Young Stand Monitoring in the Quesnel TSA: Plot Establishment Report

A Technical Report

Prepared For: Forest Analysis and Inventory Branch , Ministry of Forests, Lands, and Natural Resource Operations

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EXECUTIVE SUMMARY

This report describes the young stand monitoring (YSM) project established in the Quesnel TSA in 2009 and 2012. This project was formerly initiated as a Change Monitoring Inventory (CMI) project under the former Forest Investment Account (FIA) program. This report includes a description of the current structure and health of young stands in the TSA, as well as results of the comparison of the ground plot data with predicted values.

The target population was all post-harvest regenerated (PHR) stands between 15 and 47 years of age (since disturbance) in the Forest Managed Landbase (FMLB), approximately 152,500 ha. The target population was defined using the FMLB with ages projected to 2009. The 15- to 47-year-old age range aimed to limit sampling to stands that had merchantable volume and that were of post-harvest origin. Sixty-one plot locations were selected based on a 5 km x 5km fixed grid overlaid on the target population (sampling intensity about 0.002%). One of these locations coincided with an existing national forest inventory (NFI) plot, and was not remeasured. Plots were established (focusing mainly on tree attributes) in the remaining 60 sample locations in two batches: 30 plots in August-September 2009 following the NFI-BC protocol, and remaining 30 plots in September-November 2012 following the CMI protocol.

Data from all the 60 plots were used to describe the structure of the young stands (in terms of overall descriptive statistics (mean and standard error, SE), stand and stock tables, and height distributions), and forest health. For comparisons of YSM ground values with predicted values, data from the sample trees were screened to remove suspect residual trees. Four plots that appeared to fall outside the target population (33, 40, 50, and 52), and an additional 21 trees from the remaining plots, were removed from the comparisons analysis.

Overall, the tree mean total age ranged from 26.2 yrs (Act) to 156.4 yrs (Se), total height from 9.6 m (Sb) to 22.8 m (Se), and site index from 13.0 m (Se) to 25.9 m (Act). This was based on a sample of “suitable” trees for age (non-residuals) and height (not significantly damaged). The mean basal area and number of live trees (4.0 cm+ DBH) were 15.6 m^2/ha (SE% = 10%) and 2229 trees/ha (SE% = 9%), respectively. On average, for each species group, most of the large trees (at least 4.0 cm DBH) were within the 4.0 cm – 12.4 cm DBH range and less than 7.5 m height. The number of small trees (at least 1.3m tall and < 4.0 cm DBH) averaged 5816 trees/ha, mostly pine and deciduous species.

The average number of dead standing trees was 117 trees/ha; many of these were pine (80 trees/ha) and in the 5-cm DBH class. Approximately 953 large trees/ha (43%) showed no damage, 474 (21%) showed damage of known causes, and 792(36%) showed damage of unknown causes. The most frequent known primary damage agent was disease (western gall rust - stem and branch cankers). Most of the damaged trees were within the 5 and 10 cm DBH classes, and mostly pine and spruce.

The ground plot age, height and SI were compared to the VRI polygon SI estimates and provincial site productivity layer (PSPL) SI. The VRI ages were over-estimated by 1.8 yrs, 1.6 yrs

and 0.6 yrs, in the SBPS, SBS and overall, respectively; these biases were not statistically significant ($p < 0.05$). The VRI heights were less than the ground heights by 0.5 m, 0.6 m and 0.5 m in the SBPS, SBS and overall, respectively; these biases were also not statistically significant. There was a statistically significant underestimation of the VRI SI in pine (1.7 m) and overall (2.0 m). The biases of the PSPL SI estimates were not statistically significant overall, or in pine or spruce (0.2m, 0.4 m, and -0.1 m, respectively).

The ground plot basal area (BA) and TPH (7.5 cm+ DBH) were compared to the predicted estimates generated from TIPSY using ground inputs and other assumptions (including OAFs, tree density, and regeneration method and delay). Predicted BA was not significantly different from the ground plot values. The predicted BA values were lower than the ground values by 0.2 m^2/ha, 0.3 m^2/ha and 1.0 m^2/ha in the SBPS, SBS and overall, respectively. The predicted TPH values significantly under-estimated the ground values by 267 trees/ha overall. This under-estimation could be due to the assumptions (such as initial tree densities) used in generating the TIPSY-predicted values.

The following caveats should be kept in mind when interpreting the results presented here:

- Sample size and intensity, and the resulting statistical power of many comparisons, were relatively low.
- Results are based on only one measurement; it is uncertain if the observed biases will diminish, increase or remain the same over time.
- Suspect residual trees were removed from the database during analysis, based on subjective data screening rules that were developed specifically for this project.
- The TIPSY generated predicted values were based on assumptions that were chosen subjectively (similar to those used in the Kootenay Lake TSA YSM).
- Predicted VRI values for age, height, and SI used for comparison were polygon-based, whereas the YSM values are based on small fixed-area plots around the YSM sampling point.
- The term “merchantable” volume has been used in this report. This implies actual merchantability, which, given the small average tree size of the YSM target population, maybe premature. The phrase “net close utilization volume” might be a better descriptor of the young stand net volume.

This project has provided baseline data for monitoring, to compare with predicted changes in the future, which is the major objective of the YSM program. Thus, all the Quesnel YSM project’s 61 plots should be remeasured at the same time within three years (preferably in the fall 2015, budget and other resources permitting).

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LIST OF ABBREVIATIONS AND ACRONYMS

BC	British Columbia
BGC	Biogeoclimatic Ecological Classification
CMI	Change Monitoring Inventory
DBH	Diameter at Breast Height (of trees)
ESSF	Engelmann Spruce – Sub-alpine Fir zone
FAIB	Forest Analysis and Inventory Branch
FIA	Forest Investment Account program
GVAF	Gross Volume Adjustment Factor
GY	Growth and Yield
ICH	Interior Cedar – Hemlock zone
MFLNRO	Ministry of Forests, Lands and Natural Resource Operations
MS	Montane Spruce
NCUV	Net Close Utilization Volume
NFI	National Forest Inventory
NVAF	Net Volume Adjustment Factor
OAF	Operational Adjustment Factor
PSPL	Provincial Site productivity Layer
SAS	Statistical Analysis System
SBPS	Sub-Boreal Pine-Spruce
SBS	Sub-Boreal Spruce
SE	Standard Error (of the mean)
TIPSY	Tabular Interpolation Program for Stand Yields
TSA	Timber Supply Area
TSR	Timber Supply Review
VRI	Vegetation Resources Inventory
YSM	Young Stand Monitoring

1 Introduction

1.1 Background

This report describes the young stand monitoring (YSM) project established in the Quesnel TSA in 2009 and 2012. This project was formerly initiated as a Change Monitoring Inventory (CMI) project under the former Forest Investment Account (FIA) program. The original goals of this project included monitoring the growth and yield of young post-harvest regenerated stands (PHR) and naturally-regenerated stands in the TSA (Timberline Natural Resource Group, 2010). The intent of the British Columbia (BC) Ministry of Forests, Lands and Natural Resource Operations (MFLNRO) Forest Analysis and Inventory Branch (FAIB) YSM program is to monitor the performance of young forest stands (Omule, 2013).

Specifically, the primary goals of FAIB's YSM are to:

1. Characterize the young stand population, including composition, structure, mortality, growth, yield, and health.
2. Assess the accuracy of some vegetation resources inventory (VRI) polygon attributes (e.g., age, height and site index) for young stands.
3. Assess the accuracy of site index estimates in the provincial site productivity layer (PSPL).
4. Compare observed stand yields (e.g., basal area/ha and trees/ha) to predicted yields generated from TIPSY.
5. Provide GY model forecasts of future yields for the young stand population based on observed trends from future re-measurements.

1.2 Document Objectives

This report describes the current structure and health status of the young stands in the TSA (Section 5), and the results of the comparisons of differences between the YSM ground data and predicted values from the VRI, PSPL and TIPSY (Section 6). Section 7 provides some caveats to be borne in mind when interpreting the project results. A glossary of terms is given in Appendix I and tree species codes in Appendix II. The intended audience for this report includes primarily the MFLNRO district staff, inventory specialists, and TSR and GY specialists.

2 Monitoring Unit

The monitoring unit, the geographic area of interest, is the Quesnel TSA, which is located in the northern part of the Southern Interior Forest Region, lying in the Fraser Basin and the Interior Plateau between the Coast Mountains on the west and the Cariboo Mountains on the east (Figure 1). The TSA covers about 1.6 million hectares in total, of which approximately 84% (1.4 million hectares) is productive Crown forested landbase (BC Ministry of Forests, Mines and Lands, 2011).

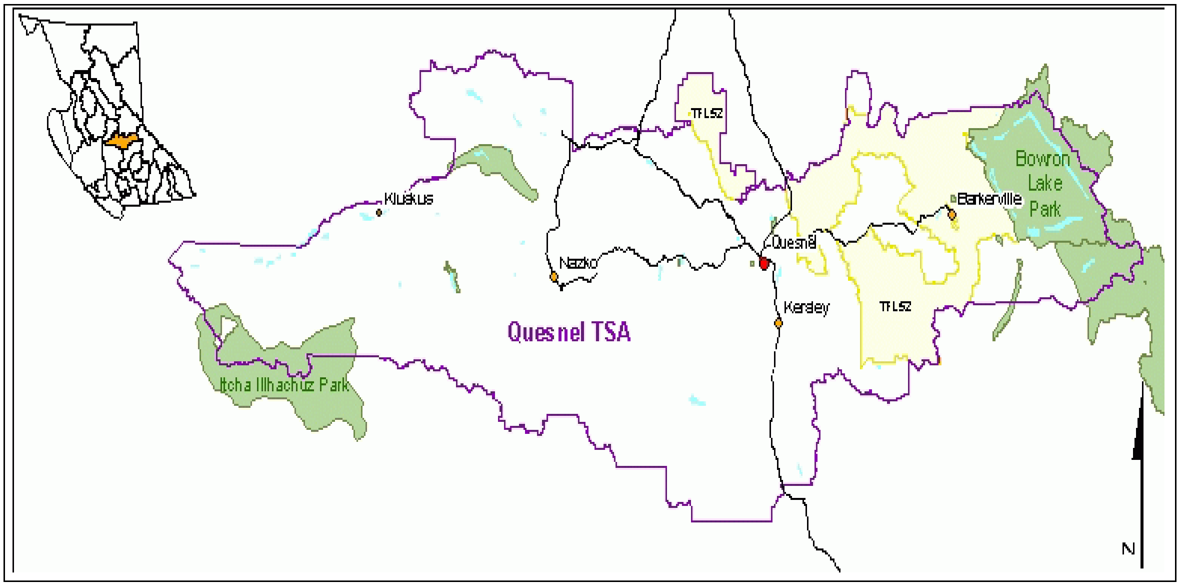

Figure 1. Map of the Quesnel TSA

3 Sample Design

3.1 Target Population

The following information is obtained from the ground sampling plan described by Timberline Natural Resource Group Ltd. (2010). The target population was all PHR stands between 15 and 47 years of age (since disturbance) in the Forest Managed Landbase (FMLB); its area was approximately 152,500 ha.[1] The inventory data used to derive the PHR program was downloaded from the LRDW website on March 10, 2009, and was updated with harvest information and FMLB definition provided by FAIB timber supply analysts on August 9, 2009. The FMLB definition, along with ages projected to 2009, was used to define the target populations and was assumed to be the best available information. The 15-47-year age range was used to

[1] The size of the target population was not provided in the sample plan. This area was approximated using the 5 km grid and number of plots falling in the target population (Table 1), i.e., approximate target population area = 5^2 x 61x 100 =152,500 ha.

limit sampling to stands that have merchantable volume (thus, the minimum of 15 years) and that were of post-harvest origin (thus, the upper limit of 47 years). Note that the standard YSM population is 15 to 50 years. This earlier defined 47-yr cut-off was established as part of the sampling plan for Quesnel TSA. The new definition of the YSM target population will be used in all future YSM projects.

3.2 Sample Size & Selection

Sample size was set at 61 sample plots in PHR stands as of 2009 (Table 1). The sample plot list is given in Timberline Natural Resource Group (2010, Appendix II, page 28). The sample size was determined based on a 5-km x 5-km grid and the target population area. The two main criteria influencing the choice of grid size were the sample size that will be achieved in the target population then, and how this sample size would increase over time as the target area expands (i.e., as natural stands are harvested, regenerated, and included in the PHR target population). The sample list included one national forest inventory (NFI) plot, which had already been established before 2009. However, this plot was excluded in the subsequent analyses, since it was not remeasured during the establishment of the remaining 60 new plots in 2009 and 2012.

Table 1. Quesnel TSA YSM: number of plots by leading species group (Timberline Natural Resource Group, 2010).

Leading Species Group	Sample plots	
	No.	%
Lodgepole pine (Pl)	41	67
Conifer (Balsam, Spruce, Fir)	15*	25
Aspen/Cottonwood/Birch	5	8
Total	61	100

*Includes one NFI plot that was excluded from this analysis.

The 5-km grid was used to systematically locate in part because they cover practically as many conditions as random plots and are convenient since plot locations are automatically known once the grid size is defined. The sampling intensity, i.e., proportion of area sampled, was about 0.002% of the target population (assuming a target population size of 152,500 ha, and a large-tree sample plot size of 0.04 ha).

The target population was not stratified prior to sample selection. Plot data may, however, be post-stratified (e.g., by BGC zone) during analysis if the sample is large enough to provide meaningful results for the desired post-strata. The BGC zones represented in the sample are given in Table 2.

Table 2: Quesnel TSA YSM: number of samples by BGC (excluding the NFI plot)

BGC zone	*Sample plots*	
	No.	*%*
Engelmann Spruce-Subalpine Fir (ESSF)	6	10
Interior Cedar-Hemlock (ICH)	3	5
Montane Spruce (MS)	8	13
Sub-Boreal Pine-Spruce (SBPS)	14	23
Sub-Boreal Spruce (SBS)	29	48
Total	60	100

3.3 Plot Design & Establishment

Sixty plots were established in the target population in two batches. Thirty plots were established during the period August-September 2009 following the NFI-BC protocol for tree attributes (Timberline Natural Resource Group, 2010), which is similar to current CMI protocol. Some modifications to the standards were implemented in the NFI-BC protocol, including tree tagging, plot cards, top height tree and site tree selection (Timberline Natural Resource Group, 2010). The remaining 30 plots were established during the period September -November 2012, following the CMI protocol version dated March 2012 ver. 1.0.1, which is similar to the NFI-BC protocol. A total sample of 2722 trees (4.0 cm+ DBH) was measured – 2555 live and 167 dead (Table 3).

Table 3: Quesnel TSA YSM: number of sample trees ($\geq$ 4.0 cm DBH) by species group. Sb is included in the Spruce group because it is a very small (<1%) component of the sample.

Tree species group	*Live sample trees*		*Dead Sample trees*	
	No	*%*	*No.*	*%*
Pine (Pli)	1420	56	128	77
Spruce (Sb, Se, Sx, Sxw)	569	22	11	7
Balsam (Bl)	198	8	17	10
Douglas Fir (Fdi)	139	5	6	4
Deciduous (Act, At, Ep)	229	9	4	2
Unknwon (Xc)	0	0	1	1
Total	2555	100	167	100

4 Data Compilation

4.1 YSM (Ground) Plot Attributes

A tree-level data file provided by FAIB on 6 December 2013 (Project ID 026M) was used to produce plot ground average and per-hectare summaries for various attributes listed in Table 4, using custom programs written in SAS. These summaries were used to calculate descriptive and forest health statistics reported in Section 5.

This tree-level file was also edited to screen out potential residual trees, and tree data summarized using the same custom SAS programs. For this project, residuals were trees classified as veterans and those that exceed DBH > 50cm and breast-height age > 50 years thresholds. The intent of data screening was to ensure that residual trees and plots outside the target population were removed from the sample prior to making the comparisons with predicted values. Details of the data screening process and results are given in Appendix III. Four plots (33, 40, 50 and 52), and a total of 21 suspect residual trees from the remaining plots were excluded from the analysis. The plot ground average and per-hectare summary values for various attributes from the edited tree-level file were used to make statistical comparisons reported in Section 6.

Table 4. Definition of YSM ground attributes. Attributes refer to live trees only, unless noted. l_GVAF, d_GVAF and l_NVAF are the gross volume adjustment factors (live, dead) and net volume adjustment factors, respectively; they are used to remove taper bias (l_GNVAF, d_GVAF), and to remove taper bias and adjust cruiser-called decay, waste and breakage estimates (NVAF). vol_wsv and vol_ntwb and vol_wsvd are live tree gross and merchantable volume and dead tree gross volume, respectively.

Attribute	*DBH utilization limit*	*Attribute Description*
Mean height		Mean total height of all suitable height trees by species.
Mean age		Mean total age of all suitable trees by species.
Site index		Average SI by species. The SI for each suitable SI tree is computed using SiteTools (GI), and the average computed by species.
Species comp.	4.0 cm	Species composition by basal area/ha.
Basal area	7.5 cm	Basal area/ha
Stems/ha	7.5 cm	Number of stems/ha.
Gross volume	7.5 cm	Whole stem volume (m^3/ha) = vol_wsv * l_GVAF.

Attribute	DBH utilization limit	Attribute Description
Net merch. volume[2]	Two types: 1) 12.5 cm for all species; and 2) 12.5 cm for pine & hardwoods, and 17.5 cm others.	Merch. Volume/ha (m^3/ha) = vol_ntwb *l_NVAF.
Mortality	7.5 cm	Whole stem volume m^3/ha (dead trees) = vol_wsvd * d_GVAF.

4.2 Predicted Yield Estimates

A list of attributes for which predicted values are required, including corresponding ground plot values and data sources, is summarized in Table 5.

Table 5. Summary of desired stand attributes and data sources (definitions of attributes are given in Tables 4 and 6).

Stand attribute	*Tree component*	*Data source*	
		Ground values	*Predicted values*
Mean age	Suitable trees	YSM: species-matched plots	VRI: leading species-matched polygons
Mean height	Suitable trees	YSM: species-matched plots	VRI: leading species-matched polygons
Site index	Suitable trees	YSM: species matched plots	VRI or Site Productivity Layer: leading species-matched polygons
Leading species	All live trees	YSM: all sample plots	VRI: all polygons
Trees/ha	All live trees, excluding residuals	YSM: all plots	TIPSY: all plots
Basal area/ha	All live trees, excluding residuals	YSM: all plots	TIPSY: all plots

[2] Will Smith of FAIB (pers. comm., March 2014) has pointed out that reference to this volume as “merchantable”, which implies actually merchantability, was premature in these young stands, given their small average tree size (see Section 5.1). To avoid possible confusion, Will Smith recommends the use of the phrase “net close utilization volume” (NCUV), which refers to the potion of stem volume between the stump and top utilization diameter, less decay, waste and breakage. Please see Appendix I for more on the definition of NCUV.

Stand attribute	Tree component	Data source	
		Ground values	Predicted values
Gross volume/ha	All live trees, excluding residuals	YSM: all plots	TIPSY: all plots
Net merchantable volume /ha[2]	All live trees, excluding residuals	YSM: all plots	TIPSY: all plots

The definitions and data sources of the desired predicted attributes are given in Table 6. The predicted values for age, height, site index, and species composition are obtained from the VRI Phase I and PSPL. The predicted values for the remaining attributes were generated from the TIPSY model. Details of the process of generating predicted values from TIPSY are given in Appendix V; they follow the approaches used in the Morice and Kootenay Lake TSA YSM analyses. The predicted values are listed in Appendix VI.

Table 6. Definitions of the VRI Phase I attributes.

Attribute	Source	Attribute Description
Proj_Height_1 & Proj_Height_2	Veg_comp_poly	The average height, weighted by basal area, of the dominant, codominant and high intermediate trees for the leading and second species of each tree layer identified. Data projected to January 1, 2012.
Proj_Age_1 Proj_Age_2	Veg_comp_poly	The average age, weighted by basal area, of the dominant, codominant and high intermediate trees for the leading and second species of each tree layer identified.
Site_Index	Veg_comp_poly	Phase I polygon site index (calculated).
Site index	Provincial site productivity layer (PSPL) ver. 3.0	PLSPL estimate of SI at a ground plot sample location. The PSPL database gives site index estimates province-wide for commercial tree species, for every one-ha grid cell.
Species composition	Veg_comp_poly	Species composition by Basal Area.
Basal area/ha	TIPSY	Generated using the polygon or ground species composition & SI and analysis unit assumptions.
Trees/ha	TIPSY	Generated using the polygon or ground species composition & SI and analysis unit assumptions.
Gross volume/ha	TIPSY	Generated using the polygon or ground species composition & SI and analysis unit assumptions.

Attribute	Source	Attribute Description
Merchantable volume/ha	TIPSY	Generated using the polygon or ground species composition & SI and analysis unit assumptions.

5 Stand Structure & Health

5.1 Stand structure

Overview

Data from the YSM plots were used to describe current structure of young stands in the Quesnel TSA, in terms of descriptive statistics (stand average and per-hectare means and standard errors) and 5-cm diameter class and 2-m height class distributions. Overall TSA descriptive statistics were calculated for age, height and SI of "suitable" [3] sample trees (Table 7), and for selected stand attributes (Table 7). The diameter distribution of trees/ha (stand table), and gross volume/ha (stock table), are depicted overall by species group in Tables 8 and 9, respectively. The height distributions are shown in Table 10. In all these tables, and the rest that follow, standard errors as a percent of the mean (SE%) are also provided; the smaller the SE%, the more precise the estimate is. It means that we are 68% sure that the estimate will be off by no more than the stated SE%.

Tree age, height and site index statistics

Overall, the suitable sample tree mean total age ranged from 26.2 yrs (Act) to 156.4 yrs (Se), total height from 9.6 m (Sb) to 22.8 m (Se), and site index from 13.0 m (Se) to 25.9 m (Act) (Table 7). The average tree size was small. For example, the mean DBH of the age-suitable sample trees was 15.1 ± 0.3 cm; and the mean DBH of all sample trees ranged from 9.3 ± 0.1 cm (Pl) to 14.2 ± 0.7 cm (Fd).

[3] A tree is not suitable for height measurement if it has significant damage (compared to what it would be if it was not damaged), e.g., broken top, dead top, for or crook, or abnormal scarring or other damage; it is not suitable for age measurement if it is a residual (a living remnant of a former stand) (FAIB 2012).

Table 7. Overall descriptive statistics of mean total age, total height and site index of "suitable" sample trees, by species for the Quesnel TSA YSM ground plots. N is the number of "suitable" sample trees from the 60 YSM plots; and SE% is the standard error as a percent of the mean.

Species	Mean Total Age (yrs)			Mean Total Height (m)			Mean Site Index (m)		
	N	Mean	SE%	N	Mean	SE%	N	Mean	SE%
Act	8	26.2	26	8	11.9	14	8	25.9	9
At	30	30.0	8	30	13.2	5	30	20.7	4
Bl	28	57.4	15	22	12.5	9	22	19.0	5
Ep	6	39.5	4	6	16.1	7	6	19.6	6
Fdi	22	48.0	12	22	16.2	10	20	21.1	4
Pli	189	26.4	2	138	9.8	3	138	19.5	1
Sb	3	31.5	17	3	9.6	32	2	14.3	10
Se	5	156.4	23	4	22.8	11	4	13.0	18
Sx	75	35.2	5	66	11.8	6	55	21.3	2

Stand statistics

Overall, the mean basal area and number of live trees (4.0 cm+ DBH) were 15.6 m^2/ha (SE% = 10%) and 2229 trees/ha (SE% = 9%), respectively (Table 8).

Table 8. Overall descriptive statistics for various stand attributes (live large trees) and mortality in the Quesnel TSA YSM. SE% is standard error as a percent of the mean based on N = 60 plots, and the utilization levels are 4.0 cm+ and 12.5 cm+. Gross volume is GVAF-adjusted, and merch. volume is gross volume less volume of stump, top, decay, waste, & breakage and is NVAF-adjusted.

Attribute	Statistics (N = 60)			
	4.0 cm+		12.5 cm+	
	Mean	SE%	Mean	SE%
Basal area (m^2/ha)	15.6	10	7.7	18
Large trees/ha	2229	9	299	14
Gross volume (m^3/ha)	79.8	14	50.5	22
Merch. Volume (m^3/ha)	44.0	22	40.7	24
Mortality (Gross volume; m^3/ha)	10.3	28	9.1	30

Stand tables

Overall, on average, for each species group, most of the large trees (at least 4.0 cm DBH) were within the 4.0 cm – 12.4 cm DBH range (Table 9). This table also includes data for small trees (at least 1.3m tall and < 4.0 cm DBH), which were most numerous (5816 trees/ha).

Table 9. Overall stand table (mean trees/ha) by species group (4.0 cm+ DBH utilization level) for the Quesnel TSA CMI. Spruce includes Sx, Sxw, & Sb (Sb is included here because it is such a small (<1%) component of the total and not justifiable to split it out); Deciduous includes Act, At & Ep. The diameter classes are 5-cm diameter class mid-points, and the values in brackets are standard errors as a percent of the mean based on N = 60 plots.

Species Group	Trees/ha (TPH) by Diameter Class (cm)							Total (Trees/ha)
	< 4.0 cm	5	10	15	20	25	30+	
Balsam	577	68	34	26	13	4	1	723
Deciduous	1596	55	59	29	10	3	3	1755
Douglas-fir	93	47	22	15	6	2	4	189
Lodgepole pine	2782	864	409	89	20	2	1	4167
Spruce	760	208	163	46	11	6	6	1200
Western red cedar	8							8
Unknown			1					1
Overall mean	5816 (16%)	1242 (14%)	688 (10%)	205 (13%)	60 (22%)	17 (33%)	15 (33%)	8043

Stock tables

Most volumes were within the 10-cm and 15-cm classes, and in lodge pole pine (Table 10).

Table 10. Overall stock table (mean gross volume at 4.0 cm+ DBH utilization level) for the Quesnel TSA YSM. Spruce includes Sx, Sxw, & Sb; Deciduous includes Act, At & Ep. The diameter classes are 5-cm diameter class mid-points. Small trees have zero volume. The values in brackets are standard errors as a percent of the mean based on N = 60 plots.

Species Group	Gross Volume/ha (m^3/ha) by Diameter Class (cm)						Total (m^3/ha)
	5	10	15	20	25	30+	
Balsam	0.50	0.87	2.67	2.81	1.33	0.41	8.59
Deciduous	0.40	2.07	2.72	2.04	0.79	1.62	9.64
Douglas-fir	0.35	0.75	1.43	1.22	0.79	4.13	8.67
Lodgepole pine	6.38	12.07	7.61	3.86	0.72	0.31	30.95
Spruce	1.41	4.53	3.64	2.18	2.19	8.03	21.98
Unknown		0.02					0.02
Overall mean	9.04 (14%)	20.31 (11%)	18.07 (14%)	12.11 (25%)	5.82 (35%)	14.50 (42%)	79.85

Height distributions

Overall, most of the trees were within the 5-cm height class (Table 11).

Table 11. Overall tree height distributions (mean trees/ha) by species group (4.0 cm+ utilization level) for the Quesnel TSA YSM. Spruce includes Sx, Sxw, & Sb; Deciduous includes Act, At & Ep. The diameter classes are 5-cm diameter class mid-points, and N = 60 plots. The values in brackets and standard errors as a percent of the mean.

Species Group	Trees/ha by Height Class (m)					
	5	10	15	20	25	
Balsam	82	35	22	7		146
Deciduous	28	87	40	5		160
Douglas-fir	41	29	14	8	4	96
Lodgepole pine	989	346	48	2		1385
Spruce	284	112	32	10	3	441
Unknown		1				1
Overall mean	1424 (13%)	610 (16%)	156 (22%)	32 (38%)	7 (67%)	2229

5.2 Forest Health

Tree mortality and damage the young stands was examined. Overall, the average number of dead stems was 117 trees/ha (SE% = 24%) (Table 12). Most of the dead trees were pine (80 trees/ha) and in the 5-cm DBH class.

Table 12. Overall number of dead standing trees/ha (4.0 cm+ DBH) at plot establishment in the Quesnel TSA YSM. The diameter classes are 5-cm diameter class mid-points, and N = 60 plots. The values in brackets are standard errors as a percent of the mean.

Species Group	Dead Trees/ha (TPH) by Diameter Class (cm)						Total (Trees/ha)
	5	10	15	20	25	30+	
Balsam	12	1	2	1		1	17
Deciduous	2			1	1		3
Douglas-fir	3	2	1			1	7
Lodgepole pine	33	15	18	10	3	1	80
Spruce	3	1	1	1	1	1	8
Unknown					1		1
Total	53 (39%)	19 (40%)	22 (29%)	13 (37%)	6 (25%)	4 (54%)	117 (24%)

The YSM plots also provided the opportunity to assess forest health. Damage agent types included abiotic, disease, insects, treatment injuries, and animal damage. Plot tree data were pooled and categorized by species group and type of primary damage agent: A, DS, DSG, and IWS and “Other” (all remaining damage agents; see Appendix VII); unknown damage, and no damage (Table 13). Most of the damaged tree species were pine and spruce. About 63% of the pine trees were damaged.

The data were also categorized by diameter class and damage agent (Table 14). Approximately 953 (43%) showed no damage, 474 (21%) showed damage of known causes, and 792 (36%) showed damage of unknown causes (Table 14). Most of the damaged trees were within the 5- to 10-cm diameter-classes and were mostly pine and spruce (Table 14). The most common known and severe primary damage agent appears to be disease (DSG – western gall rust, with branch and stem cankers) (Table 15).

Table 13. Overall number of undamaged and damaged live trees/ha by primary damage agent and species group in the Quesnel TSA YSM. The damage agents' codes are explained in Appendix VII. N = 60 plots and the values in brackets are standard errors as a percent of the mean.

Species Group	No Damage (O)	Number of damaged trees by Damage Agent							Total
		U	A	IWS	DS	DSG	Other	Sub-Total	
Balsam	84	49	2		2	4	5	62	146
Deciduous	80	43	33		1	1	2	80	160
Douglas-fir	58	37			1		25	38	96
Lodgepole pine	518	500	5		35	303	16	868	1386
Spruce	223	163		31		8		221	444
Overall mean	963 (12%)	792 (10%)	40 (55%)	31 (56%)	39 (46%)	316 (21%)	48 (23%)	1266	2229

Table 14. Overall number of undamaged and damaged live trees/ha by primary damage agent and diameter class in the Quesnel TSA YSM. The damage agents' codes are explained in Appendix VII. The diameter classes are 5-cm diameter class mid-points. The values in brackets are standard errors as a percent of the mean based on N = 60 plots.

Diameter class (cm)	No Damage (O)	Number of damaged trees/ha by Primary Damage Agent							Total
		U	A	IWS	DS	DSG	Other	Sub-Total	
5	572	459		7	23	158	24	671	1243
10	265	238	27	18	13	115	11	422	687
15	80	65	10	6	2	34	7	124	204
20	27	21	3	1	1	7	3	35	62
25	10	4				2	2	8	18
30+	9	5					1	6	15
Total	963 (12%)	792 (10%)	40 (55%)	31 (56%)	39 (46%)	316 (21%)	48 (23%)	1266	2229

Table 15. Overall number of damaged live trees/ha by primary damage agent and severity code in the Quesnel TSA YSM. N = 60 plots. The damage agents' codes are described in Appendix VII.

Severity Code	Severity Code description	Number of damaged trees/ha by Primary Damage Agent						Total
		U	A	IWS	DS	DSG	Other	
None			38	9	39		43	129
Unknown		792						792
10%	Percent girdled		2					2
BC	Branch cankers					188		188
SC	Stem cankers					127		127
1F	One-year attack; forking			7				7
2F	Two-year attack; forking			1				1
S	Staghead			14				14
2	Hawksworth's rating system						1	1
3	Hawksworth's rating system						1	1
4	Hawksworth's rating system						1	1
FA	Failed attack (bark beetles)						1	1
GR	Green attack (bark beetles)						1	1
Overall mean		792	40	31	39	316	48	1266

6 Comparison of YSM Plot and Predicted Values

6.1 Overview

Yield comparisons were made between the YSM ground plot measurements and their corresponding predicted values from the VRI Phase I, PSPL or TIPSY. These predicted values are given in Appendix VI.

Total bias was calculated for each plot for the attributes of interest as follows: Total bias = YSM plot value – Predicted plot value. Average bias was calculated across all the plots, and by BGC Zone (SBPS and SBS only, where the number of plots was > 10). These values were then used to make the yield comparisons for plot mean age, height, site index, basal area/ha, trees/ha (TPH) and gross and net volume/ha, by testing the statistical significance of the mean bias using the ordinary paired t-test (assuming normality of the bias distributions). The mean age and height comparisons are given in section 6.2, site index in section 6.3, basal area/ha and TPH in section 6.4, gross volume/ha in section 6.5, and merchantable volume in Appendix IX. In all these comparisons, a negative bias means the predicted values are over-estimated, and positive bias means the predicted values are under-estimated.

6.2 Stand Age and Height

Comparisons were made between YSM plot mean total age versus VRI Phase I polygon projected total age, and between YSM mean height versus VRI Phase I polygon projected mean height. The comparisons are based on data from the leading species (Sp0)-matched YSM ground plots and VRI polygon leading (or second species) (Sp0). The process of matching the YSM ground plot leading species and VRI leading/second species is described in Appendix III. The YSM age is mean total age based on tree breast-height age of suitable trees and a years-to-breast-height correction factor (FAIB VRI/CMI compiler), and VRI age (or height) is the projected polygon age (or height) to January 2012. A total of 40 plots had a match between the inventory polygon leading/second species (Sp0) and the YSM plot leading species (Sp0) (Cases 1 and 2; Appendix III), and had "suitable" estimates of ground age and height.

Plotting of the ground plot mean total age (or mean total height) versus predicted total age (or total height) showed some correspondence in mean age (Figure 2) and mean height (Figure 3).

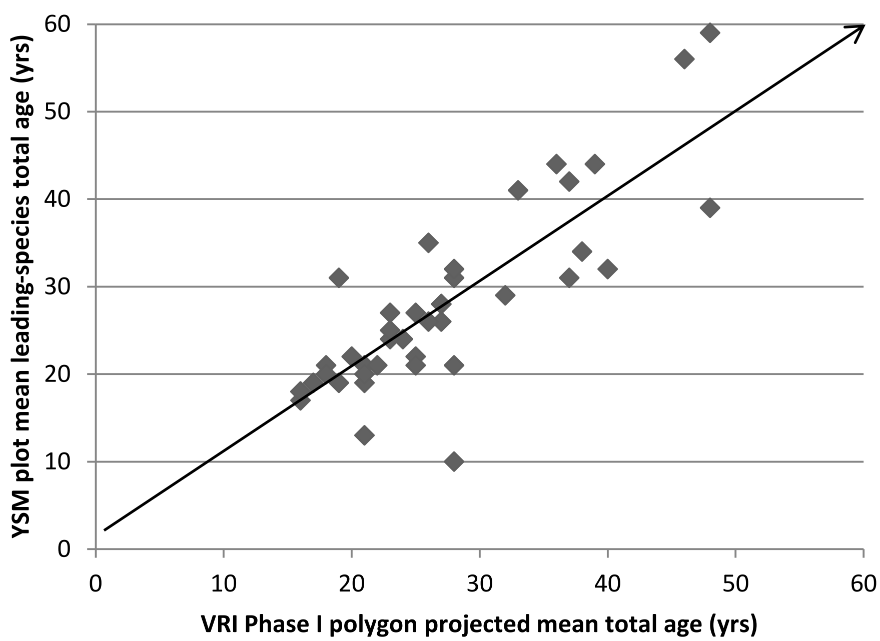

Figure 2. Graph of the ground plot leading species mean total age versus matched VRI Phase I polygon projected mean total age (40 plots). The diagonal arrow line shows the line of correspondence between the VRI and ground ages.

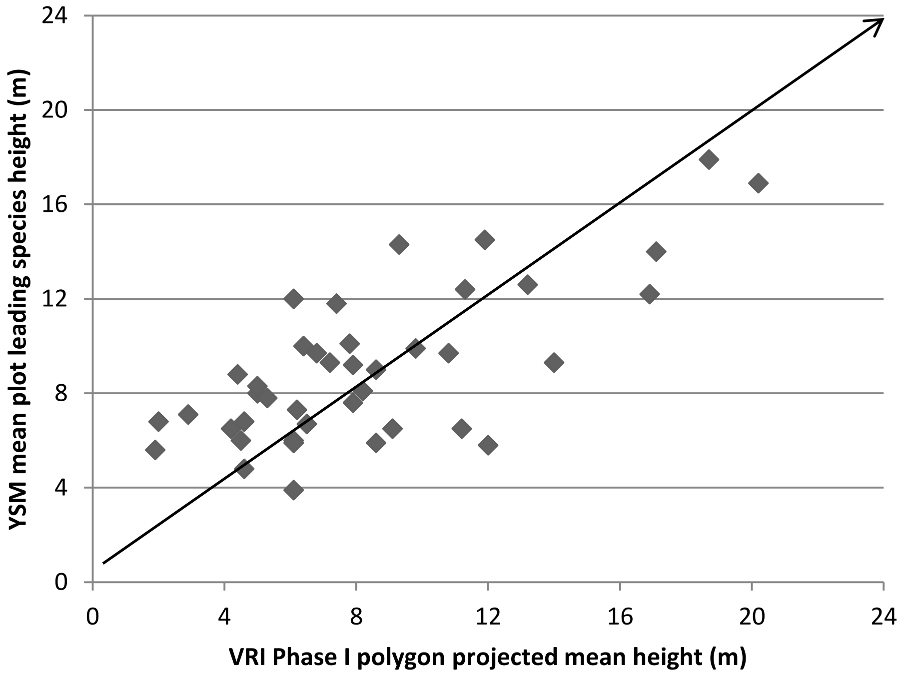

Figure 3. Graph of the YSM plot leading species mean height versus matched VRI Phase projected (40 plots). The diagonal arrow line shows the line of correspondence between the VRI and ground heights.

The overall and BGC zone age and height biases were not statistically significant ($p < 0.05$) (Table 16), suggesting that the estimated VRI age and height are not biased. Note, however, that the power of the paired t-tests is generally low. The FAIB recommended minimum power value is 0.6. Description of the interpretation of statistical power is given in Appendix VIII.

Table 16. Comparison of the ground plot and VRI Polygon ages and heights. The values after ± sign are standard errors; and N is the number matched plots/polygons.

		Mean Total Age					Mean Total Height				
Strata	N	Ground (yrs)	VRI (yrs)	Bias (yrs)	p-value (bias ≠ 0)	Power (1 -β)	Ground (m)	VRI (m)	Bias (m)	p-value bias ≠ 0)	Power (1 -β)
SBPS	9	26.9	25.1	1.8 ± 1.7	0.33	0.15	7.8	7.3	0.5 ± 0.8	0.60	0.09
SBS	20	28.6	27.7	1.6 ± 1.2	0.48	0.24	10.3	9.7	0.6 ± 0.6	0.32	0.16
Overall	40	27.2	26.7	0.6 ± 0.8	0.51	0.11	8.9	8.4	0.5± 0.5	0.23	0.16

6.3 Site index

This is a comparison of YSM plot mean site index (SI) versus VRI Phase I polygon SI and PSPL SI. The matched dataset for Cases 1 and 2, as in the age/height comparisons, were used (40 plots). Plotting of the ground plot SI and predicted SI seemed to show some bias, although the variation in the data appears high particularly for the VRI Phase I estimate (Figures 4 and 5).

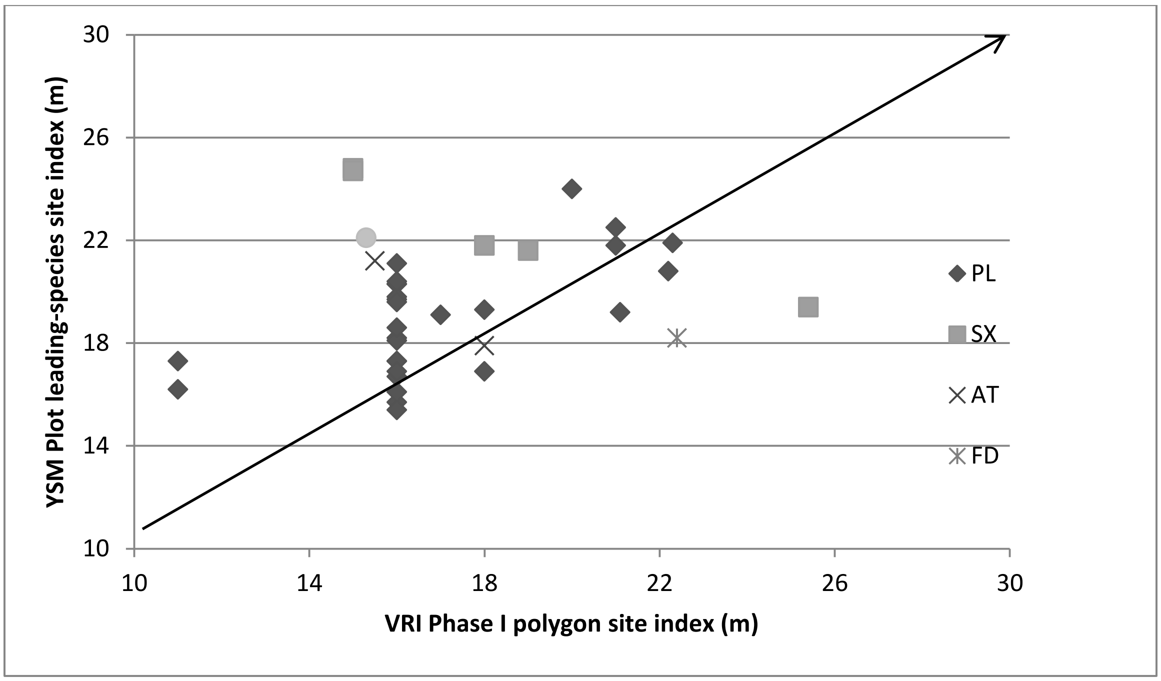

Figure 4. Graph of the matched VRI Phase I polygon SI and YSM ground plot leading-species SI by leading YSM plot leading species (40 plots). The diagonal line arrow shows the line of correspondence between the two SI estimates.

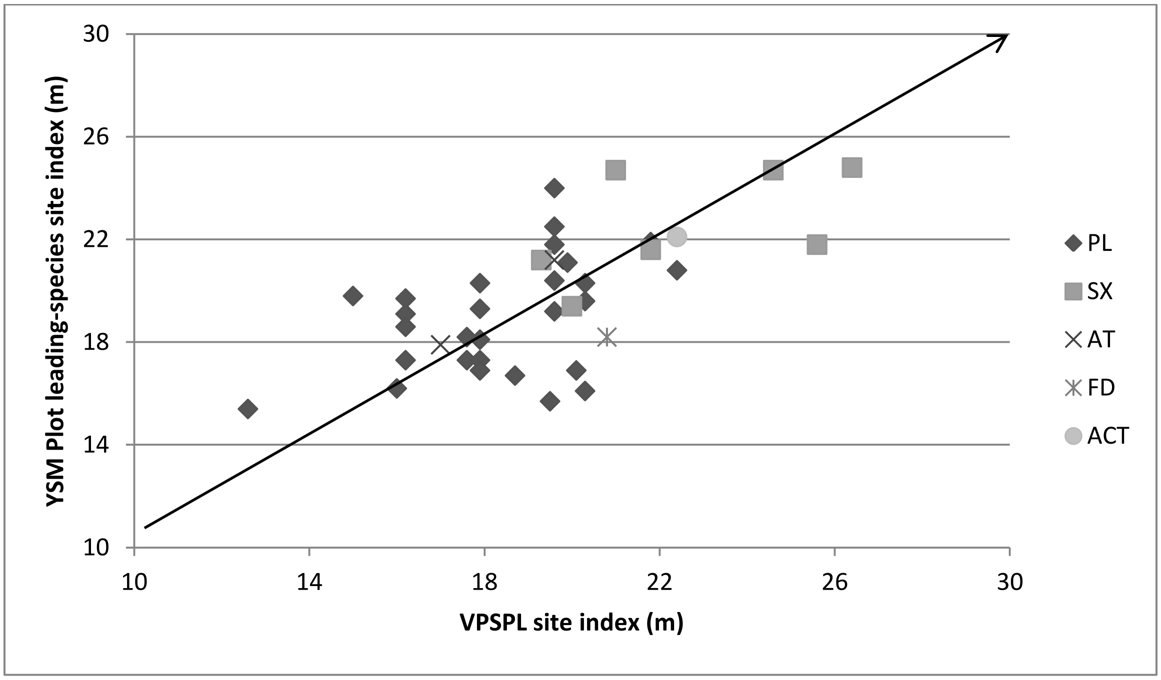

Figure 5. Graph of the matched PSPL SI and YSM plot leading-species SI by YSM plot leading species (40 plots). The diagonal arrow line shows the line of correspondence between the two SI estimates.

There was evidence of statistically significant ($p < 0.05$) underestimation of VRI SI, overall and in pine (Table 17) The PSPL SI bias was not statistically significant for overall and by species (Table 18).

Table 17. Comparison of the ground plot SI versus VRI polygon site index. Statistically significant ($p < 0.05$) biases are shaded; the values after ± sign are standard errors; and N is the number matched plots. Individual species comparisons for ACT, Ac, and Fd were not made because of very small samples sizes (N < 3 in each case).

Strata	N	Ground SI (m)	VRI SI (m)	Bias (m)	p-value (bias ≠0)	Power (1 -β)
Pine (Pl)	29	18.6	16.9	1.7 ± 0.5	0.00	0.91
Spruce (Sx, Sb)	7	22.6	19.1	3.5 ± 2.2	0.24	0.27
Overall	40	19.4	17.4	2.0 ± 0.6	<0.00	0.90

Table 18. Comparison of the ground plot SI versus PSPL SI. The values after ± sign are standard errors; and N is the number matched plots. Individual species comparisons for ACT, Ac, and Fd were not made because of very small samples sizes (N < 3 in each case).

Strata	N	Ground SI (m)	PSPL SI (m)	Bias (m)	p-value (bias ≠0)	Power (1 -β)
Pine (Pl)	29	18.6	18.2	0.4 ± 0.5	0.43	0.12
Spruce (Sx, Sb)	7	22.6	22.7	-0.1 ± 0.9	0.93	0.05
Overall	40	19.4	19.2	0.2 ± 0.4	0.51	0.08

6.4 Basal Area and Number of Trees

The YSM ground measurements and TIPSY predictions were compared overall and by BGC zone (SBPS and SBS only), in terms of basal area (BA) and trees per hectare (TPH) (7.5 cm+ DBH), based on 53 plots; three plots did not have ground species composition labels. Data used for these comparisons are given in Appendix VI (Table 26). The TIPSY predictions were based on YSM inputs and other assumptions (Appendix V). The results of these comparisons are given in Table 19.

The differences between the ground and TIPSY TPH (model biases) were statistically significant overall ($p < 0.05$), but barely non-significant for the two BGC zones (Table 19). The TIPSY BA model biases were not statistically significant overall and in the two BGC zones. Overall, there appears to be evidence that TIPSY may under-estimate TPH in the young stands in the Quesnel TSA. However, the assumptions used in generating TIPSY estimates were chosen arbitrarily (similar to those in the Kootenay Lake TSA YSM; Omule (2013b)); refer to Appendix V for further details. Thus, caution should be exercised when interpreting these results.

Table 19. Comparison of ground plot and TIPSY TPH and BA (7.5 cm+ DBH) (model biases) in the Quesnel TSA YSM. Statistically significant ($p < 0.05$) biases are shaded. The values after ± sign are standard errors; N = 53 plots.

Attribute	N	Trees/ha (TPH)					Basal Area (BA)				
		Ground	TIPSY	Bias	p-value (bias ≠ 0)	Power (1 -β)	Ground (m^2/ha)	TIPSY (m^2/ha)	Bias (m^2/ha)	p-value (bias ≠ 0)	Power (1 -β)
SBPS	13	938	739	199 ± 88	0.05	0.55	8.8	8.6	0.2 ± 0.9	0.88	0.05
SBS	27	1076	855	221 ± 106	0.05	0.52	12.3	12.0	0.3 ± 1.3	0.85	0.06
Overall	53	739	1006	267 ± 72	0.00	0.95	10.5	9.5	1.0 ± 0.8	0.21	0.23

6.5 Gross Volume

The YSM ground volume (VOL1) was compared to two TIPSY-generated total volumes (VOL2 and VOL3). The data used for these comparisons are given in Appendix VI (Table 27). The VOL2 was based on the TIPSY inputs YSM ground species composition and site index. The VOL3 was based on the TIPSY inputs VRI Phase I species composition and PSPL site index. In addition, both volumes were based on arbitrarily specified initial density, regeneration method, regeneration delay, and OAFs assumptions, and on the 7.5 cm+ utilization level. The difference between VOL1 and VOL3 is volume total bias, with components model-related bias (VOL1 - VOL2) and attribute bias (VOL2-VOL3). Details of how these volumes were generated, and how the partitioning of total bias into components was done, are given in Appendix V. Net volume comparisons, which were downplayed since the stands are quite young, are given in Appendix IX.

Total bias were statistically significant ($p < 0.05$) in the overall and the two BGC zones comparisons (power: 0.30, 0.30 and 0.21, respectively) (Table 20). Model-related bias was also statistically significant overall and in the two BGC Zones (power: 0.47, 0.17 and 0.23, respectively). Significant model bias could be attributed to the observed significant bias in TPH (see Table 19). As indicated earlier, note that the assumptions used in generating TIPSY estimates were chosen subjectively (following the assumptions similar to those in the Kootenay Lake TSA YSM); see Appendix V for further details. Thus, caution should also be exercised when interpreting these results.

Table 20. Comparison of ground plot and TIPSY gross volumes (7.5 cm+ DBH utilization level) in the Quesnel TSA YSM. Statistically significant biases ($p < 0.05$) are shaded gray.

		Volume (m^3/ha)			Model Bias		Total Bias	
Strata	N	VOL1	VOL2	VOL3	VOL1-VOL2 (m^3/ha)	p-value (bias ≠ 0)	VOL1-VOL3 (m^3/ha)	p-value (bias ≠ 0)
SBPS	9	31.4	27.4	24.7	4.0 ± 3.6	0.03	6.7 ± 4.1	0.03
SBS	23	63.3	54.2	49.3	9.1 ± 7.1	0.00	14.0 ± 11.6	0.02
Overall	42	46.6	38.3	37.0	8.3 ± 4.3	0.00	9.6 ± 6.6	0.00

7 Discussion

The Quesnel TSA YSM plot data provided an opportunity to compare the ground data with predicted from the VRI or TIPSY, and to demonstrate the utility of YSM data. The following caveats should, however, be kept in mind when reviewing the results of these comparisons:

- The sample size and intensity were low, resulting in low statistical power in many of the comparisons.
- The results are based on only one measurement. Remeasurement of these plots would quantify attribute changes and trends, and determine if the observed biases diminish, persist or increase over time.
- Some residual trees were not identified, or were incorrectly identified. These trees are normally included in the data summaries from the VRI/CMI compiler, but may not be suitable for TIPSY volume predictions comparisons. These potential residual trees were removed, prior to making all the comparisons, based on subjective data screening rules that were developed specifically for this project.
- Predicted VRI age, height, and SI are polygon-based, whereas the YSM values are based on only a small portion of the polygon (small fixed-area plots around the YSM sampling point). Thus, while the YSM plot values are unbiased, they have low precision because only one plot value is compared to the entire parent polygon value. Thus, caution should be exercised when interpreting the comparisons of these attributes or those generated from TIPSY using the VRI inputs.
- The TIPSY-generated values were based on assumptions that were chosen subjectively (similar to those in the Kootenay Lake TSA YSM); see Appendix V for further details.
- The term “merchantable” volume has been used in this report. This implies actual merchantability, which, given the small average tree size of the YSM target population, maybe premature. The phrase “net close utilization volume”, suggested by Will Smith of FAIB, might be a better descriptor of the young stand net volume.

This project has provided baseline data for monitoring (measuring change), to compare with predicted changes in the future, which is the major objective of the YSM program. Thus, it is important that the Quesnel YSM project be absorbed into the YSM program and that all the 61 original plots in this study are remeasured at the same time within three years (preferably in the fall 2015, budget and other resources permitting). The fall 2015 remeasurement results in a one-year delay in the remeasurement of the plots established in 2009 (assuming the YSM nominal 5-year remeasurement cycle), and a two-year early remeasurement of the plots established in 2012.

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Appendix I – Glossary of Statistical and Other Terms

Change is the difference in the level of the resource (e.g., basal area/ha) between two time points, Time *t* and Time *t-1*.

Monitoring is the process of observing the growth and yield (GY) in a forest and comparing this with the predicted GY of that forest.

Net close utilization volume (NCUV) refers to the stem volume between a 30-cm high stump and a 10-cm inside bark upper (top) stem diameter for all trees, except coastal mature species (> 120 years of age) where a 15-cm inside bark top diameter is used. It excludes decay, waste2 (sound wood in a log or a tree that has > 50% volume in decay) and breakage volume. (Source: Will Smith, FAIB, March, 2014.)

Post-Stratification involves the division of the monitoring unit into mutually exclusive sub-populations (strata) *after* ground sampling has been completed. Samples that fall in each post-stratum are analyzed separately and the results are applied to the corresponding population post-strata to improve the precision of the inventory's overall averages and totals.

Pre-Stratification involves the division of a monitoring unit into mutually exclusive sub-populations (strata) *before* ground sampling to provide estimates for specific areas, or to increase the confidence in the overall estimates by considering the special characteristics of each stratum.

Sample Size for monitoring is the number of sample plots to be established in a management unit or other population of interest to meet specified goals (such as statistical power and differences to be detected).

Standard deviation is a measure of the variation (or spread) of the actual data from their average (or expected value). A low standard deviation indicates that the data points tend to be very close to the mean, and a high standard deviation indicates that the data points are widely spread out over a large range of values from the mean.

Standard error (of the mean) is the standard deviation (SD) of the mean: it is SD of the observations divided by the square root of sample size.

Statistical power is the chance of correctly rejecting the null hypothesis using a statistical test (such a paired *t*-test); its value ranges from 0 to 100%. See also Appendix VIII.

Paired *t*-test is a *t*-test that consists of comparing a sample of matched pairs of similar sampling units, such as in YSM.

Target Population is the population from which the monitoring samples are chosen and the sample-based estimates and conclusions apply**.**

Appendix II – Tree Species Codes

Species Symbol	**Common Name**	**Scientific Name**
Conifers		
Bl	subalpine fir	*Abies lasiocarpa*
Fd	Douglas-fir	*Pseudotsuga menziesii*
Pl	lodge pole pine	*Pinus contorta*
Sb	black spruce	*Picea mariana*
Se	Engelmann spruce	*Picea engelmannii*
Ss	Sitka spruce	*Picea sitchensis*
Sw	white spruce	*Picea glauca*
Sx	hybrid spruce	*Picea hybrids*
Sxw	hybrid white spruce	*Picea engelmannii x glauca*
Deciduous trees		
Act	black cottonwood	*Populus balsamifera ssp. trichocarpa*
At	trembling aspen	*Populus tremuloides*
Ep	common paper birch	*Betula papyrifera*

Appendix III – Data Preparation

Data screening

The intent of the data screening was to ensure that residual trees are removed from the young stand sample and subsequent comparisons analyses. The reason for removing the residuals is that TIPSY does not handle residual trees. The following subjective rules applied to screen out the residuals were: live trees, DBH > 50 cm, breast-height age > 50 yrs, or trees identified as residuals or veterans in the field. The screening also included checking the DBH and height profiles of each plot. Recent orthophotos of the suspect plots were also reviewed (photos at time of plot establishment were not available). Plots 33, 40, 50 and 52 were dropped as they appeared to fall outside the target population (mature stands). Ortho images confirmed that these plots were indeed established adjacent non-target polygons. There were additional 21 suspect residual trees, according to these rules, that were dropped from analysis (Table 21).

Table 21. Quesnel TSA YSM: Potential residual live trees (DBH > 50 cm, or age_bh > 50 yrs, or cr_cl = 'V') that were removed from the YSM analysis. *lv_d* is live/dead status, *cr_cl* is crown class, *Suit_ht* and *Suit_tr* are suitability for height and age measurement, respectively, and *Age_bh* is age at breast height (yrs).

Samp_no	Species	Tree_no	cr_cl	DBH	height	suit_ht	suit_tr	SI_tree	Age_bh
2	SXW	580	C	28.3	19.1	Y	Y	16.88037	58
2	SXW	586	C	31	22.4	Y	N		125
2	SXW	592	C	25.8	22.3	Y	Y	18.66318	63
2	SXW	633	C	22.5	19	Y	Y	15.01074	66
2	PLI	642	C	25.2	16.8	N	Y		60
2	SXW	661	D	22.8	20.4	Y	Y	18.10898	58
11	SXW	299	C	39.5	19.5	Y	N		144
18	SXW	692	C	32.7	19.9	Y	N		74
29	SB	927	C	20	14.6	Y	N		89
29	SXW	940	C	30	21.1	Y	N		93
29	SXW	957	C	22.7	15.4	Y	N		52
31	FDI	924	C	18.9	12.4	N	N		123
35	FDI	39	D	29.1	21.1	Y	Y	17.21587	68
35	FDI	55	C	36.6	21.9	Y	Y	16.84204	75
35	FDI	73	C	21.7	17.1	Y	Y	14.9458	61
35	FDI	56		30.7	22.4				
35	FDI	66		30.5	22.4				
36	FDI	899	C	24.7	14.1	N	Y		57

Samp_no	Species	Tree_no	cr_cl	DBH	height	suit_ht	suit_tr	SI_tree	Age_bh
36	FDI	919	C	34.8	23.8	Y	N		65
36	PLI	918		36	19.4				
36	FDI	900		22	5				

Ground Sampling Year and Projection Year

The ground sampling occurred in two batches in fall 2009 and fall 2012. Thus, the ground and projection years were set as follows to account for the growing season. The plots measured in 2009 were assumed to include the 2009 growing season (ground year = 2009), and the plots measured in 2012 were assumed to include the 2012 growing season (ground year = 2012). The available VRI plot age and height data, which had been projected to January 2012, were adjusted to the corresponding plot ground year prior to comparison. The VRI age was reduced by 2 years for the ground year 2009 plots and incremented by 1 year for the ground year 2012 plots. Then the adjusted age and SiteTools were used to adjust the VRI heights. The VRI SI data were not adjusted.

Leading Species Matching for Age, Height and Site Index

Leading species matching is used to select plots to be used for calculating height, age and site index ground biases, based on measured suitable trees. The matching procedure used is similar to that used in the matching of VRI Phase I and II (FAIB, 2011) was used for the YSM data. The following two cases were considered acceptable matches for age, height and SI comparisons:

- Case 1: VRI polygon leading Sp0 matches the YSM plot leading Sp0 (42 plots)
- Case 2: VRI polygon second Sp0 matches the YSM plot leading Sp0 (6 plots).

The leading species matching rules were also used for site index comparisons, but only the plots in Case 1 and Case 2 were considered satisfactory matches.

Of the 48 plots that had acceptable matches, 40 had matched age, height and SI pairs. The remaining 8 plots either had zero BA, missing height/age for second leading Sp0, or suspicious VRI age values (e.g., plot 14 had a VRI age of 199 yrs, and plot 26 was 1 yr old).

Appendix IV – Ground Plot Data Summaries (excluding suspect residual trees)

The YSM ground plot summaries are given in Table 22 (4.0 cm+ DBH) and Table 23 (7.5 cm+ DBH) below. They are summaries of the screened tree file where suspect residual trees were removed. The re-compilation was done using custom programs written in SAS.

Table 22. Quesnel TSA YSM ground plot summaries (4.0 cm+ utilization level) based on the screened tree file (removed residual trees). TPH is trees/ha, BA is basal area/ha, TV is gross volume, Age is total age and SI is site index.

Sample no	BGC Zone	TPH	BA (m^2/ha)	TV (m^3/ha)	Species composition (% BA)	Leading species			
						Species	Height (m)	SI (m)	Age (yrs)
1	SBS	6479	15.3	52.1	Pl 100	PL	8.1	15.7	28
2	SBS	3502	37.1	240.1	Sx 91 Pl 07 Bl 02	SX			
3	MS	2777	6.7	14.7	Pl 100	PL	4.8	15.4	19
4	MS	6204	11.0	27.7	Pl 100	PL	5.8	8.4	44
5	MS	3702	15.2	48.6	Pl 95 Sx 05	PL	8.0	17.3	26
6	MS	1026	3.6	8.7	Pl 91 Sx 09	PL	6.0	18.2	19
7	MS	1901	5.6	14.0	Pl 100	PL	5.9	17.3	21
8	SBPS	1801	6.6	18.9	Pl 100	PL	6.5	19.7	18
9	SBPS	2051	12.7	54.9	Pl 66 At 27 Sx 07	PL	8.3	20.3	21
10	SBS	3753	11.6	34.8	Pl 100	PL	6.3	17.3	21
11	SBPS	926	8.5	55.5	Pl 85 Sx 15	PL	13.3	16.7	44
12	SBS	3477	20.5	85.8	Pl 90 Sx 05 Bl 05	PL	9.7	20.3	24
13	SBS	1851	5.5	13.9	Sx 54 Bl 38 Pl 08	SX	5.6	21.2	22
14	MS	100	0.1	0.2	Pl 100	PL			
16	SBPS	0	0.0	0.0					
17	SBPS	4378	14.1	56.4	Pl 100	PL	9.3	19.8	24
18	SBPS	450	6.3	36.8	At 47 Sx 42 Pl 11	AT			
19	SBPS	2852	10.4	26.8	Pl 97 At 03	PL	6.8	16.2	27
20	SBS	2402	10.2	33.6	Pl 100	PL	6.7	18.1	21
21	MS	3252	12.4	33.5	Pl 100	PL	6.0	19.1	18
22	MS	6955	29.1	102.8	Pl 91 Bl 06 Sx 03	PL	9.2	18.6	26
23	SBS	1776	15.5	72.0	Pl 93 Bl 05 Sx 02	PL	10.1	19.3	27
24	SBPS	1901	10.6	32.8	Pl 62 Sx 348	PL	7.6	16.9	35
25	SBS	1426	15.0	69.1	Pl 94 Bl 06	PL	9.9	16.9	32
26	SBPS	2777	20.6	130.0	Pl 83 Sb 10 Sx 07	PL	13.1	17.1	41
27	SBPS	801	1.8	4.1	Pl 68 Sb 32	PL	3.9	19.6	13

Sample no	BGC Zone	TPH	BA (m^2/ha)	TV (m^3/ha)	Species composition (% BA)	Leading species			
						Species	Height (m)	SI (m)	Age (yrs)
28	SBPS	1326	10.5	44.1	Pl 97 Sx 03	PL	9.0	16.1	31
29	SBPS	1376	12.7	64.5	Sb 50 At 17 Sx 15 Ep 09 Pl 09	Sb	10.4	15.8	43
30	SBPS	1101	12.4	61.9	Pl 100	PL	12.4	21.1	29
31	SBS	100	1.5	5.0	Pl 47 Fd 23 Act 15 At 15	PL			
32	SBS	4103	30.6	155.1	At 51 Pl 47 Sx 02	AT	12.0	17.9	31
34	SBS	1076	6.5	27.3	Pl 56 Sx 31 Fd 09 Act 04	PL	12.2	19.2	32
35	SBS	2402	18.9	94.6	Fd 95 At 04 Pl 01	FD	17.9	18.2	59
36	SBS	951	4.8	16.7	Pl 76 24 Pl 31 At 21	PL	7.3	22.5	17
37	SBPS	1776	14.2	73.3	Pl 96 Sx 04	PL	11.2	18.8	31
38	SBS	2402	16.8	77.7	Pl 100	PL	10.0	24	20
39	SBS	1051	2.4	8.3	Pl 60 Act 27 At 13	ACT	7.2	22.1	17
41	SBS	3102	23.5	118.2	At 44 Sx 23 Fd 18 Pl 08 Ep 05 Act 02	AT	14.5	21.2	31
42	SBS	2252	16.8	76.3	Pl 97 Fd 03	PL	9.7	21.8	22
43	SBS	6354	18.2	65.3	Pl 94 Bl 04 Sx 02	PL	7.8	20.4	19
44	SBS	400	10.8	80.3	Pl 85 Ep 15	PL	16.9	21.9	39
45	SBS	1526	28.3	180.2	Ep 48 Bl 27 Sx 15 At 10	EP	17.1	20.9	39
46	SBS	2151	17.5	76.2	Sx 53 Pl 41 At 04 ACT 02	SX	10.7	22.9	30
47	SBS	901	8.0	31.5	Sx 35 Fd 31 Bl 22 Pl 11 At 01	Fd	9.3	24.7	25
48	SBS	2252	22.1	123.4	Sx 43 Pl 41 Fd 10 At 05 Act 01	SX	12.6	19.4	42
49	SBS	1226	19.4	117.5	Pl 60 Sx 21 At 15 Bl 04	PL	12.3	20.8	34
51	SBS	3377	23.9	108.6	Sx 55 Bl 28 Pl 12 Act 05	SX	13.2	21.6	33
53	ESSF	2977	20.8	83.9	At 64 Sx 36	At	14.1	23.3	26
54	SBS	2677	13.1	45.0	Sx 48 Bl 46 Pl 06	SX	7.4	22.1	28
55	SBS	1701	5.8	16.9	Pl 91 At 03 Bl 03 Ep 03	PL	6.3	22.2	14
56	ESSF	1476	7.3	18.7	Sx 95 Ac 05	SX	7.1	24.8	21
57	ESSF	500	4.2	11.8	Sx 100	SX	8.1	26.2	21
58	ICH	675	4.0	12.4	Sx 72 Pl 28	SX	6.8	24.7	20
59	ICH	2101	22.0	111.4	Pl 55 At 26 Sx 19	SX	13.2	23.6	26
60	ESSF	3152	19.9	66.8	Sx 73 Pl 15 At 12	SX	8.8	21.8	28
61	ICH	1051	12.6	42.9	Sx 94 Pl 06	SX	9.8	22.2	30

Table 23. Quesnel TSA YSM plot summaries (7.5 cm+ DBH utilization level) based on the screened tree file (removed residual trees). TPH is trees/ha, BA is basal area/ha, and TV (VOL1) is gross volume.

Sample No.	TPH	BA (m^2/ha)	TV (VOL1) (m^3/ha)
1	475	2.8	11.3
2	2201	33.7	227.2
3	275	1.5	3.7
4	0	0.0	0.0
5	1401	9.9	33.4
6	225	1.5	4.0
7	400	2.4	6.5
8	500	3.3	9.9
9	1151	10.1	46.0
10	650	4.4	14.4
11	725	8.0	53.3
12	1876	16.1	70.6
13	250	1.4	4.2
14	0	0.0	0.0
16	0	0.0	0.0
17	1076	6.3	25.9
18	250	6.0	35.9
19	951	6.0	17.2
20	901	5.6	19.5
21	1151	7.1	19.1
22	2552	17.6	65.2
23	1176	14.0	66.6
24	1001	8.4	27.4
25	1226	14.3	66.6
26	1876	17.3	114.4
27	100	0.5	1.3
28	1126	10.1	42.9
29	876	11.6	61.3
30	901	11.8	59.6
31	100	1.5	5.0
32	2802	27.0	139.3
34	575	4.8	22.6

Sample No.	TPH	BA (m^2/ha)	TV (VOL1) (m^3/ha)
35	1001	15.4	84.4
36	550	3.9	14.5
37	976	12.3	65.2
38	1801	15.0	70.6
39	50	0.6	3.3
41	1501	19.3	104.9
42	1751	15.2	69.8
43	851	5.0	19.7
44	400	10.8	80.3
45	1126	27.2	176.5
46	1451	15.6	70.9
47	700	7.4	30.3
48	1651	20.7	119.7
49	1126	19.0	116.4
51	1576	19.2	95.0
53	1676	17.9	75.0
54	876	9.0	33.8
55	400	2.7	8.9
56	776	5.6	15.3
57	400	3.9	11.2
58	375	3.4	11.3
59	1101	19.3	104.2
60	1651	16.2	57.9
61	1051	12.6	42.9

Appendix V – Methods & Assumptions for TIPSY Predicted Volume & Bias

Predicted Volume

The following descriptions include excerpts from the Kootenay Lake TSA YSM establishment report (Omule, 2013b).

For each sample plot, YSM ground volumes were compared against two separate sets of TIPSY-generated predicted gross and net volumes, to quantify the total volume bias as well as to partition the total bias into model-related bias and attribute-related bias components. We chose one model to test the model biases, noting that TSR uses two models including VDYP7.

<u>VOL1</u>: Ground-based gross (whole stem) plot volume. VOL1 is the ground compiled volume (with residual trees removed). The tree file provided by FAIB on December 2, 2013 (Project ID 026M) was used. These data were screened to remove residual trees, and data recompiled to obtain plot gross volume (*vha_wsv*) and net volume (*vha_nwb*). Net volume is gross volume between a 0.30-m high stump and a 10-cm top diameter, net of decay, waste and breakage and NVAF). Gross volume adjustment factor (GVAF for live trees) and net volume adjustment factor (NVAF) provided by FAIB were applied to *vha_wsv* and *vha_nw* , respectively, to obtain GVAF- and NVAF-adjusted estimates of gross and net volume.

<u>VOL2</u>: TIPSY estimated volumes (gross volume at 7.5 cm+, and net volume at 12.5 cm+ and 17.5 cm+ DBH utilization levels) using ground plot inputs and assumptions.

- The ground plot inputs include site index and species composition. If SI was not available for the leading species, it was taken from the provincial site productivity layer. If SI was not available for non-leading species, site index conversion equations were used to impute the SI from the SI of the leading species. If no conversion equations exist, the leading species SI was used for non-leading species.
- TSR assumptions. If there was a record of harvesting in the polygon and the leading species was a conifer, the regeneration method was assumed to be planting and the planting density was assumed to be 1400 stems/ha, which was assumed to account for potential ingress. Otherwise the regeneration method was assumed to be natural with an initial density of 5,000 stems/ha. If the leading species was balsam, natural regeneration with an initial density of 5,000 stems/ha was assumed. A regeneration delay of two years and default OAFs (OAF1 = 0.85 and OAF2 = 0.95) were assumed for all runs.
- For plots with a hardwood component, each species present in the ground sample was projected as a pure species stand with the appropriate site index, and the regeneration

method and planting density taken from the leading species. The TIPSY volume was computed as the species composition (BA%) weighted average of the pure species TIPSY volumes.

The ground plot and TIPSY heights were matched and the corresponding VOL2 TIPSY volume extracted.

VOL3: TIPSY estimated volumes using SI from the VRI Phase I inventory species composition and PSPL SI (gross volume at 7.5 cm+ and net volume at 12.5 cm+ and 17.5 cm+ DBH utilization levels). The subsequent TIPSY runs were similar to those for VOL2. The TIPSY age was matched to adjusted projected age (PROJ_AGE_1).

All the TIPSY runs were done in interactive mode. For all TIPSY runs for VOL2 and VOL3, all other input assumptions were held constant by sample (initial density, stand origin, OAFs, and regeneration delay) (Table 24).

Table 24. Quesnel TSA YSM TIPSY runs assumptions. The TIPSY ground plot inputs, and VRI Phase I and PSPL inputs, are given in Tables 22 and 25, respectively. AOF1 was 0.85 and OAF2 was 0.95. Regen. method: N is for natural and P planted.

Sample ID	Harvest date	BGC zone	YSM leading sp.	Regen. method	Regen. Density (TPH)	Regen delay (yrs)
026M-0001-MO1		SBS	Pl	N	5000	2
026M-0002-MO1		SBS	Sx	N	5000	2
026M-0003-MO1	8/1/1989	MS	Pl	P	1400	2
026M-0004-MO1		MS	Pl	N	5000	2
026M-0005-MO1	1/1/1979	MS	Pl	P	1400	2
026M-0006-MO1	1/1/1987	MS	Pl	P	1400	2
026M-0007-MO1	1/1/1987	MS	Pl	P	1400	2
026M-0008-MO1	1/1/1988	SBPS	Pl	P	1400	2
026M-0009-MO1	1/1/1986	SBPS	Pl	P	1400	2
026M-0010-MO1	1/1/1987	SBS	Pl	P	1400	2
026M-0011-MO1		SBPS	Pl	N	5000	2
026M-0012-MO1	1/1/1984	SBS	Pl	P	1400	2
026M-0013-MO1	1/1/1988	SBS	Sx	P	1400	2
026M-0014-MO1		MS	Pl	N	5000	2
026M-0016-MO1	1/1/1994	SBPS	Pl	P	1400	2
026M-0017-MO1		SBPS	Pl	N	5000	2
026M-0018-MO1	1/1/1986	SBPS	At	N	5000	2
026M-0019-MO1	1/1/1986	SBPS	Pl	P	1400	2
026M-0020-MO1	1/1/1985	SBS	Pl	P	1400	2

Sample ID	Harvest date	BGC zone	YSM leading sp.	Regen. method	Regen. Density (TPH)	Regen delay (yrs)
026M-0021-MO1	12/1/1991	MS	Pl	P	1400	2
026M-0022-MO1	1/1/1978	MS	Pl	P	1400	2
026M-0023-MO1	1/1/1980	SBS	Pl	P	1400	2
026M-0024-MO1	5/31/1986	SBPS	Pl	P	1400	2
026M-0025-MO1	8/1/1976	SBS	Pl	P	1400	2
026M-0026-MO1	10/1/1976	SBPS	Pl	P	1400	2
026M-0027-MO1	5/31/1988	SBPS	Pl	P	1400	2
026M-0028-MO1	1/1/1973	SBPS	Pl	P	1400	2
026M-0029-MO1	1/1/1970	SBPS	Sb	P	1400	2
026M-0030-MO1	1/1/1976	SBPS	Pl	P	1400	2
026M-0031-MO1	6/1/1994	SBS	Pl	P	1400	2
026M-0032-MO1		SBS	At	N	5000	2
026M-0034-MO1	6/1/1971	SBS	Pl	P	1400	2
026M-0035-MO1		SBS	Fd	N	5000	2
026M-0036-MO1	1/1/1991	SBS	Pl	P	1400	2
026M-0037-MO1	1/1/1977	SBPS	Pl	P	1400	2
026M-0038-MO1	1/1/1991	SBS	Pl	P	1400	2
026M-0039-MO1		SBS	Pl	N	5000	2
026M-0041-MO1		SBS	At	N	5000	2
026M-0042-MO1	1/1/1992	SBS	Pl	P	1400	2
026M-0043-MO1	1/1/1991	SBS	Pl	P	1400	2
026M-0044-MO1	1/1/1970	SBS	Pl	P	1400	2
026M-0045-MO1		SBS	Ep	N	5000	2
026M-0046-MO1		SBS	Sx	N	5000	2
026M-0047-MO1	1/1/1988	SBS	Sx	P	1400	2
026M-0048-MO1	1/1/1974	SBS	Sx	P	1400	2
026M-0049-MO1		SBS	Sx	N	5000	2
026M-0051-MO1	1/1/1975	SBS	Pl	P	1400	2
026M-0053-MO1		ESSF	At	N	5000	2
026M-0054-MO1	1/1/1994	SBS	Sx	P	1400	2
026M-0055-MO1		SBS	Pl	N	5000	2
026M-0056-MO1	1/1/1989	ESSF	Sx	P	1400	2
026M-0057-MO1	1/1/1991	ESSF	Sx	P	1400	2
026M-0058-MO1	1/1/1992	ICH	Sx	P	1400	2
026M-0059-MO1		ICH	Pl	N	5000	2
026M-0060-MO1	1/1/1984	ESSF	Sx	P	1400	2

Sample ID	Harvest date	BGC zone	YSM leading sp.	Regen. method	Regen. Density (TPH)	Regen delay (yrs)
026M-0061-MO1		ICH	Sx	N	5000	2

Volume Biases

Volume total bias and its components were calculated using VOL1, VOL2 and VOL3 as follows:

Total Bias	=	VOL1 – VOL3
Model Bias	=	VOL1 – VOL2
Attribute Bias	=	VOL2 – VOL3

These biases were calculated for three utilization levels of VOL1, VOL2 and VOL3:

1. Gross (whole stem) based on the 7.5 cm+ utilization level.
2. Net volumes based on 12.5 cm+ utilization level for all species, as suggested by FAIB.
3. Net volumes based on a mix of utilization levels (pine and hardwood leading 12.5 cm+ utilization level and all other leading species 17.5 cm+), as is typically done in TSR.

Appendix VI – Predicted Plot Values

The plot values predicted from VRI Phase I and PSPL SI are given in Table 25. Note that the VRI Phase I Age1 and Ht1 are adjusted for plot differences in growing season as is described in Appendix II. The BA and TPH ground and TIPSY outputs (7.5 cm+ DBH), based on the ground-attribute inputs and TSR assumptions, are given in Table 26. The TIPSY volumes VOL2 and VOL3, along with corresponding ground values, are given in Table 27. Note that the VOL2 and VOL3 are TIPSY output gross volumes based on the ground inputs and VRI inputs, respectively (7.5 cm+ DBH); their definitions are given in Appendix IV. The VOL1 was obtained from Table 23 (Appendix III).

Table 25. Quesnel TSA plot predicted values from VRI Phase I and PSPL SI.

Sample No	Sp1	Age1 (yrs)	Ht1 (m)	SI (m)	PSPL SI (m)									
					Sx	Hw	Hm	Bl	Cw	Pl	Lw	Fd	At	Ep
1	Pl	27	8.2	16.0	20.7			19.8		19.5			15	16.5
2	S	46	9.3	15.0	20.7			19.8		19.5			17.6	16.6
3	Pl	17	4.6	16.0	12.6					12.6			18.7	
4	Pl	39	12.0	16.0	16.6					13.6			17.3	
5	Pl	27	5.0	11.0	18.4					17.6			17.6	
6	Pl	21	6.1	16.0	18.4					17.6			18.4	
7	Pl	28	8.6	16.0	16.9					16.2			17.5	
8	Pl	16	4.2	16.0	16.9					16.2			17.6	
9	Pl	18	5.0	16.0	20.7					20.3		17.2	15.2	
10	Pl	21	6.1	16.0	18.8			15.4		17.9			17.9	16.3
11	Pl	36	11.2	16.0	18.3					18.7			14.6	
12	Pl	23	6.8	16.0	18.8			15.4		17.9			17.1	
13	Pl	20	1.9	13.0	19.3			19.1		19.9			17.4	
14	Pl	199	20.1	10.6	9					15			20.8	
16	Pl	16	4.2	16.0	15					20.1		18.4	17.2	
17	Pl	24	7.2	16.0						15			16.9	
18	PL	19	6.9	20.0	15					20.1			15.4	
19	Pl	25	4.6	11.0	15					16			15.2	
20	Pl	22	6.5	16.0	18.8			15.4		17.9			18.6	16.3
21	Pl	16	4.5	17.0	16.9			17.3		16.2			20.6	
22	Pl	26	7.9	16.0	16.9			16.9		16.2			21	
23	Pl	23	7.8	18.0	18.8			15.4		17.9			16.8	15.8
24	Pl	26	7.9	16.0	15					20.1			14.9	
25	Pl	28	9.8	18.0	18.8			15.4		17.9			17.9	16.4

Sample No	Sp1	Age1 (yrs)	Ht1 (m)	SI (m)	PSPL SI (m)									
					Sx	Hw	Hm	Bl	Cw	Pl	Lw	Fd	At	Ep
26	Pl	1		18.0	21.6					20.3		18.3	16.8	
27	Pl	21	6.1	16.0	21.6					20.3			12.7	
28	Pl	28	8.6	16.0	21.6					20.3		16.5	13.7	
29	PL	1		18.0	21.6					20.3		17.5	14.7	
30	Pl	32	11.3	16.0	15					20.1			18	
31	Pl	16	4.2	16.0	19.9					19.9		19.1	18.9	17.3
32	At	19	6.1	18.0	18.8			15.4		17.9			17.5	16.6
34	Pl	40	16.9	21.1	19.2			17.5		19.6		20.8	17	18.4
35	Fd	48	18.7	22.4	19.2			17.5		19.6		20.8	17	17.5
36	Pl	16	6.2	21.0	19.2			17.7		19.6		20.8	17	17.8
37	Sx	2		19.0	18.3			18		20.6		18.8	17	17.6
38	Pl	18	6.4	20.0	19.2			18.9		19.6		20.8	17	18.7
39	At	28	9.1	15.3	15.6			18.8		22.4		15.6	21.3	19.4
41	At	37	11.9	15.5	20.2			19.5		21		21	19.6	19.2
42	Pl	25	10.8	21.0	19.2			17.9		19.6		20.8	17	17.3
43	Pl	19	5.3	16.0	19.2			18		19.6		20.8	17	17.4
44	Pl	48	20.2	22.3	21			18.8		21.8		21	20.2	19
45					20			15		22.4		22.6	20.4	17.8
46					21			15		24		21	20.4	17.7
47	Sx	23	14.0	28.1	21			15		24		21	19	17.9
48	Sx	37	13.2	25.4	20			15		22.4		22.6	20.3	18
49	Sx	38	17.1	22.2	21.9			18		21		20.2	18.5	17.8
51	Pl	33	7.4	19.0	21.8			18.6		21.2		25.3	21.8	17
53					15			19.5		19.8		19.1		
54					21.9			18		21		21.4	20.9	16.5
55					24			18		24		21	20.5	17.9
56	Sx	25	2.9	15.0	15			19.5		19.8		19.4		
57					15			19.5		19.8		19.9		
58	Sx	21	2.0	15.0	26.4	18.4		19	17.2	24.6		24		16.9
59					18	18.5		19.7	16.8	21.8		24		18.8
60	Sx	27	4.4	18.0	25.6	18.6		18.7	17.5	24		24	22.4	
61					18	19.8		19.7	17.7	22.4		24.3		18.2

Table 26. Quesnel TSA YSM ground plot values and TIPSY predicted values (7.5 cm+ DBH utilization) for TPH (is trees/ha) and BA (basal area/ha). These data were used in the comparisons reported in Table 19. The TIPSY BA and TPH correspond to VOL2 TIPSY runs. Only 53 plots that had no missing YSM input data to TIPSY were used.

Sample No.	BGC zone	YSM ground plot values		TIPSY predicted values	
		TPH (trees/ha)	BA (m2/ha)	TPH (trees/ha)	BA (m2/ha)
1	SBS	475	2.8	927	8
2	SBS	2201	33.7	1779	27
3	MS	275	1.5	10	0
4	MS	0	0.0	133	1
5	MS	1401	9.9	133	1
6	MS	225	1.5	306	2
7	MS	400	2.4	202	2
8	SBPS	500	3.3	402	3
9	SBPS	1151	10.1	681	7
10	SBS	650	4.4	517	2
11	SBPS	725	8.0	538	4
12	SBS	1876	16.1	939	14
13	SBS	250	1.4	90	1
17	SBPS	1076	6.3	1344	13
19	SBPS	951	6.0	488	4
20	SBS	901	5.6	500	4
21	MS	1151	7.1	225	2
22	MS	2552	17.6	899	12
23	SBS	1176	14.0	980	15
24	SBPS	1001	8.4	564	7
25	SBS	1226	14.3	976	15
26	SBPS	1876	17.3	1010	24
27	SBPS	100	0.5	19	0
28	SBPS	1126	10.1	893	11
29	SBPS	876	11.6	864	10
30	SBPS	901	11.8	1037	2
31	SBS	100	1.5	257	2
32	SBS	2802	27.0	849	12
34	SBS	575	4.8	1009	18
35	SBS	1001	15.4	1481	14

36	SBS	550	3.9	634	5
37	SBPS	976	12.3	1029	18
38	SBS	1801	15.0	1028	15
39	SBS	50	0.6	266	2
41	SBS	1501	19.3	1670	20
42	SBS	1751	15.2	993	14
43	SBS	851	5.0	751	7
44	SBS	400	10.8	1010	32
45	SBS	1126	27.2	830	17
46	SBS	1451	15.6	711	7
47	SBS	700	7.4	689	9
48	SBS	1651	20.7	1020	19
49	SBS	1126	19.0	1578	25
51	SBS	1576	19.2	1023	16
53	ESSF	1676	17.9	1050	10
54	SBS	876	9.0	326	3
55	SBS	400	2.7	248	2
56	ESSF	776	5.6	263	2
57	ESSF	400	3.9	474	4
58	ICH	375	3.4	229	3
59	ICH	1101	19.3	1601	19
60	ESSF	1651	16.2	645	6
61	ICH	1051	12.6	1043	11

Table 27. Quesnel TSA YSM ground plot and TIPSY-predicted gross volumes (7.5 cm+ DBH utilization); VOL1 is ground plot gross volume, and VOL2 and VOL3 are TIPSY gross volumes. These values were used in the volume comparisons reported in Table 20. Only 42 plots that had no missing VRI Phase I labels or YSM input data to TIPSY were used.

Sample No.	BG zone	VOL1 (m^3/ha)	VOL2 (m^2/ha)	VOL3 (m^2/ha)
1	SBS	11.3	22	13
2	SBS	227.2	136	35
3	MS	3.7	0	0
4	MS	0.0	2	84
5	MS	33.4	22	1
6	MS	4.0	6	3
7	MS	6.5	3	31

Sample No.	BG zone	VOL1 (m^3/ha)	VOL2 (m^2/ha)	VOL3 (m^2/ha)
8	SBPS	9.9	8	0
9	SBPS	46.0	21	0
10	SBS	14.4	3	5
11	SBPS	53.3	11	62
12	SBS	70.6	49	11
13	SBS	4.2	4	0
17	SBPS	25.9	46	2
19	SBPS	17.2	10	1
20	SBS	19.5	9	8
21	MS	19.1	4	0
22	MS	65.2	40	13
23	SBS	66.6	53	12
24	SBPS	27.4	22	52
25	SBS	66.6	51	41
27	SBPS	1.3	0	27
28	SBPS	42.9	38	31
30	SBPS	59.6	91	47
31	SBS	5.0	4	0
32	SBS	139.3	51	0
34	SBS	22.6	74	168
35	SBS	84.4	61	185
36	SBS	14.5	15	3
38	SBS	70.6	51	5
39	SBS	3.3	5	11
41	SBS	104.9	110	45
42	SBS	69.8	48	38
43	SBS	19.7	21	1
44	SBS	80.3	184	264
47	SBS	30.3	33	35
48	SBS	119.7	78	90
49	SBS	116.4	119	120
51	SBS	95.0	66	43
56	ESSF	15.3	6	0
58	ICH	11.3	11	22
60	ESSF	57.9	21	44

Appendix VII – Primary Damage Agents Codes

The primary damage agents observed in Quesnel TSA YSM are shown below. The first letter indicates the type of damage agent: abiotic (N), disease (D), insect (I), treatment (T) and animal damage (A). The second and third letters indicate the specific agent, if it can be determined. The shaded rows indicate the top four damage agents (main primary damage agents).

Damage Code	*Code Description*
Main primary agents	
A	Animal:
DS	Disease: stem disease
DSG	Disease: western gall rust
IWS	Insect: white pine weevil
Other primary agents	
DBF	Disease: Fir broom rust
DMP	Disease: Lodgepole pine dwarf mistletoe
DSA	Disease: Atropellis canker (Pl)
DSB	Disease: white pine blister rust
IAG	Insects: Cooley spruce gall adelgid
IBM	Insects: Mountain pine beetle
ID	Defoliators:
NX	Abiotic: scarring and rubbing
NY	Abiotic: snow or ice
TL	Treatment injuries: logging wounds

Appendix VIII – Power Analysis

The statistical power of a statistical test is the probability of rejecting the null hypothesis when the null hypothesis is false. A type II error occurs when the null hypothesis is rejected when it is true. The probability of a type II error is β so the power is 1 – β. The power is affected by the sample size, the magnitude and variability of the bias, and the correlation between the two estimates (in a paired sample). A powerful test is one that has a high chance in detecting even small differences. As power increases, however, the required sample size increases rapidly. The suggested minimum power level is 0.60 (FAIB 2012). Statistical power was calculated using either SAS program or Microsoft Excel program. These power values are used to check the power of the comparison of predicted and YSM plot values. They can also be used to estimate future monitoring sample size for similar populations.

Appendix IX – TIPSY Net Volume Comparisons

The following two types of analysis are for net merchantable volume:

1. Net merchantable volumes (net of decay, waste and breakage and NVAF) based on 12.5 cm+ utilization level for all leading species (Table 28). This was suggested by FAIB.
2. Net merchantable volume based on a mix of utilization levels (12.5 cm+ for pine and hardwoods leading species and 17.5 cm+ utilization level for the remaining leading species (Table 29). This mimics what is normally done in TSR.

The volume predictions were made as outlined in Section 6.5 and in Appendix V. The overall sample size is 42 because some plots did not have species composition labels. In the type 1 analysis, total bias was not statistically significant overall and in the SBS zones, but was significant in the SBPS zone (Table 28). Model bias was significant overall and in the SBS zone. The observed model biases may be due to the assumptions used in TIPSY. In the type 2 analysis, all the biases were not statistically significant (Table 29).

Table 28. Quesnel TSA YSM TIPSY comparison of merchantable volume at the 12.5 cm+ DBH utilization for all species). Standard errors as percent of the mean follow the ± sign with N plots.

Strata	N	Mean volume (m^3/ha)			Bias (m^3/ha)			p-value (bias ≠ 0)		
		VOL1	VOL2	VOL3	Total	Model	Attribute	Total	Model	Attribute
SBPS	9	9.3	12.1	11.0	-1.7 ± 6.8	-2.8 ± 6.6	1.1 ± 9.1	0.03	0.16	0.42
SBS	23	28.2	29.4	31.4	-3.2 ± 18.9	-1.2 ± 8.7	-2.0 ± 12.9	0.54	0.04	0.60
Overall	42	18.2	19.5	21.7	-3.5 ± 10.5	-1.3 ± 5.1	-2.2 ± 7.6	0.17	0.00	0.73

Table 29. Quesnel TSA YSM TIPSY comparison of merchantable volume at the 12.5 cm+ DBH utilization for Pl and hardwoods leading species and 17.5 cm+ DBH for remaining leading species. N is the number of plots. Standard errors as percent of the mean follow the ± sign.

Strata	N	Mean volume (m^3/ha)			Bias (m^3/ha)			p-value (bias ≠ 0)		
		VOL1	VOL2	VOL3	Total	Model	Attribute	Total	Model	Attribute
SBPS	9	9.3	12.1	11.0	-1.7 ± 7.7	-2.8 ± 7.2	1.1 ± 11.0	0.40	0.59	0.81
SBS	23	21.9	22.4	28.0	-6.1 ± 16.5	-0.5 ± 8.1	-5.6 ± 10.3	0.40	0.27	0.64
Overall	42	14.4	15.5	19.3	-4.9 ± 9.5	-1.1 ± 4.7	-3.8 ± 6.5	0.32	0.09	0.84