. In the Moderate priority areas, volume 12.5+ increased by almost 60%, but the 95% sampling error was high at 38%. When only High and Moderate priority areas were considered, volume increased by approximately 19%. The 95% sampling error for the combined High and Moderate priority areas was 10.3%, marginally higher than the 10% target.

Table 13. Volume 12.5+ adjustment statistics by priority class and leading species.

Priority Class	Spp.	Area (ha)	Sample Size	Volume (m^3/ha) Pop Avg.	Sample Avg. Ground	Sample Avg. Map	ROM	Adj. Pop (m)	95% E (m)	95% E %
High	Decid.	48,801	10	176.4	196.3	165.6	1.186			
	Pl	99,808	39	233.9	294.8	244.7	1.205			
	Others	108,974	37	252.7	306.3	272.2	1.125			
	All	*257,583*	*86*	*231.0*	*281.0*	*241.3*	*1.164*	*268.9*	*29.1*	*10.8*
Moderate	Decid.	9,738	4	63.2	218.0	73.4	2.970			
	Pl	24,094	11	77.1	82.9	70.3	1.180			
	Others	16,716	6	59.1	87.5	69.2	1.264			
	All	*50,549*	*21*	*68.5*	*112.2*	*71.3*	*1.574*	*107.8*	*40.9*	*38.0*
Low	Bl	107,023	8	96.2	147.8	100.6	1.469			
	Pl	32,161	7	112.0	194.2	86.9	2.234			
	Others	70,270	5	162.0	254.1	208.5	1.219			
	All	*209,454*	*20*	*120.7*	*190.6*	*134.7*	*1.415*	*170.8*	*61.3*	*35.9*
All	*All*	*517,586*	*127*	*170.5*	*227.9*	*181.6*	*1.252*	*213.5*	*36.0*	*16.9*

Volume 17.5+ increased by almost 20% in the High priority areas, while the 95% sampling error was slightly less than 12% (Table 14, Appendix V). In the Moderate priority areas, volume 17.5+ increased by 68%, with a 95% sampling error of 55%. When only High and Moderate priority areas were considered, volume increased by 21%. The 95% sampling error for the combined High and Moderate priority areas was 12%.

Table 14. Volume 17.5+ adjustment statistics by priority class and leading species.

Priority Class	Spp.	Area (ha)	Sample Size	Volume (m^3/ha) Pop Avg.	Sample Avg. Ground	Sample Avg. Map	ROM	Adj. Pop (m)	95% E (m)	95% E %
High	Decid.	48,801	10	167.3	186.2	154.4	1.206			
	Pl	99,808	39	206.9	273.6	220.5	1.241			
	Others	108,974	37	238.2	299.8	259.1	1.157			
	All	*257,583*	*86*	*212.6*	*268.1*	*224.3*	*1.195*	*254.1*	*30.1*	*11.8*
Moderate	Decid.	9,738	4	44.7	165.7	50.4	3.288			
	Bl	4,141	2	33.7	38.3	8.6	4.448			
	Pl	24,094	11	47.6	48.5	41.0	1.183			
	Sx	12,575	4	46.1	70.6	65.5	1.079			
	All	*50,549*	*21*	*45.5*	*76.0*	*45.2*	*1.680*	*76.5*	*41.9*	*54.7*
Low	Bl	107,023	8	79.2	129.5	81.4	1.590			
	Pl	32,161	7	83.4	143.4	59.8	2.400			
	Others	70,270	5	149.5	239.8	191.2	1.254			
	All	*209,454*	*20*	*103.4*	*168.6*	*114.9*	*1.467*	*151.8*	*62.5*	*41.2*
All	*All*	*517,586*	*127*	*152.1*	*209.1*	*162.6*	*1.284*	*195.4*	*39.0*	*19.9*

Table 15. Net merchantable volume change after adjustment.

Priority Class	Area (ha)	Volume 12.5+ Phase I	Volume 12.5+ Adj.	Volume 12.5+ Diff.	Volume 17.5+ Phase I	Volume 17.5+ Adj.	Volume 17.5+ Diff.
High	257,583	226.7	268.9	19%	209.1	247.5	18%
Moderate	50,549	62.6	107.8	72%	41.6	71.6	72%
Low	209,454	99.7	170.8	71%	83.6	146.4	75%
All	*517,586*	*159.3*	*213.5*	*34%*	*142.0*	*189.4*	*33%*

The average Phase I volume 12.5+ of 159 m^3/ha increased to an overall average of 214 m^3/ha after adjustments, a total increase of 34% (Table 15). The same level of overall increase was observed for volume 17.5+. When only High and Moderate priority areas were taken into account, volume 12.5+ increased 21% over Phase I unadjusted volume.

3.3.3 2005 TSR Volume

The volume used in TSR is based on utilization standards of 12.5 cm+ for Pl-leading stands and 17.5 cm+ for all other stands. In the last AAC determination, the AAC was split into volume from conifer- and deciduous-leading stands. Therefore, we looked at the impact of the statistical adjustment on TSR volume by forest cover type. Only High and Moderate priority areas were included in this analysis since these two strata will most likely make up the THLB in TSR III.

Average TSR volume/ha increased by approximately 21% after adjustment in both conifer- and deciduous-leadings stands (Table 16). MAI increased by about 0.5 m^3/ha/year (29%), and showed similar relative increases in both conifer- and deciduous-leading stands. There were an additional 189 million (MM) m^3 of standing volume after adjustment (158 and 31 MM m^3 in conifer- and deciduous-leading stands, respectively). These results confirm that there should be more volume available on TFL 48 for TSR III.

Table 16. TSR volume/ha, MAI, and total volume by leading forest cover type.

Cover Type	Priority Class	Area (ha)	Volume/ha (m^3/ha) PhaseI	Volume/ha Adj.	Volume/ha Diff.	MAI (m^3/ha/yr) PhaseI	MAI Adj.	MAI Diff.	Total Volume (MM m^3) PhaseI	Total Volume Adj.	Total Volume Diff.
Conifer	High	208,782	231.6	274.9	19%	1.8	2.2	26%	729	863	18%
	Medium	40,810	59.5	99.4	67%	1.0	1.5	50%	35	59	68%
	All	249,593	203.5	246.2	21%	1.6	2.1	28%	764	922	21%
Deciduous	High	48,801	166	194.7	17%	1.6	2.0	24%	138	161	17%
	Medium	9,738	31.4	70.4	124%	0.6	1.2	97%	7	15	109%
	All	58,539	143.6	174	21%	1.4	1.9	30%	145	176	22%
All	High	257,583	219.2	259.7	18%	1.7	2.2	26%	867	1,025	18%
	Medium	50,549	54.1	93.8	73%	0.9	1.4	56%	42	73	75%
	Total	308,132	192.1	232.5	21%	1.6	2.1	29%	909	1,098	21%

4. DISCUSSION

4.1 SAMPLE VS. POPULATION

A sample must adequately cover the range of observed values in the population to avoid extrapolating information to areas that were not sampled. We expect that a minimal amount of extrapolation will be required with a random sample since the minimum and maximum values observed in the population will not always be included in the sample. With a random sample of size n, one would expect on average that 100%/2*n of the population is below (above) the minimum (maximum) observed in the sample.

Table 17. Proportion of the population below (above) the minimum (maximum) observed in the sample.

Priority Class	Expected Proportion	Height		Age		Volume	
		Below	Above	Below	Above	Below	Above
High	0.6%	0.8%	1.6%	0.1%	3.2%	1.8%	0.2%
Moderate	2.3%	5.9%	6.8%	0.0%	0.4%	0.0%	1.3%
Low	2.5%	4.2%	12.8%	2.6%	9.4%	0.0%	7.4%

In the High priority areas, the sample generally covered the range of height, age, and volume (Table 17). In the Moderate priority areas, the sample did not adequately cover the range of heights (6% of the population was below the minimum observed in the sample and 7% was above the maximum). Therefore, adjusted heights at the extremities of the range in this stratum (below 6.6 m, above 19.9 m) were extrapolated beyond the sampled range, and could be biased. Similarly, in the Low priority areas, stands at the upper end of the range of height, age, and volume required extrapolation and could be biased.

4.2 95% SAMPLING ERROR

The targeted 95% sampling error for volume 12.5+ was 10% for the High and Moderate priority areas. The sampling error achieved on TFL 48 (10.3%) was marginally higher than the target. Therefore, while the target error was not met, the precision of the adjusted volume should not be a cause for concern in TSR III. The sampling errors for height, age, and NVAF ratios were all within acceptable limits for timber supply analysis.

4.3 IMPACT OF CHANGE

4.3.1 Age

There was little change in the age distribution after adjustment (Figure 6). The largest differences were observed in age classes 5 and 8 (based on Phase I age), where the area proportion increased by 5% and decreased by 6%, respectively.

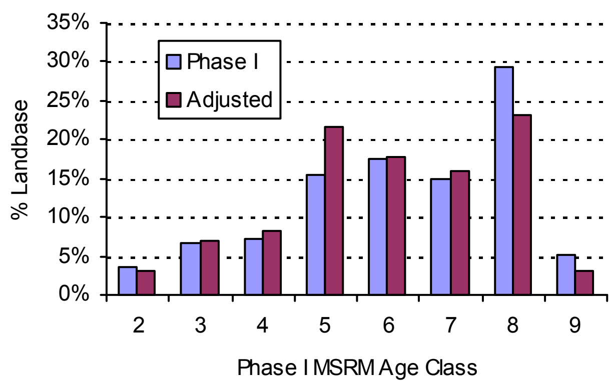

Figure 6. Change in the MSRM age class distribution after adjustment.

4.3.2 Volume

The overall 34% increase in volume 12.5+ was relatively consistent across all age classes (Table 18). The increases in age classes 3 and 9 were significantly more important but these two age classes represent relatively small areas.

Table 18. Change in volume 12.5+ by age class due to adjustment.

Age	Phase I		Adjusted		Vol.
Class	Area (ha)	Vol. (m^3/ha)	Area (ha)	Vol. (m^3/ha)	Diff.
2	18,674	11.8	16,365	15.8	34%
3	34,690	37.5	35,525	60.3	61%
4	36,760	93.7	43,125	129.0	38%
5	80,449	124.6	111,449	172.6	39%
6	91,084	162.2	91,788	217.6	34%
7	77,747	198.1	82,865	267.8	35%
8	151,550	204.6	120,167	290.4	42%
9	26,632	236.2	16,303	382.1	62%
Total	*517,586*	*159.3*	*517,586*	*213.5*	*34%*

4.3.3 MAI

MAI (12.5+) increased 42% on average after adjustment (Table 19). The MAI increased mostly in age classes 4 and 5, age classes where MAI culminates in most stands. The MAI increase is an indication that *VDYP version 6.6d* is under-estimating volume growth and yield on TFL 48. This could become a serious problem if yield tables for the next management plan are generated using *VDYP version 6.6d.* Canfor should investigate using a different model, such as VDYP7 if it is available, for generating natural stand yield tables for Management Plan (MP) 4.

Table 19. Change in MAI 12.5+ by age class due to adjustment.

Age	Phase I		Adjusted		MAI
Class	Area (ha)	MAI (m^3/ha/yr)	Area (ha)	MAI (m^3/ha/yr)	Diff
2	18,674	0.3	16,365	0.4	13%
3	34,690	0.7	35,525	1.1	58%
4	36,760	1.3	43,125	1.8	62%
5	80,449	1.4	111,449	1.9	96%
6	91,084	1.5	91,788	2.0	36%
7	77,747	1.5	82,865	2.1	45%
8	151,550	1.2	120,167	1.7	10%
9	26,632	0.8	16,303	1.4	2%
Total	*517,586*	*1.2*	*517,586*	*1.8*	*42%*

4.3.4 Site Index

Site index was not directly adjusted. Instead, it was derived from the adjusted height and adjusted age of the leading species using the MOF program Sindex version 1.21. Overall, site index increased by approximately 10% after adjustment (Table 20); however, most of the adjustment occurred in the older age classes (8 and 9) where a change in site productivity has no impact in timber supply analysis since yield tables for these age classes are usually flat-lined at the current volume.

Table 20. Change in average site index by age class due to adjustment.

Age Class	Area (ha)	Phase I SI (m)	Adj. SI (m)	Diff.
2	18,094	14.2	13.3	-6%
3	34,576	13.9	13.7	-1%
4	36,758	13.5	14.0	4%
5	80,437	12.1	13.4	10%
6	91,084	12.1	13.1	9%
7	77,747	12.2	13.2	9%
8	151,545	9.3	10.9	17%
9	26,632	6.4	8.5	33%
Total	*516,873*	*11.4*	*12.4*	*10%*

Note: polygons do not have a site index estimate if height is less than 1.3 m.

The increase in site index was observed across all major species groups (Table 21). In Pl-leading stands, site index increased by approximately 5% (from 13.3 to 13.9 m). Most Bl-leading stands were located in the Low priority areas. Site index increased by approximately 34% in these stands, but remained extremely low after adjustment at 8.3 m. Site index in Sx-leading stands increased by an overall average of 10% (from 10.8 to 11.9 m). Finally deciduous-leading stands increased the least (4%, from 15.6 to 16.3 m). Site index in stands in the High priority areas increased slightly (4%, from 14.0 to 14.6 m), while site index decreased in the Moderate priority areas (-7%, from 15.4 to 14.3 m). The Moderate priority areas covered only 50,549 ha.

Table 21. Average site index (m) before and after adjusting height and age by priority class and leading species.

Priority Class	Pl		Bl		Sx		Deciduous		All	
	Before	After	Before	After	Before	After	Before	After	Before	After
High	14.4	14.8	12.1	13.2	12.3	13.3	16.9	17.2	14.0	14.6
Moderate	14.6	14.1	13.2	11.3	15.7	13.9	18.1	16.9	15.4	14.3
Low	9.0	10.7	5.8	8.2	6.1	8.1	11.7	14.0	7.0	9.2
All	*13.3*	*13.9*	*6.2*	*8.4*	*10.8*	*11.9*	*15.6*	*16.3*	*11.4*	*12.4*

Note: Sx includes interior and black spruce; Pl includes small areas where Lw was leading.

4.4 RISKS AND UNCERTAINTY

4.4.1 Height

The height residual graph (Appendix II) in the High priority areas shows a potential bias for predicted heights below 18 m and above 30 m. Adjusted height tended to under-estimate ground height (positive residuals) when the adjusted height was less than 18 m while it tended to over-estimate ground height (negative residuals) when the adjusted height was greater than 30 m. Predicted height was less than 18 m on 31,695 ha (12% of the stratum), and greater than 30 m on 15,450 m (6% of the stratum). No age bias could be detected in the High priority areas by looking at the age residual graph (Appendix III). Therefore, it is possible that site index is under-estimated in shorter stands and over-estimated in taller stands. A larger sample size in these areas would be required to confirm the potential bias.

4.4.2 Species composition

Species composition was not adjusted; therefore, the species proportions should be assumed to be biased. Methods exist to adjust species composition, but the MSRM has not yet approved a method for TSR. While unbiased species composition cannot be developed for TSR III, Canfor should consider implementing a species composition adjustment for internal forest management purposes.

4.4.3 Age Trend

Timber supply analysts in the MOF Forest Analysis Branch require that the inventory adjustment not distort the dynamic nature of the inventory data. They are concerned that adjustment ratios might be correlated with age, which would cause a bias if the ratios are not computed and applied by age class. The stratification used for adjustment was based on broad age classes and site index. Within each stratum, we tested if the volume residuals were correlated with age (Appendix IV and V). There was no significant correlation in the Moderate or Low priority areas; however, there was a positive correlation between volume residuals and age in the High priority areas. Volume will tend to be over-estimated at younger ages and under-estimated at older ages. In most cases, the bias should be less than 25 m^3/ha.

4.4.4 Site Index

Site index remained lower than expected after adjustment. For instance, site index in managed Pl-leading stands on TFL 48 should be approximately 18 m on average; however, the adjusted site index was between 12-13 m across most age classes (Figure 7). Future yield will be grossly under-estimated if these site index estimates are used to generate yield tables for future, managed stands. A few options exist to obtain more accurate potential site index estimates for managed stands.[17] Canfor should investigate these options before TSR III.

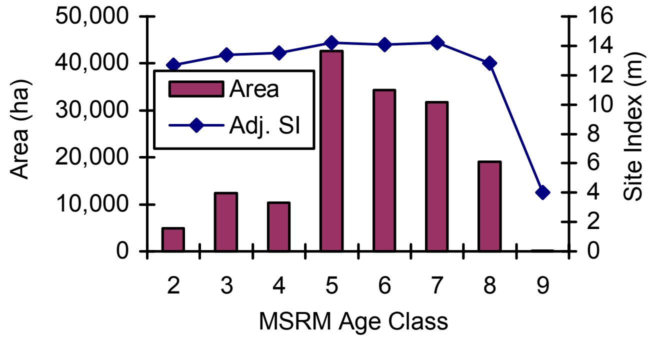

Figure 7. Average adjusted site index in Pl-leading stands.

[17] J.S. Thrower & Associates Ltd. 2003. Site productivity analysis for TFL 48. Version 2.0. Unpublished report, Contract No. CFC-006, July 15, 2003. 27 pp.

5. RECOMMENDATIONS

The TFL 48 VRI statistical adjustment showed that net merchantable volume increased by 34% after adjustment. The adjusted volume is an unbiased estimate of the volume on TFL 48 and should be used for the next MP for TSR III. Therefore, we recommend that:

The adjusted height, age, and volume be used in MP4.

The adjusted site index estimates do not reflect the potential site productivity on TFL 48 in most cases. Site productivity is one of the most important inputs for generating yield tables for a timber supply analysis. The under-estimated site index will translate into a lower long-run sustained yield than can be supported by the landbase. As a result, the potential AAC will probably be severely understated. A number of options for improving site index estimates exist. Therefore, we recommend that:

Canfor investigate methods to improve site index estimation on TFL 48.

The adjusted Phase I inventory represents the state of the inventory in the year 2000. The inventory must be projected forward to 2005 to be used in TSR III. The new version of VDYP (VDYP7) would be the ideal tool to project an adjusted inventory. If VDYP7 is not available, Canfor should discuss the best method to project an adjusted inventory with the MSRM. Therefore, we recommend that:

Canfor investigate options to project the adjusted Phase I inventory to 2005 in time for TSR III.

APPENDIX I – NVAF GRAPHS

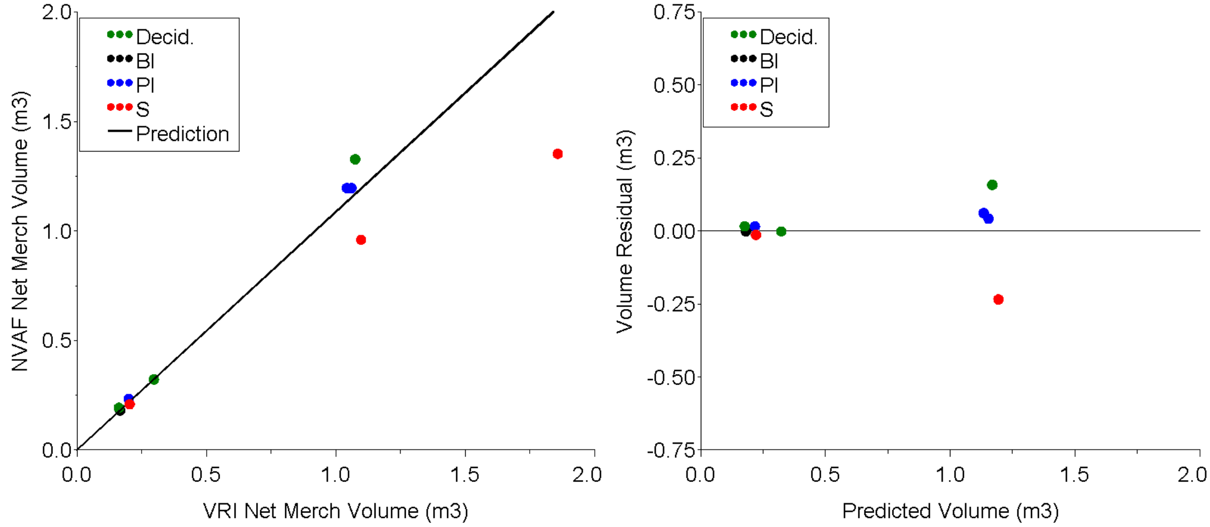

Figure 8. NVAF scattergram and residual plot for the Immature species group.

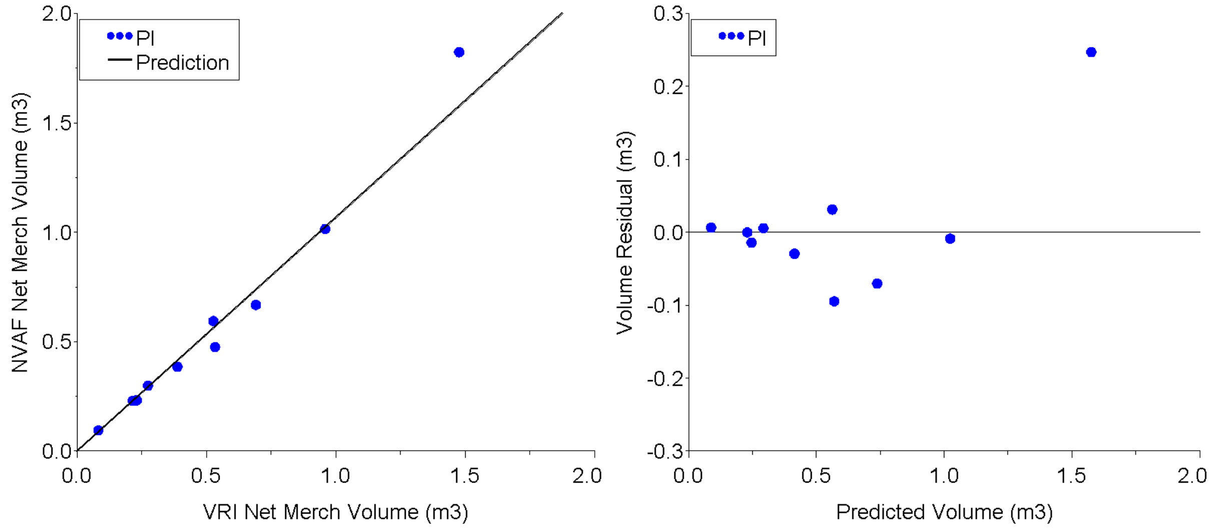

Figure 9. NVAF scattergram and residual plot for the Mature-Pl species group.

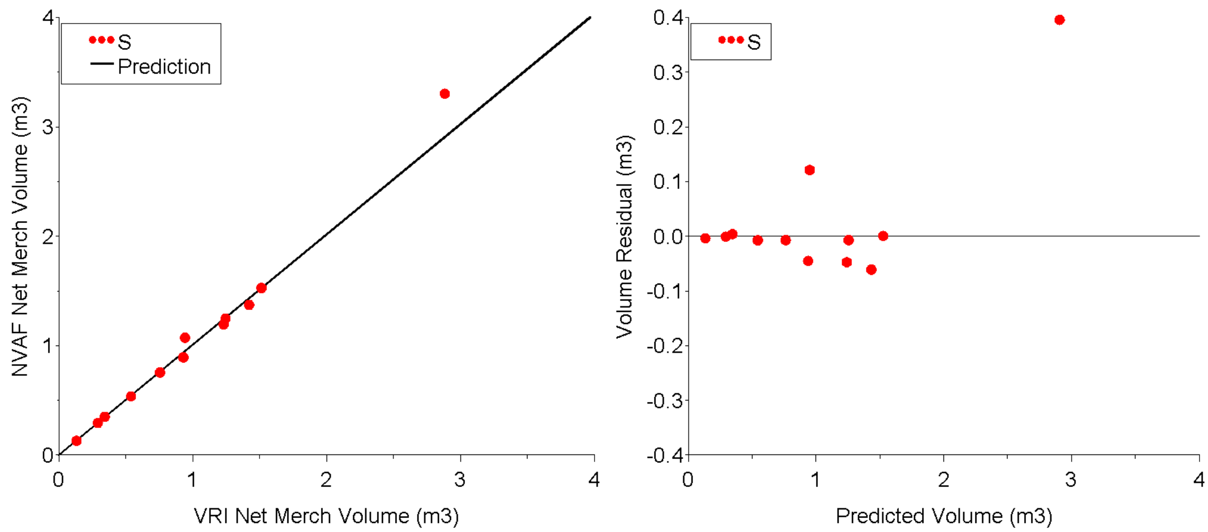

Figure 10. NVAF scattergram and residual plot for the Mature-S species group.

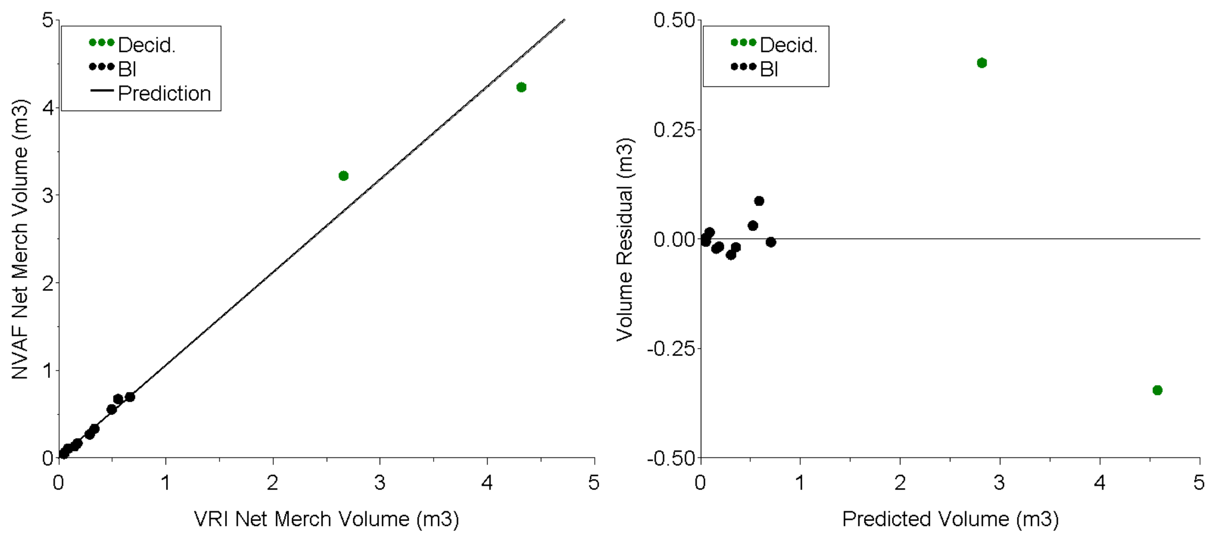

Figure 11. NVAF scattergram and residual plot for the Mature-Others species group.

APPENDIX II – HEIGHT ADJUSTMENT GRAPHS

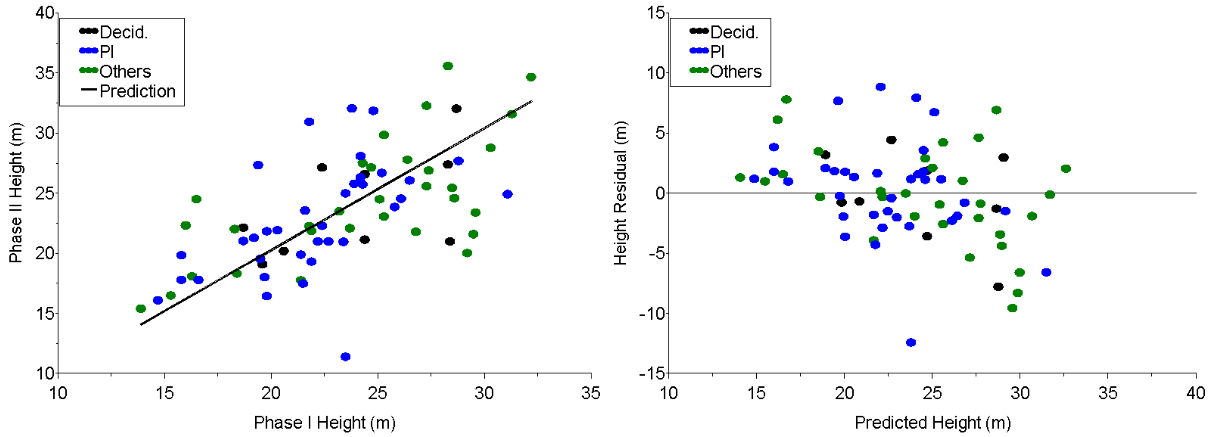

Figure 12. Height prediction and residual graphs for the High priority areas.

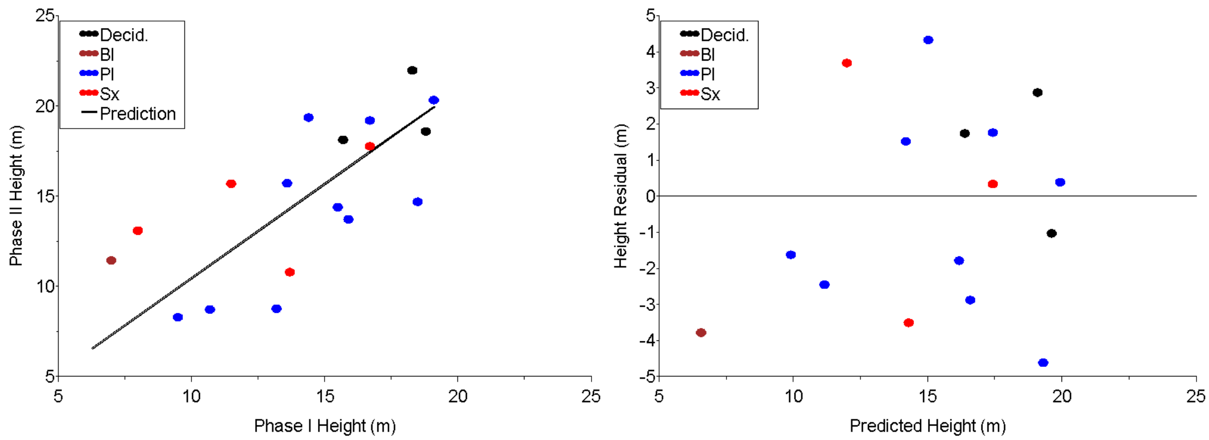

Figure 13. Height prediction and residual graphs for the Moderate priority areas.

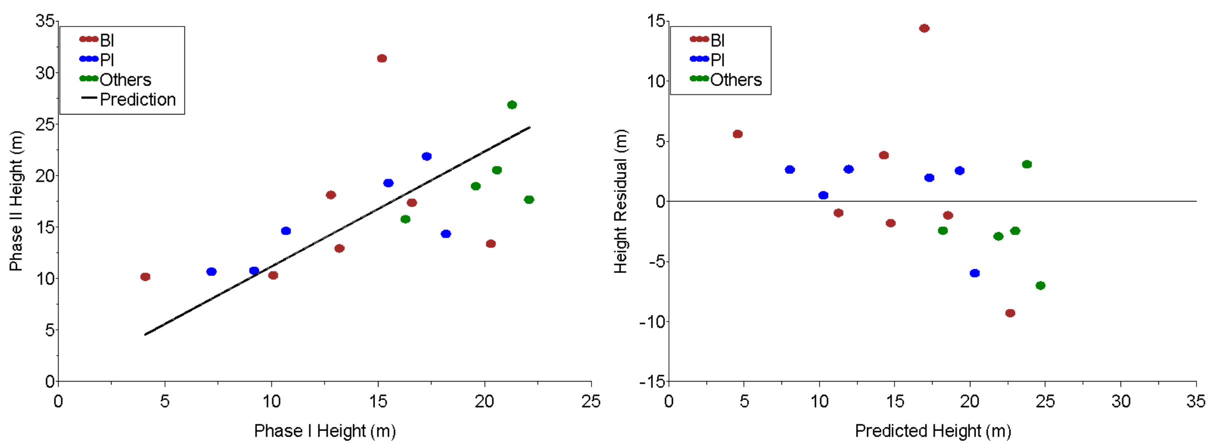

Figure 14. Height prediction and residual graphs for the Low priority areas.

APPENDIX III – AGE ADJUSTMENT GRAPHS

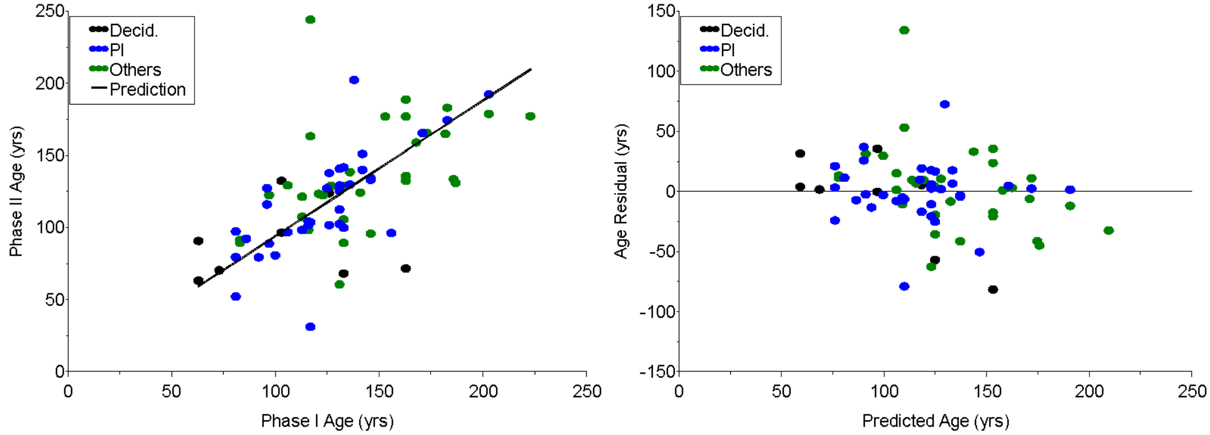

Figure 15. Age prediction and residual graphs for the High priority areas.

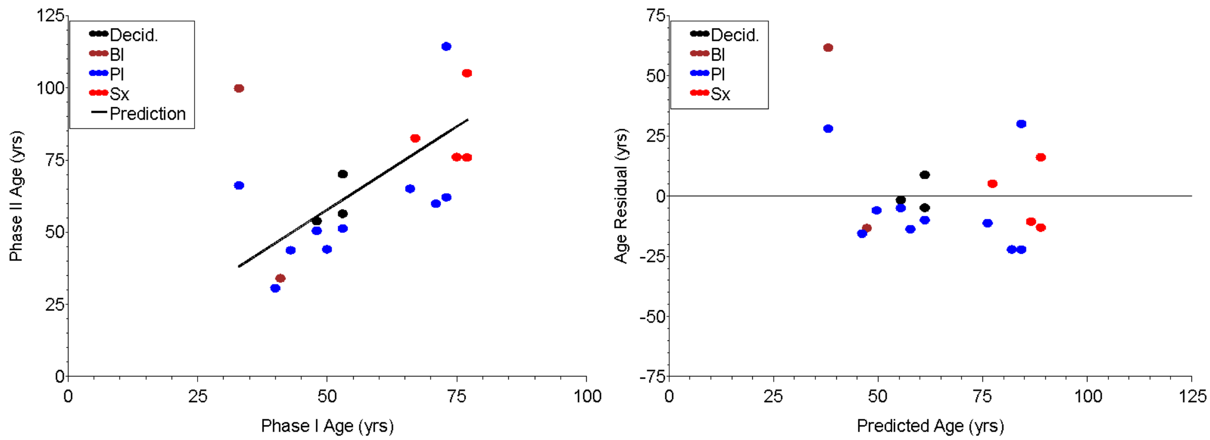

Figure 16. Age prediction and residual graphs for the Moderate priority areas.

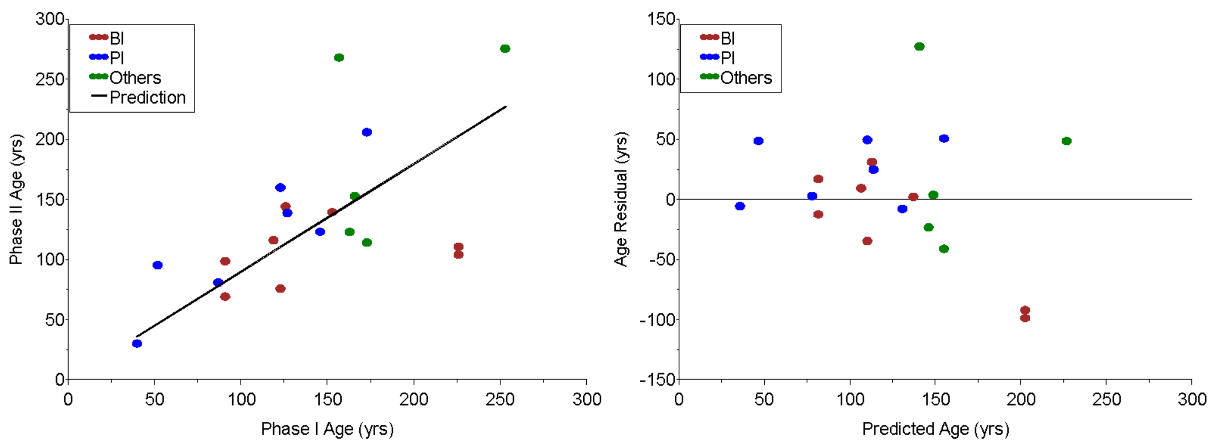

Figure 17. Age prediction and residual graphs for the Low priority areas.

APPENDIX IV – VOLUME 12.5+ GRAPHS

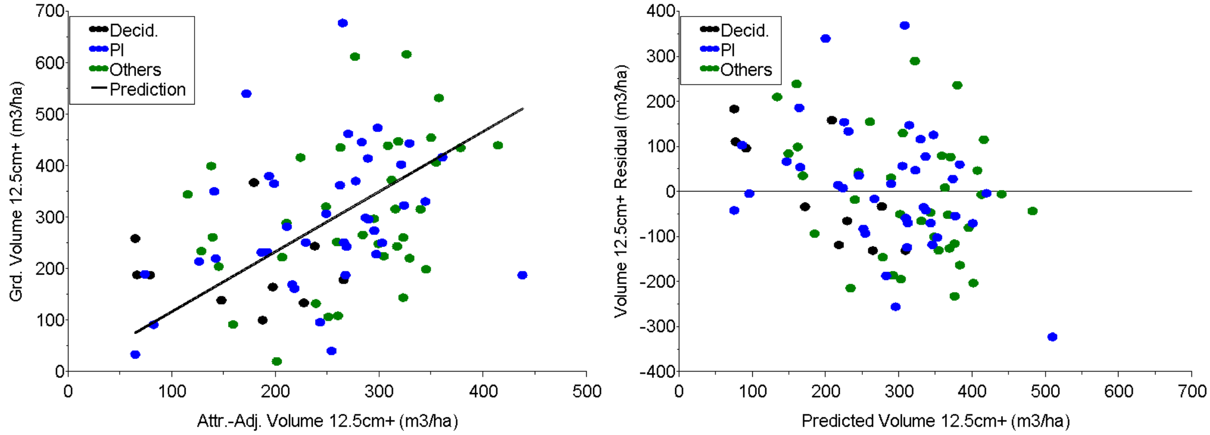

Figure 18. Volume 12.5+ prediction and residual graphs for the High priority areas.

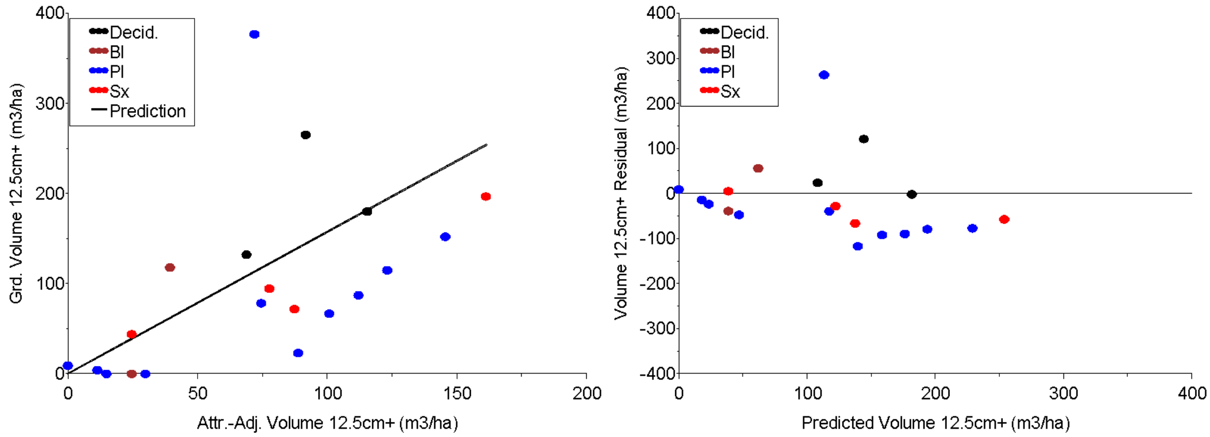

Figure 19. Volume 12.5+ prediction and residual graphs for the Moderate priority areas.

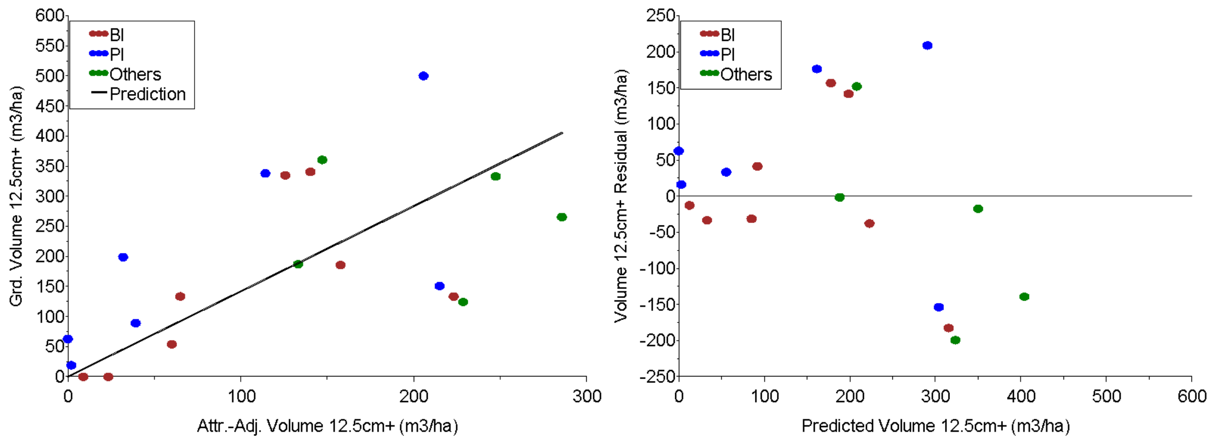

Figure 20. Volume 12.5+ prediction and residual graphs for the Low priority areas.

APPENDIX V – VOLUME 17.5+ GRAPHS

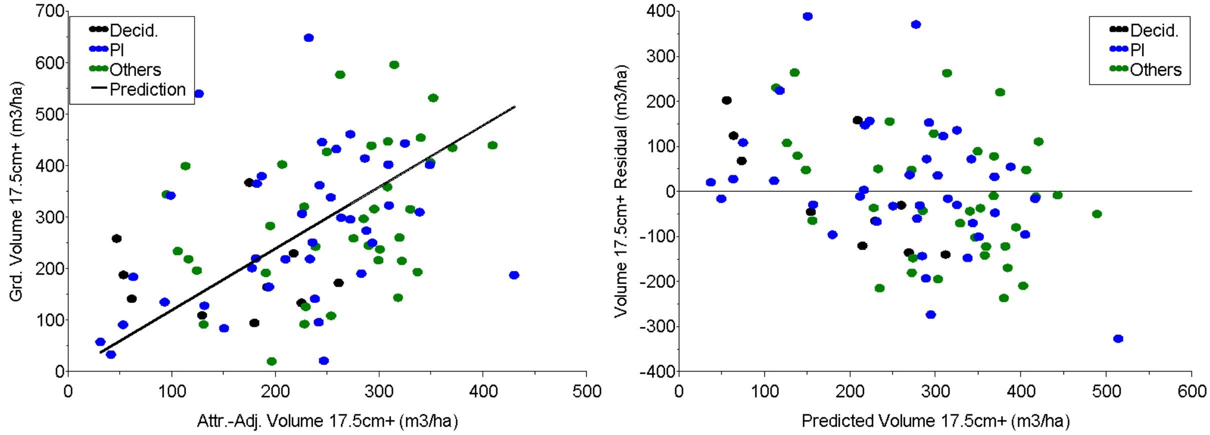

Figure 21. Volume 17.5+ prediction and residual graphs for the High priority areas.

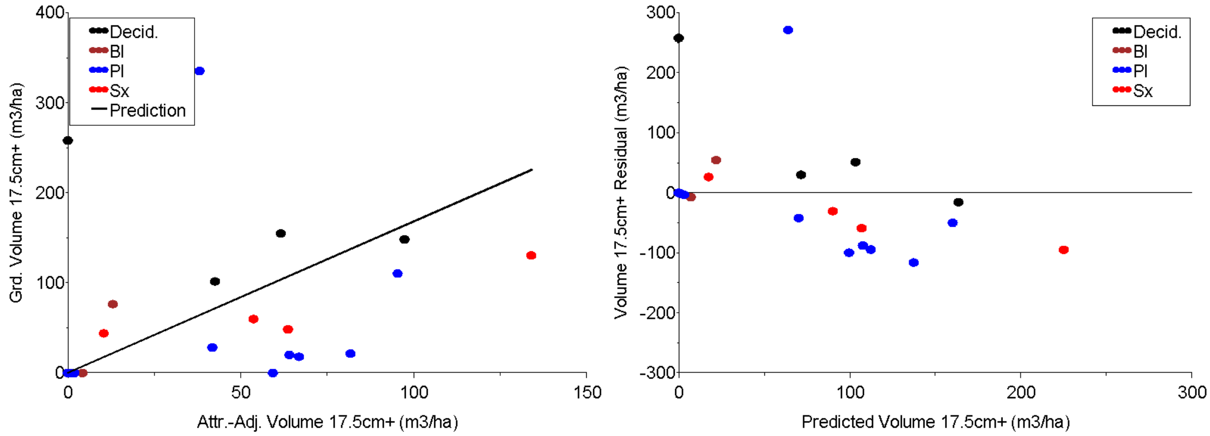

Figure 22. Volume 17.5+ prediction and residual graphs for the Moderate priority areas.

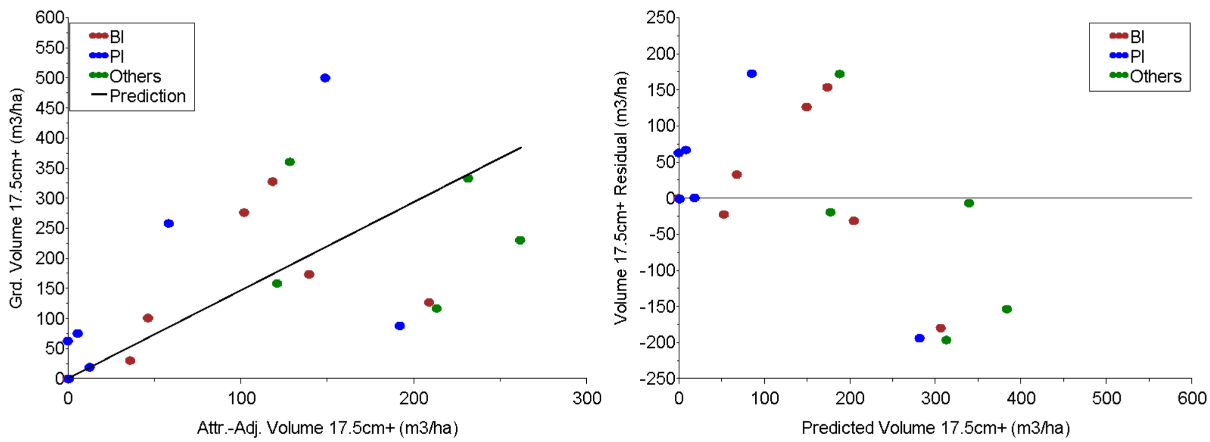

Figure 23. Volume 17.5+ prediction and residual graphs for the Low priority areas.