Interfor Hope IFPA
Change Monitoring Inventory
Pilot Project:
First Measurement Results

Prepared for

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Executive Summary

A Change Monitoring Inventory (CMI) pilot project was completed on International Forest Products Ltd.'s Innovative Forestry Practices Agreement (IFPA) area near Hope, BC. The primary objective of this CMI project was to install a set of permanent sample plots across the IFPA area to monitor the growth and yield of regenerated stands. The sample was restricted to regenerated stands between 21 and 80 years of age in the Coastal Western Hemlock (CWH) biogeoclimatic zone. The secondary objective of the CMI project was to pilot test some modifications to the Ministry of Sustainable Resource Management (MSRM) CMI methods to help ensure that plots could be installed in one day by a two-person crew.

The CMI sample included 45 plots established across the regenerated stands on a 2.0 km grid. The plots were 11.28 m radius (400 m^2) where tree measurements were recorded by 100 m^2 quadrants. There were two major modifications to the MSRM methods. First, tree heights were estimated in the sample plots and 10 were randomly selected for measurement. A ratio was developed between the estimated and measured heights from these 10 trees and the ratio was applied to all trees in the plot. The second modification was to increase the tagging limit to measure trees greater than 9 cm diameter at breast-height in the main sample plot instead of the MSRM standard of 4.0 cm.

Comparison of the CMI plots showed that the inventory under-estimated the average merchantable volume, height, and age (under-estimates were about 156 m^3/ha for volume, 4.7 m for height, and 15 years for age). Further analysis showed that the difference in merchantable volume was reduced and was not statistically different when stand volume was predicted using the age of the CMI plots instead of the age of the polygon indicated in the inventory. The inventory site index assigned to these regenerated stands using the recently completed Site Index Adjustment (SIA) project were not significantly different from the CMI plots.

Recommendations from this project include:

1. Test the implications of the age under-estimation in timber supply analysis.
2. Review the procedures used to estimate inventory and CMI ages to determine the source of differences.
3. Use the sample design developed in this project for future CMI programs.
4. Expand the target population for monitoring to include the productive portion of the MH and ESSF zones.
5. Consider including whole stem volume in the yield curve database.
6. Archive versions of the inventory used for selecting this CMI sample.
7. Make the re-measurement period coincide with the Forestry Plan cycle

Acknowledgements

We thank Kevin Chisholm, *RPF* of International Forest Products Ltd. (Interfor), Hope Logging Division for helping develop the project and making the sample design fit Interfor’s business needs. We thank Jon Vivian, *RPF* of the Ministry of Sustainable Resource Management (MSRM), Terrestrial Information Branch for his help designing the project. We also thank Kim Iles, *PhD* of Kim Iles and Associates Ltd. and Joe Braz, *RPF* of the MSRM for their help designing the random height adjustment method. Finally, we thank Roman Bilek of the MSRM, Vancouver Forest Region for his feedback in the field audit process. This project was funded by Forest Renewal BC.

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1. INTRODUCTION

1.1 BACKGROUND

The Ministry of Forests (MOF) awarded an Innovative Forestry Practices Agreement (IFPA) to International Forest Products Ltd. (Interfor) Hope Logging Division in 1997. The goal of the agreement is to develop and implement innovative forestry practices to help improve the timber harvest and environmental management in the area. The first two years of the IFPA focused on improving the inventory, growth & yield (G&Y), and environmental information for the IFPA area. Improved estimates of potential site index (PSI) from a Site Index Adjustment (SIA) project[1] were applied to existing and future regenerated stands in an innovative timber supply analysis completed in March 2001. Interfor wants to ensure the volume and PSI data used in timber supply analyses accurately reflect the growing conditions of the IFPA area. As a result, this Change Monitoring Inventory (CMI) pilot project was developed to monitor the volume and PSI estimates for timber supply analyses in the IFPA area.

1.2 MONITORING OBJECTIVES

Interfor's goal for this CMI program is to:[2]

> *Monitor the G&Y of regenerated stands in the Coastal Western Hemlock (CWH) biogeoclimatic zone to ensure the G&Y estimates used in timber supply analysis accurately reflect the IFPA area.*

This CMI program was designed to detect practically significant differences[3] between actual and predicted change in key G&Y attributes. The CMI field data from this project were compared to the yield table data incorporated into the second innovative timber supply analysis.[4]

1.3 REPORT OBJECTIVES

The objectives of this report are to:

1. Summarize and present the data from the CMI plots.
2. Compare the CMI plot data with the corresponding estimates from the yield tables.

1.4 TERMS OF REFERENCE

J.S. Thrower & Associates Ltd. (JST) completed this project for Kevin Chisholm, *RPF* of Interfor. The JST project manager was Hamish Robertson, *RPF* and Guillaume Thérien, *PhD* provided analytical support. The field program was coordinated by Mike Ciccotelli, *DoT* and field work was completed by Tysen LeBlanc, *BNRSc,* Andrei Spazier, *BSF,* Marc Laverdière, *BSF,* and Darryl Klassen, *BNRSc*. This report will be submitted to Jon Vivian, *RPF* of the Ministry of Sustainable Resource Management (MSRM). Funding was provided by Forest Renewal BC.

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[1] J.S. Thrower & Associates Ltd. 2001. Potential site index estimates for major commercial tree species in the Hope IFPA area. Final Report. Contract No. IFH-033-016. March 28, 2001. 14 pp.

[2] J.S. Thrower & Associates Ltd. International Forest Products Ltd. Hope IFPA change monitoring inventory sample plan. October 18, 2001.

[3] Practically significant differences (as opposed to statistically significant differences) are defined here as ones that impact management decisions. Timber supply sensitivity analyses can be used to help determine the impacts of potential differences on timber supply.

[4] J.S. Thrower & Associates Ltd. 2001. Yield tables for the second innovative timber supply analysis for the Hope IFPA. Final Report. Contract No. IFH-033-024. March 30, 2001.

2. SAMPLE DESIGN

2.1 Objectives

The primary objective of this CMI program is to:

Monitor the net merchantable volume in target stands.

The secondary objectives of this CMI program are to:

1. *Monitor the change in PSI in target stands.*
2. *Develop and test sample methods to help ensure that one plot is completed per day.*
3. *Develop a flexible sampling design that can be modified for future information needs.*

G&Y monitoring is the process of comparing the actual G&Y of a forest or stand to the predicted G&Y for that forest or stand. This program was designed to check the existing G&Y predictions for target stands and not to develop new G&Y predictions or estimate stand response to silviculture treatments. However, these data may be used to develop other growth models and for other uses.

The sampling design was developed to meet two objectives. First, timber data were collected on trees greater than 9 cm diameter at breast-height (DBH) to provide a check of stand-level volume and PSI estimates used in the second innovative timber supply analysis. Second, the field measurements had to be completed in one day by a two-person crew. This meant that data were not collected for trees less than 9 cm DBH, coarse woody debris, range, stump, or ecological attributes.

2.2 Target Population

The target population was all Douglas-fir (Fd), western hemlock (Hw), balsam (Ba), and western redcedar (Cw) leading stands between 21 and 80 years in the CWH biogeoclimatic (BGC) zone (excluding parks, non-forest, non-crown, and woodlots) (22,272 ha, Appendix I). The target population was created by the union of the Vegetation Resources Inventory (VRI) Phase I and Terrestrial Ecosystem Mapping (TEM) databases. This definition can be adjusted in the future if Interfor chooses to alter the CMI program.

2.3 Sample Plot Location

A 2.0 km grid was intersected with the target population generating 48 sample locations in the target stand types. Forty-five (45) plots were installed in the target population. Three plots were not established; two were rejected because the sample locations were unsafe and one was located under a power line (this plot was incorrectly included in the original target population) (Appendix II).

2.4 Sample Plot Design

The CMI sample plot was 11.28 m radius (400 m^2) divided into four quadrants along cardinal directions (Figure 1). These quadrants were sub-divided to form two sectors per quadrant, and data were collected from each sector starting clockwise from north. The plot is centered at the point identified in the 2.0 km grid. This plot design differs from the standard MSRM CMI plot design in that the Small Tree plot (5.64 m radius) and the Regeneration plot (2.5 m radius) were not included.

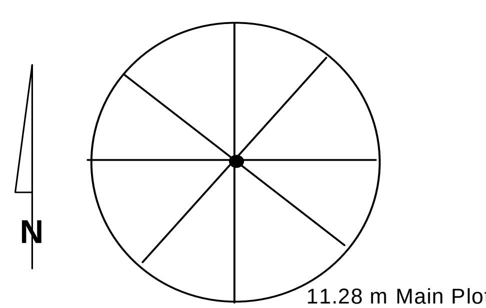

Figure 1. Plot design used in the Hope CMI.

2.5 TREE TAGS

Special plastic tree tags were made for this project (3.8 cm in diameter [1.5 inches]). The tags are blue, labeled "Hope IFPA" and numbered 001 to 999.

2.6 FIELD MEASUREMENTS

All field data were collected to CMI standards.[5] To meet the project objective that one plot be installed per day, the CMI plot design was altered so that only those measurements contributing directly to the project objectives were sampled. Thus the sampling procedures were:

1. *Plot Establishment:* The crew located the plot, inserted a metal stake at plot center, and recorded location using a Global Positioning System (GPS). Main Plot boundaries and sectors were identified.
2. *Tree Identification:* All trees greater than 9 cm diameter at breast height (DBH) were tagged with species and diameter recorded.
3. *Height Measurement:* All heights were measured on plots where the crew estimated the work could be completed in one day. When the crew estimated that all tree measurements could not be completed in one day, tree heights were first estimated and then 10 trees were randomly selected and measured for height. The intent was to reduce the time on the plot to ensure that measurements could be completed in one day. A ratio was developed between the measured and estimated height of each tree and applied to all estimated heights in the plot (herein called the random height adjustment method).[6,7,8]
4. *Call Grade & Net Factoring:* Call grade and net factoring data were collected on all trees in plots where all heights were measured. Where heights were developed using the random height adjustment method, call grade and net factoring data were collected on those 10 trees only, and a reduction factor was developed and applied to all trees in the plot (Appendix VI).

The crews measured the heights of all trees in 14 of the 45 plots. The remaining 31 plots used the height adjustment method detailed above.

The largest diameter tree of each species in each 100 m^2 quadrant was assessed for suitability for estimating PSI. The largest diameter tree in the north-east quadrant was used as the top height tree, and the largest diameter of the remaining species in all four quadrants were used for site trees (Appendix VI). Stump, coarse woody debris, and range data were not collected. A visual estimate of BEC site series was recorded on the Ecology Header (EH) card. A summary of non-standard CMI data collection is given in Appendix VII.

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[5] Ministry of Forests. 2001. Change monitoring inventory. Ground sampling procedures for the provincial change monitoring inventory program. BC Min. For., Res. Inv. Br. March 30, 2001. Version 1.1. 203 pp.

[6] The random height adjustment method was developed with help from Kim Iles, *PhD*. This procedure was approved by Joe Braz, *RPF* (MSRM, Terrestrial Information Branch) on September 19, 2001.

[7] In some plots, there was insufficient time to measure 10 trees, so the crews chose a number of trees to use in the adjustment that would allow them to complete the plot in one day.

[8] In the first week of sampling, the height ratio adjustment was developed using the measured height of site trees instead of random trees.

3. DATA MANAGEMENT

3.1 DATA ENTRY & ERROR CHECKING

Field data were entered using the MSRM software program *VIDE version 1.2.02*. Validation reports were generated by VIDE for each plot to check for completeness and anomalies. Corrections were made accordingly and edited data were submitted to MSRM for data compilation.

3.2 PLOT DATA COMPILATION

Gitte Churlish, *BSc* (MSRM) computed the tree volumes and JST compiled the plot summary statistics. Thirty-seven (37) of the 45 CMI plots were located in the timber harvesting landbase (THLB) and thus had yield tables for the polygons where the plots were located (Table 1, Appendix III).[9] One of the 37 plots did not contain any trees and therefore had no height or age measurement or estimates of volume and mean annual increment (MAI). PSI observations were available for the leading species on 38 plots.

Table 1. Statistics for the CMI sample plots.

Attribute	n	Mean	Min.	Max.	95% CI
Volume (m^3/ha)	37	254	0	808.0	[181, 327]
MAI (m^3/ha/yr)	37	4.7	0.0	13.3	[3.4, 6.0]
Height (m)	36	19.8	5.2	32.3	[17.4, 22.2]
Age (yrs)	36	53	18	120.0	[45, 61]
Site Index (m)	38	24	7	36	[22, 27]

3.3 INVENTORY DATA & YIELD TABLES

Measurements from the CMI plots were compared to the corresponding estimates from the inventory as used in the second innovative timber supply analysis.[2] The yield estimates for these the polygons where the plots were located were generated using *BatchVDYP version 6.6d* (plots in polygons >60 years) and *BatchTIPSY version 3.0a* for the three plots in polygons ≤60 years (Table 2, Appendix III).

Table 2. Polygon yield table statistics for the CMI plots in the THLB.

Attribute	n	Mean	Min.	Max.	95% CI
Volume (m^3/ha)	37	97.9	0.0	287.6	[70.4, 125.4]
MAI (m^3/ha/yr)	37	2.3	0.0	6.3	[1.8, 2.8]
Height (m)	37	14.9	5.4	23.8	[13.3, 16.5]
Age (yrs)	37	37.9	21.0	70.0	[33.2, 42.7]

3.4 POTENTIAL SITE INDEX

The CMI plot estimates of site index were compared to the PSI estimates in the inventory from the SIA project[1] (Table 3, Appendix V).

Table 3. PSI data statistics for CMI sample plots.

Species	n	Mean	Min.	Max.	95% CI
Ba	44	22.1	14.8	37.5	[20.8, 23.4]
Cw	44	22.5	16.1	30.4	[21.5, 23.4]
Fd	44	29.8	23.1	35.9	[28.8, 30.8]
Hw	44	22.6	15.6	30.2	[21.6, 23.6]

3.5 UTILIZATION STANDARDS

The utilization limit to determine volume and MAI for the CMI plots and yield table projections was 12.5 cm+ for stands ≤60 years and 17.5 cm+ for older stands. The CMI plot measurements of height, age, and site index were based on the measured trees (minimum 9 cm DBH). Yield table estimates for the same attributes had no minimum DBH limit. For this report, volume is net merchantable volume (whole-stem volume less top and stump, decay, waste, and breakage). CMI plot decay and waste were estimated using the MSRM loss factor equations. Yield table decay and waste were estimated using the loss factor equations associated with PSYU 193.

[9] Eight plots were located outside the THLB as defined in the second innovative timber supply analysis.

4. ANALYSIS & RESULTS

4.1 First Measurement Analysis

The analysis for the first measurement of these 45 CMI plots is conducted as an inventory audit. This focused on comparing the yield attributes (i.e., at a single point in time) of key stand and tree attributes from the CMI plots with the corresponding attributes in the inventory. The analysis of the second and subsequent measurements of these CMI plots will include similar comparisons at the time of measurements and a comparison of the growth (i.e., change) of these attributes between the measurement periods.

4.2 Comparison of Measured & Inventory Attributes

Sample plot and predicted values were determined for net merchantable volume, MAI, height, age, and site index. For each attribute, the difference between the plot and the predicted values was calculated as:

Difference = plot value – predicted value.

The average difference across all plots, or a subset of plots, is referred to as bias. A positive bias indicates predicted values under-estimate the observed value in the CMI plots, and a negative bias indicates predicted values over-estimate the values in the plots. Graphs showing the differences versus the inventory age are presented for each attribute (Figures 2-9). The 95% confidence intervals for the biases (average differences) were also calculated.

4.3 Volume & MAI

The plot volume was compiled using individual tree records above the minimum utilization standard. In 17 plots, the tree net merchantable volume was available for all trees. For the remaining 20 plots, net merchantable volume was only available for site trees (since only site trees had been net factored); however, whole-stem volume was available for all trees. An average ratio of net merchantable/whole-stem volume was computed for each of these 20 plots. The plot ratio was used to estimate net merchantable volume when absent. Attributes used in the comparison were:

- Stand volume = sum of the individual tree net merchantable volume multiplied by 25 (the tree factor for a 400 m^2 plot).
- Yield table volume = volume of the corresponding yield table for the polygon in which the plot was located at age indicated in the inventory.
- Plot age = average total age for all site trees in the plot.
- Plot MAI = plot volume divided by plot age.
- Inventory age = the VRI adjusted age (age at the end of the 1999 growing season).
- Yield table MAI = yield table volume divided by the inventory age.

The results showed that the average volume and MAI in the CMI plots was greater than the corresponding estimates in the inventory generated by the yield tables. The CMI plots showed a significant positive bias (under-prediction) for both volume and MAI (Table 4). The 95% confidence interval (CI) of the difference did not include zero, which indicates that the difference was statistically significant. The average difference was 156 m^3/ha for volume and 2.3 m^3/ha/yr for MAI. All CMI plots had merchantable volume, but the inventory yield tables for two plots did not show trees above the minimum utilization standard and thus did show merchantable volume (the CMI plot volumes for these two polygons was 97 and 122 m^3/ha). The difference in volume and MAI between the CMI plots and the inventory did not appear well correlated with inventory age (Figure 2, Figure 3), which suggests that age is under-estimated in the inventory.

Table 4. Volume and MAI statistics for the 36 CMI plots in the THLB.

Statistic	Volume (m^3/ha)				MAI (m^3/ha/yr)			
	CMI Plot	Yield Table	Difference (m^3/ha)	Difference (%)	CMI Plot	Yield Table	Difference (m3/ha)	Difference (%)
Mean	254	98	156	160	4.7	2.3	2.3	100
Min.	0	0	-134	-	0.0	0.0	-2.4	-
Max.	808	288	680	236	13.6	6.3	11.3	179
95% CI	[181, 327]	[70, 125]	[93, 219]		[3.4, 6.2]	[1.8, 2.8]	[1.2, 3.5]	

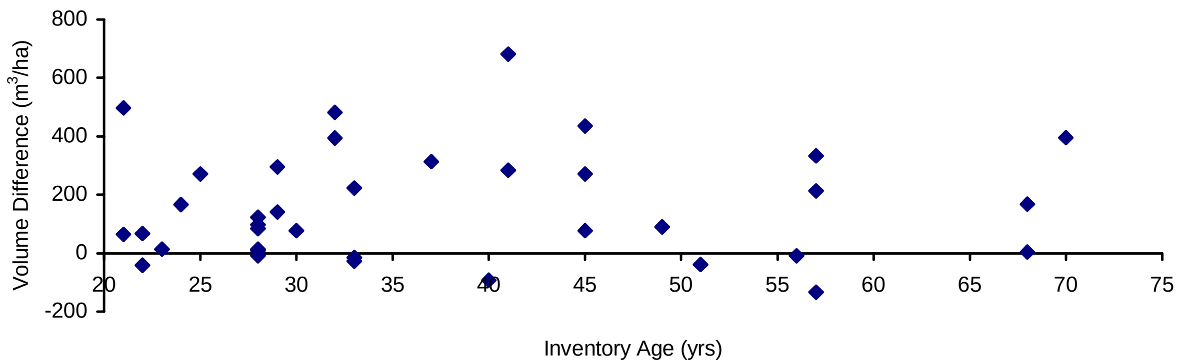

Figure 2. Difference between the CMI plot and yield table volumes by inventory age. Points above the x-axis show CMI plots with higher volumes than the yield tables.

Figure 3. Difference between the CMI plot and yield table MAI by inventory age. Points above the x-axis show CMI plots with MAIs higher than the yield tables.

4.4 HEIGHT

The CMI plot height was computed as the average height of site trees in the plot and the yield table height was the height from the table at inventory age. The sample plots showed a significant positive bias (under-estimation) for height (Table 5, Figure 4). The average height of the site trees in the CMI plots was 4.7 m higher than indicated in the inventory by the yield tables, which is statistically significant as shown by the 95% confidence interval not included zero (Table 5). The minimum height in the plots and the yield tables were both about 5 m, but maximum height in the yield tables was about 24 m and 32 m in the CMI plots. This height difference appears correlated with inventory age and there was more variability in height difference below 30 years than above 50. This may be the result of age under-estimation in stands below 30 years (Section 4.5).

Table 5. Height statistics (m) for the 36 CMI plots in the THLB.

Statistic	Plot	Yield Table	Difference
Mean	19.8	15.1	4.7
Min.	5.2	5.4	-5.3
Max.	32.3	23.8	18.7
95% CI	[17.4, 22.2]	[13.5, 16.7]	[2.7, 6.8]

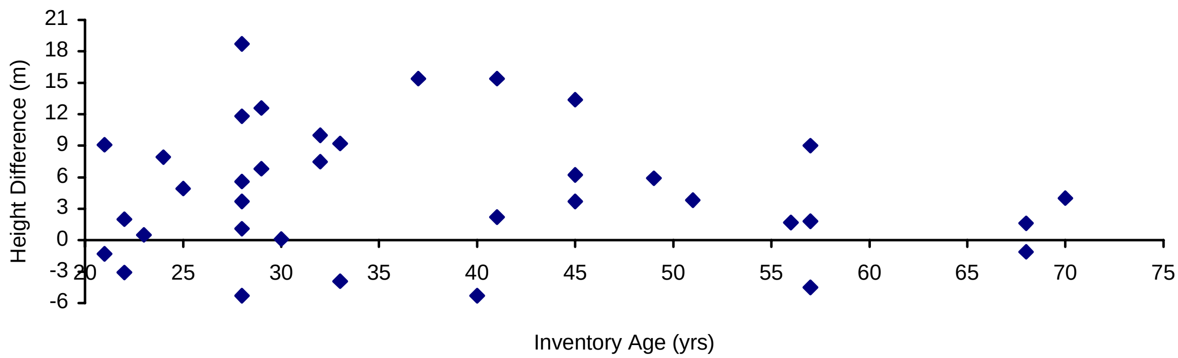

Figure 4. Difference between the CMI plot height and yield table height by inventory age. Points above the x-axis show CMI plots with higher heights than the inventory.

4.5 AGE

The CMI plot data show that age is significantly under-estimated in the inventory. On average, the average age of site trees in the CMI plots were 15 years older than the inventory age (Table 6, Figure 5). This large difference was not expected as the inventory age was recently updated using VRI methods. There are a few possible explanations for this underestimation. The MSRM criteria for adjusting age in the VRI may not be accurate for immature stands. It is also possible that residual trees were selected for age in some CMI plots. This age difference should be investigated further as it may also cause the under-estimation of other attributes.

Table 6. Age statistics (yrs) for the 36 CMI plots in the THLB.

Statistic	CMI Plot	Yield Table	Difference
Mean	53	38	15
Min.	18	21	-11
Max.	120	70	95
95% CI	[45, 61]	[33, 43]	[7, 22]

The comparison of age was repeated using plot age instead of inventory age to generate predicted values to test the sensitivity of age on the results. This showed that plot volume, MAI, and height were not statistically different from their corresponding yield table estimates when using plot age (Table 7).

Table 7. Difference statistics for volume, MAI, and height for the 36 CMI plots in the THLB.

Statistic	Volume (m^3/ha)	MAI (m^3/ha/yr)	Height (m)
Mean Diff.	-4.1	0.4	-0.6
Min. Diff.	-797.8	-7.8	-25.2
Max. Diff.	467.2	8.5	16.5
95% CI	[-87.5, 79.4]	[-0.9, 1.7]	[-3.4, 2.1]

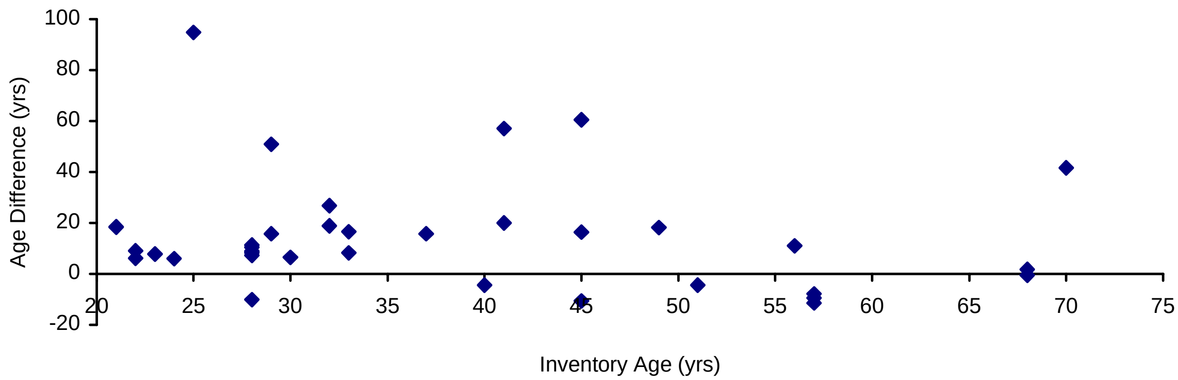

Figure 5. Difference between the CMI plot age and inventory age by inventory age. Points above the x-axis indicate yield table age under-estimates CMI plot age.

4.6 Site Index

The CMI plot site index was computed as the average PSI of all suitable site trees of the leading species in the plot. PSI was also computed separately for each species in the plot. Suitable site trees are the largest diameter dominant or codominant trees of each species in each 100 m^2 quadrant containing less than 5% observed height loss. The plot site indices were then compared to the SIA estimates for the polygon where each plot was located.

The plot site index for Fd and Hw (the two most important species for the timber supply analysis) were not statistically different from the PSI estimate on the inventory polygons assigned using the SIA results (Table 8). The average difference was -1.2 m for Fd (Figure 6) and -0.4 m for Hw (Figure 7). The 95% confidence interval for these differences included zero thus are not statistically different from the inventory.

Table 8. Fd and Hw PSI statistics (m) for the 45 CMI plots.

	Fd			Hw		
Statistic	CMI Plot	SIA	Diff.	CMI Plot	SIA	Diff.
n	29	29	0	31	31	0
Mean	27.6	28.8	-1.2	22.4	22.8	-0.4
Min.	18.4	23.1	-10.4	10.7	15.6	-8.8
Max.	36.3	35.9	8.1	33.2	30.2	9.2
95% CI	[25.7, 29.5]	[27.5, 30.0]	[-3.1, 0.7]	[20.2, 24.6]	[21.5, 24.1]	[-2.1, 1.3]

Table 9. Cw and Ba PSI statistics (m) for all 45 CMI plots.

	Cw			Ba		
Statistic	CMI Plot	SIA	Diff.	CMI Plot	SIA	Diff.
n	15	15	15	16	16	16
Mean	19.3	22.7	-3.3	19.6	23.0	-3.4
Min.	11.3	14.8	-7.3	7.8	17.9	-11.6
Max.	35.7	37.5	2.4	28.3	28.1	1.2
95% CI	[15.7, 22.9]	[19.9, 25.4]	[-4.9, -1.7]	[16.6, 22.6]	[21.3, 24.7]	[-5.6, -1.2]

For Cw and Ba (marginal species for timber supply analysis)[10] the SIA estimates were higher than the CMI plots and differences were statistically significant (Table 9). The sample size, however, was small for Cw (16 observations [Figure 8]) and Ba (15 observations [Figure 9])), thus additional sampling is needed to give more meaningful results.

[10] For future stands in the second innovative timber supply analysis, Cw was the leading species on 6% of the THLB and Ba was not used as a leading species.

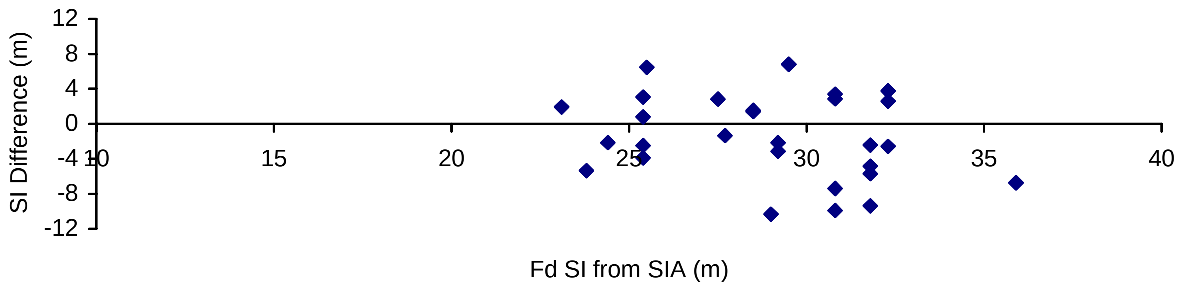

Figure 6. Fd site index – SIA site index (m) versus SIA site index (m). Points above the x-axis indicate SIA estimate under-estimates CMI site index for Fd.

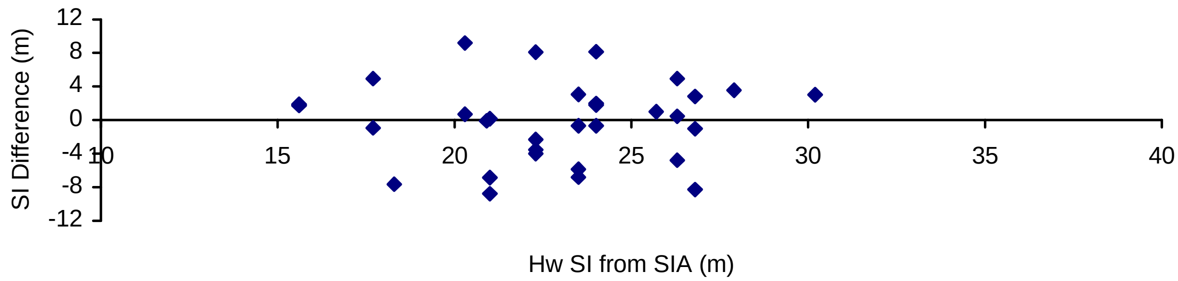

Figure 7. Hw site index – SIA site index (m) versus SIA site index (m). Points above the x-axis indicate SIA estimate under-estimates CMI site index for Hw.

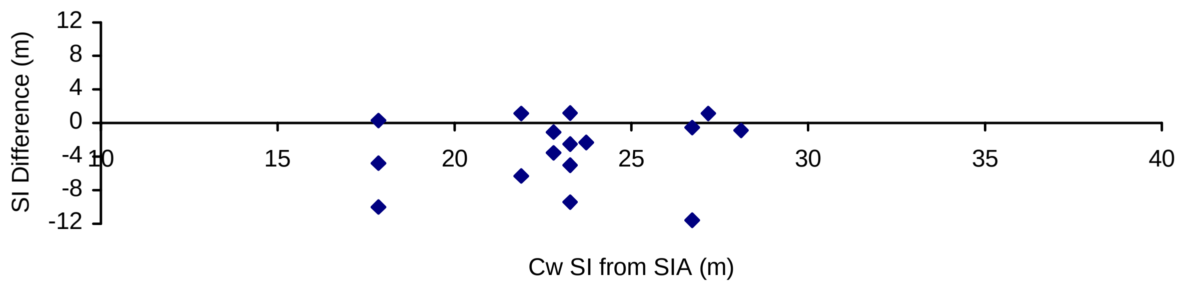

Figure 8. Cw site index – SIA site index (m) versus SIA site index (m). Points above the x-axis indicate SIA estimate under-estimates CMI site index for Cw.

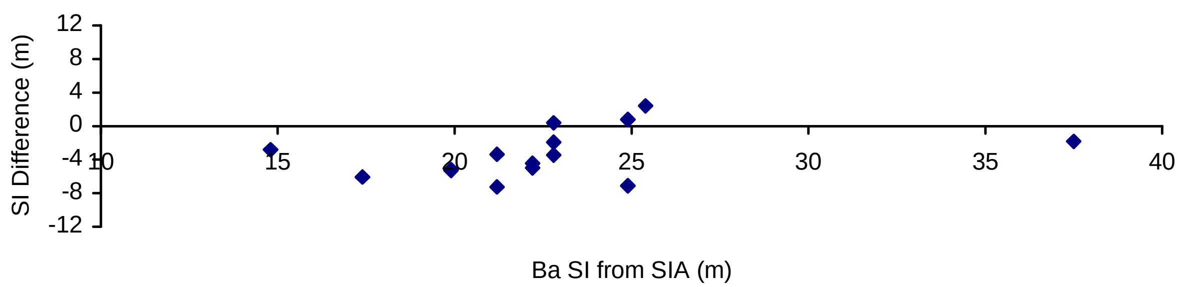

Figure 9. Ba site index – SIA site index (m) versus SIA site index (m). Points above the x-axis indicate SIA estimate under-estimates CMI site index for Ba.

5. CONCLUSIONS

5.1 INTERPRETATION OF RESULTS

1. ***The age of regenerated stands is under-estimated in the inventory.***
   The CMI plot data showed that age was under-estimated by 15 years (on average) in the inventory. This under-estimation has significant impacts on volume and MAI projections and can severely impact forest management decisions, green-up and adjacency restrictions, and timber supply projections. As a result of these low ages, merchantable volume was under-estimated by about 156 m^3/ha and height was under-estimated by about 4.7 m.

2. ***The yield curves accurately predict stand yield when age is corrected.***
   Comparison of volumes showed the CMI plots had more volume than indicated in the inventory; however, this difference was reduced and was not statistically significant when volume was predicted using the CMI plot age instead of inventory age. This suggests that the volume difference shown in this comparison is due to the age used to generate the yield estimate and not the yield table.

3. ***The PSI estimates for Fd and Hw are not statistically different from the inventory.***
   The CMI average plot site indices for Fd and Hw (the two most important species in the timber supply analysis) were not statistically different from the SIA estimates used in the innovative timber supply analysis. However, the CMI plots suggest that the PSI for Cw and Ba are over-estimated. The sample included only 16 observations for Cw and 15 for Ba, thus incorrect conclusions may be made because of the small sample size. If Interfor determines that these species are an important input into the yield tables, the CMI sample should be expanded to include at least 30 observations for these species.

5.2 SAMPLE METHODS & DESIGN

1. ***This sample design is reasonable to check yield curve predictions for the target population.***
   The sample design developed for this pilot was suitable for tracking the yield inputs into the second innovative timber supply analysis. Estimating tree heights followed by a statistical adjustment was a cost-effective method of producing accurate height estimates. Call grading and net factoring on a subset of trees was also a useful modification to the MSRM CMI standards. The sample size of 44 plots provided reasonable overall precision for the target population. Additional plots are needed to analyze a subset of this population.

2. ***The height estimation methods were efficient for data collection.***
   The height estimation method pilot tested in this project produced efficient results. This procedure of correcting estimated heights using an unbiased ratio allowed us to ensure that one CMI plot was installed per day and produced substantial cost savings.

3. ***Existing MOF/MSRM data management procedures were not efficient for this project.***
   The modifications made to the standard MOF plot design to meet Interfor business needs were not easily handled with the existing MOF/MSRM data entry, error checking, and compilation procedures.

6. RECOMMENDATIONS

6.1 Interpretation of Results

1. ***Examine the timber supply implications of the results of this analysis.***
   A significant under estimation of age in the inventory was found in this study. This means that at time zero in the timber supply analysis the initial condition of the stands sampled in this study were incorrectly modeled. The implications of this should be tested with additional timber supply analyses.

2. ***Determine the source of error contributing to the age difference.***
   A review of the procedures used to estimate inventory ages and to estimate ages in the CMI project should be done to determine the source of the differences. This could include examining silviculture history records to determine how many site trees selected in the CMI project were residuals. This should also include examining how the VRI process adjusts ages and if this may have caused this difference in ages.

6.2 Sample Methods & Design

1. ***Consider including whole stem volume in the yield curve database.***
   Including whole stem volume allows a check of stem volume below merchantable size. If both plot and predicted merchantable volumes are zero, then a zero difference is assumed. To detect a possible over or under-prediction of merchantable volume in the future, whole stem volumes are required.

2. ***Integrate this sample design into future CMI programs.***
   We modified the standard MSRM CMI procedures to collect data that contributed directly to Interfor's business needs. We also developed a method to adjust height estimates in each plot. These two changes ensured that one plot was installed per day, which produced substantial cost savings.

3. ***Modify data entry and compilation procedures.***
   The MSRM *VIDE* was not appropriate for these monitoring plots. We recommend that Interfor consider developing an in-house data entry program and compiler for the next CMI measurement. The MSRM programs should be revisited at that time; however, they will not be appropriate unless significant changes are made. Interfor should also consider using hand-held electronic data recorders for the next plot measurements.

4. ***Archive versions of the inventory used for sample selection.***
   Inventory updates will inevitably cause some areas to be reclassified into or out of the target population. In addition, as was demonstrated in this analysis, the version of the inventory being checked with the monitoring data may not be the same version used to select the plot locations. To avoid confusion, it is critical that the version of the inventory (including line work and attributes) used to select sample plot locations are archived.

6.3 Future Modifications

1. ***Expand the target population to include the productive portion of the MH and ESSF zones.***
   The productive portion of the MH and ESSF BGC zones comprises 35% of the IFPA's productive area (44,619 ha). In the second innovative timber supply analysis, the site index estimates used in

the yield tables for these areas were generated from the VRI database. These estimates tend to under-estimate the yield potential of regenerated stands in these areas. We recommend developing an elevation model to produce more accurate site index and volume estimates to input in the next timber supply analysis. The CMI program could be expanded to ensure that all regenerated yield projections in the timber supply analysis are accurate.

2. ***Adjust the plot re-measurement period to coincide with the Forestry Plan cycle.***
   Re-measuring these plots prior to each Forestry Plan will provide updated G&Y information for each timber supply analysis. The remeasurement period can be lengthened once there is better understanding of the yield in the target stands.

3. ***Review the contribution of these CMI plots to the PSP program.***
   These CMI plots are permanent sample plots (PSPs) that include the standard measurements for plots established for provincial growth and yield model development. Given that the MSRM has recently decided not to remeasure any of the provincial PSPs, Interfor should consider the use of these CMI plots to meet the needs of model development instead of funding a separate program.

APPENDIX I – LANDBASE NETDOWN

The IFPA area surrounds the town of Hope in the Chilliwack Forest District of the Vancouver Forest Region. The IFPA area is comprised of the Yale, Silverhope, and Manning Landscape Units and covers 194,456 ha. In the net down process to determine the CMI target population, the following areas were removed from the entire IFPA area:

1. Parks: 56, 900 ha
2. Non-crown, woodlot, non-forest: 11,956 ha
3. AT, ESSF, and MH BGC zones: 44,619 ha
4. Minor leading species: 12,468 ha
5. Polygons less than 21 years or older than 80 years: 46,600.

The final target population was 22, 272 ha (11% of the entire IFPA area).

Table 10. Area distribution in the Hope IFPA area by land classification type.

Land Type	Area (ha)	(%)
Total IFPA area	194,456	
Parks	56,900	29
Outside parks	137,556	71
Non-crown, woodlot, non-forest	11,596	6
Public forest	125,960	65
Non-CWH	44,619	23
CWH	81,341	42
Minor species	12,468	6
Ba, Cw, Fd, Hw-leading	68,873	35
Age < 21 or > 80	46,600	24
21 ≤ Age ≤ 80	22,272	11

APPENDIX II – SAMPLE PLOT INFORMATION

Table 11. Hope CMI sample list attributes and adjustment statistics.

Plot No.	Mapstand		GIS UTM Easting	Northing	Inv. Age (yrs)	Installed	Inside THLB	Measured Heights	Height Ratio Adjust.t	Call Grade Net Factoring
1	092H063	904	613904	5500201	45	Yes	Yes	Random	1.0036	Random
2	092H064	1227	619904	5500201	23	Yes	Yes	All	1.0000	All
3	092H064	542	617904	5498201	40	Yes	Yes	Random	1.0136	Random
4	092H063	2040	609904	5496201	28	Yes	Yes	All	1.0000	All
5	092H063	2040	611904	5496201	28	Yes	Yes	All	1.0000	All
6	092H064	841	621904	5496201	28	Yes	Yes	Random	1.0146	Random
7	092H054	1306	617904	5494201	56	Yes	No	All	1.0000	All
8	092H053	453	609905	5490201	28	Yes	Yes	All	1.0000	All
9	092H054	249	619905	5486201	22	Yes	Yes	All	1.0000	All
10	092H053	34	607905	5484200	33	Yes	Yes	N/A	N/A	N/A
11	092H053	44	609905	5484201	57	Yes	Yes	Random	1.0068	Random
12	092H053	56	611905	5484201	41	Yes	Yes	Random	1.0157	Random
13	092H044	1131	617905	5484201	28	Yes	Yes	Random	1.0118	Random
14	092H043	1058	611905	5482201	45	No	Yes	N/A	N/A	N/A
15	092H044	890	615905	5482201	68	Yes	Yes	Site	0.9208	All
16	092H043	810	609905	5480201	33	Yes	Yes	Site	0.8822	All
17	092H043	781	611905	5480201	51	Yes	No	Random	0.9962	Random
18	092H043	488	611905	5478201	57	Yes	No	Random	1.0407	Random
19	092H044	1189	617905	5478201	49	Yes	Yes	Random	0.8950	Random
20	092H043	429	609905	5476201	45	Yes	Yes	Site	0.9880	All
21	092H043	430	615905	5476201	80	No	Yes	N/A	N/A	N/A
22	092H043	216	615905	5474201	45	Yes	Yes	Random	1.0395	Random
23	092H033	445	605905	5466200	70	Yes	Yes	Random	1.0035	Random
24	092H033	454	611905	5466201	29	Yes	Yes	Random	0.9013	Random
25	092H033	221	611905	5464201	21	Yes	Yes	All	1.0000	All
26	092H033	272	613905	5464201	24	Yes	Yes	Random	1.0235	Random
27	092H033	14	603905	5462200	25	Yes	Yes	Random	1.0117	Random
28	092H033	64	613905	5462201	37	Yes	Yes	Site	1.0276	All
29	092H033	70	615905	5462201	33	Yes	Yes	Random	1.1001	Random
30	092H022	541	599905	5460200	28	Yes	Yes	Site	0.9986	All
31	092H022	763	599905	5458200	32	Yes	Yes	Random	0.9864	Random
32	092H023	923	601905	5458200	57	Yes	Yes	Random	0.9736	Random
33	092H023	682	603905	5456200	57	Yes	Yes	Site	0.9505	All
34	092H024	773	623905	5456201	56	Yes	Yes	Random	1.0240	Random
35	092H024	763	627905	5456201	68	Yes	No	Random	1.0289	Random
36	092H025	578	631905	5456201	49	Yes	No	All	1.0000	All
37	092H022	183	601905	5454200	35	Yes	No	Random	0.9766	Random
38	092H023	519	605905	5454200	30	Yes	Yes	All	1.0000	All
39	092H024	263	627905	5454201	21	Yes	No	All	1.0000	All
40	092H022	91	599905	5452200	32	Yes	Yes	Random	1.0114	Random
41	092H023	1457	613905	5452200	21	Yes	Yes	Random	1.0068	Random
42	092H024	166	617905	5452201	22	Yes	Yes	All	1.0000	All
43	092H012	924	599905	5450200	29	Yes	Yes	Random	1.0017	Random
44	092H014	1136	617905	5450201	41	No	Yes	N/A	N/A	N/A
45	092H014	1104	619905	5450201	51	Yes	Yes	Site	1.0483	All
46	092H015	1442	641905	5450201	49	Yes	No	All	1.0000	All
47	092H014	841	621905	5448201	41	Yes	Yes	All	1.0000	All
48	092H014	74	627905	5440201	68	Yes	Yes	Random	1.0168	Random

APPENDIX III – CMI PLOT DATA VS. YIELD TABLE PROJECTIONS

Table 12. Detailed statistics for the CMI sample plots.

		CMI Plot Data								Yield Table Projections			
						Site Index (m)							
Plot No.	Model	Volume (m^3/ha)	MAI (m^3/ha/yr)	Height (m)	Age (yrs)	Fd	Hw	Cw	Ba	Volume (m^3/ha)	MAI (m^3/ha/yr)	Height (m)	Age (yrs)
1	TIPSY	380.5	11.1	23.0	34	36.1	32.2			110.0	2.4	19.3	45
2	TIPSY	14.2	0.5	7.2	31	21.5		7.8		0.3	0.0	6.8	23
3	TIPSY	8.2	0.2	10.7	36	18.6	20.8			100.0	2.5	16.0	40
4	TIPSY	96.7	2.7	17.2	35	28.4				0.0	0.0	5.4	28
5	TIPSY	122.2	3.2	24.1	38	34.9				0.0	0.0	5.4	28
6	TIPSY	14.6	0.4	14.7	36	22.4		19.2		1.6	0.1	9.1	28
7	TIPSY	N/A	N/A	N/A	N/A	27.1				N/A	N/A	N/A	N/A
8	TIPSY	1.4	0.1	5.2	18	29.8	29.5			10.2	0.4	10.5	28
9	TIPSY	96.0	3.1	13.9	31	26.4				28.0	1.3	11.9	22
10	TIPSY	0.0	0.0							14.5	0.4	10.2	33
11	TIPSY	573.5	12.0	30.5	48		33.2		35.7	240.5	4.2	21.5	57
12	TIPSY	810.0	13.3	32.3	61	36.3	29.6	28.3		128.2	3.1	16.9	41
13	TIPSY	39.2	1.0	12.3	39				19.3	29.8	1.1	11.2	28
15	VDYP	135.2	1.9	19.4	70	18.4				131.4	1.9	20.5	68
16	TIPSY	37.2	0.9	10.2	41		16.7	13.8	17.3	64.8	2.0	14.1	33
17	TIPSY	N/A	N/A	N/A	N/A					N/A	N/A	N/A	N/A
18	TIPSY	N/A	N/A	N/A	N/A					N/A	N/A	N/A	N/A
19	TIPSY	165.4	2.5	18.9	67	22.9	16.7	13.1		75.5	1.5	12.9	49
20	TIPSY	535.8	8.7	30.6	61	32.0				100.5	2.2	17.2	45
22	TIPSY	296.9	2.8	28.7	106	22.2		21.4		219.5	4.9	22.5	45
23	VDYP	639.7	5.7	23.2	112		14.1		14.6	244.0	3.5	19.2	70
24	TIPSY	189.4	4.2	22.3	45	30.3	26.7			49.0	1.7	15.4	29
25	TIPSY	108.4	2.7	11.8	39		21.5	15.1	17.8	44.2	2.1	13.1	21
26	TIPSY	182.3	6.1	17.3	30	33.6	30.4			15.8	0.7	9.4	24
27	TIPSY	313.4	2.6	16.8	120		10.7		11.3	42.5	1.7	11.9	25
28	TIPSY	346.0	6.6	27.1	53	29.1	31.5	27.2		32.0	0.9	11.7	37
29	TIPSY	240.3	4.8	21.1	50		18.5			17.8	0.5	12.0	33
30	TIPSY	207.3	5.6	21.1	37	34.2				123.6	4.4	17.3	28
31	TIPSY	518.7	10.2	24.2	51		26.7	26.2		124.6	3.9	16.7	32
32	TIPSY	82.5	1.8	16.5	46	23.4	18.8			216.4	3.8	21.1	57
33	TIPSY	453.5	9.2	23.2	49	29.7	25.8	24.4		240.5	4.2	21.5	57
34	TIPSY	134.2	2.0	17.1	67		18.3		13.9	143.0	2.6	15.4	56
35	TIPSY	N/A	N/A	N/A	N/A		20.0	15.6	17.8	N/A	N/A	N/A	N/A
36	TIPSY	N/A	N/A	N/A	N/A	26.2	22.6	18.1		N/A	N/A	N/A	N/A
37	TIPSY	N/A	N/A	N/A	N/A	29.3	26.5			N/A	N/A	N/A	N/A
38	TIPSY	140.5	3.8	14.9	37		26.0	20.7	23.2	63.0	2.1	14.8	30
39	TIPSY	N/A	N/A	N/A	N/A		17.5		12.0	N/A	N/A	N/A	N/A
40	TIPSY	605.8	10.3	26.7	59		25.8		27.8	124.6	3.9	16.7	32
41	TIPSY	536.3	13.6	21.8	40		23.3		20.9	39.6	1.9	12.7	21
42	TIPSY	9.0	0.3	9.8	28	25.0	17.4			50.8	2.3	12.9	22
43	TIPSY	477.4	6.0	31.6	80		31.2		25.7	181.8	6.3	19.0	29
45	TIPSY	134.3	2.9	23.1	47	30.0	21.0			173.2	3.4	19.4	51
46	TIPSY	N/A	N/A	N/A	N/A		12.2		14.7	N/A	N/A	N/A	N/A
47	TIPSY	436.3	4.5	19.6	98	20.9		23.0		152.7	3.7	17.4	41
48	VDYP	454.9	6.7	25.4	68	26.1	21.1			287.6	4.2	23.8	68

APPENDIX IV – GPS PLOT LOCATIONS

Table 13. GPS post-processed plot center (PC), tie point (TP), and access point (AP) locations.

Plot	Loc.	Northing	Easting	Elev. (m)
1	PC	5500179	613902	456
1	TP	5500182	613663	491
2	AP	5500192	619301	639
2	PC	5500195	619902	927
2	TP	5500206	619568	769
3	PC	5498183	617908	885
3	TP	5498157	617878	855
4	AP	5496476	609804	1169
4	PC	5496190	609895	980
4	TP	5496182	609843	994
5	AP	5495881	610926	672
5	PC	5496190	611898	594
6	AP	5495834	621750	864
6	PC	5496196	621898	871
6	TP	5496174	621908	853
7	AP	5494392	617769	994
7	PC	5494191	617897	869
7	TP	5494338	617728	937
8	AP	5490985	610614	944
8	PC	5490203	609907	942
8	TP	5490233	609893	967
9	AP	5487009	619875	1281
9	PC	5486209	619909	926
9	TP	5486159	619833	843
10	AP	5483972	608182	605
10	PC	5484214	607904	745
11	PC	5484181	609879	427
11	TP	5484267	609943	399
12	AP	5484674	611869	252
12	PC	5484213	611914	372
12	TP	5483875	611875	393
13	AP	5484208	618090	1172
13	PC	5484194	617913	1078
13	TP	5484380	617993	1075
15	PC	5482137	615917	371
15	TP	5482162	615586	225
16	AP	5480396	609028	742
16	PC	5480222	609901	908
16	TP	5480235	609788	848
17	AP	5481728	612161	314
17	PC	5480190	611850	481
17	TP	5480167	612017	541
18	PC	5478181	611895	544
19	AP	5478239	618694	1217
19	PC	5478194	617910	1039
19	TP	5478215	617889	1021
20	AP	5476051	610146	422
20	PC	5476200	609891	460
21	AP	5476598	615928	293
21	PC	5476218	615912	369
21	TP	5476255	615928	364
22	PC	5474188	615894	475
22	TP	5473956	615872	366
23	PC	5466201	605904	1089
23	TP	5466181	605882	1069
24	AP	5466595	611846	137
24	PC	5466209	611915	432
24	TP	5466194	611927	429
25	PC	5464199	611894	948
25	TP	5464331	611833	915
26	AP	5464193	614293	408
26	PC	5464176	613901	634
26	TP	5464227	614069	533
27	AP	5461715	604741	774
27	PC	5462202	603910	1086
27	TP	5462161	604034	1140
28	AP	5462289	613861	530
28	PC	5462191	613908	545
29	AP	5462229	616350	333
29[a]	PC	5462223	615907	383
29	PC	5462219	615920	415
29	TP	5462418	615932	329
30	AP	5459726	600469	431
30	PC	5460193	599889	646
30	TP	5460276	599926	594
31	AP	5458340	600117	573
31	PC	5458201	599902	599
31	TP	5458194	599953	603
32	PC	5458191	601906	911
33	PC	5456185	603885	806
33	TP	5455980	604109	761
34	AP	5456040	623979	1125
34	PC	5456204	623908	1199
34	TP	5456141	623900	1184
36[a]	PC	5456189	631889	991
36	TP	5456810	632189	636
36	PC	5454198	601904	708
37	TP	5454421	601673	636
38	AP	5453965	605939	905
38	PC	5454192	605893	930
38	TP	5454134	605828	896
39	PC	5454203	627898	1215
39	TP	5454276	628123	984
40	AP	5452241	600142	618
40	PC	5452204	599898	728
40	TP	5452291	600068	664
41	PC	5452197	613912	700
41	TP	5452256	613898	697
42	AP	5452455	617637	478
42	PC	5452214	617901	713
42	TP	5452178	617969	723
43	PC	5450214	599910	766
43	TP	5449845	600247	1060
44	AP	5450468	617655	1109
44	PC	5450178	617892	968
44	TP	5450433	617645	1112
45	AP	5449814	619539	501
45	PC	5450195	619901	603
45	TP	5450249	619874	595
46	AP	5448828	642716	1472
46	PC	5450205	641925	1376
46	TP	5450078	641709	1269
47	PC	5448223	621908	867
47	TP	5447765	621583	604
48	AP	5440134	627950	1168
48	PC	5440191	627916	1102
48	TP	5440119	627944	1169

[a]identifies more than one GPS reading for the same location.

APPENDIX V – PSI ESTIMATES FROM THE SIA PROJECT

Table 14. SIA PSI estimates (m) for the 44 CMI plots.

Plot No.	Fd	Hw	Cw	Ba
1	32.3	24.0	24.0	22.8
2	25.4	17.7	17.9	16.7
3	29.0	20.9	20.6	19.8
4	25.4	17.7	17.9	16.7
5	32.3	24.0	23.3	22.8
6	31.8	23.5	22.8	22.2
7	29.2	21.0	20.7	19.9
8	28.5	20.3	20.2	19.3
9	27.7	19.7	19.6	18.6
11	35.4	30.2	30.4	37.5
12	29.5	26.8	27.2	30.1
13	32.3	24.0	24.0	22.8
15	23.8	22.2	22.9	25.4
16	31.8	23.5	23.3	22.2
17	31.8	23.5	23.3	22.2
18	31.8	23.5	22.8	22.2
19	25.4	17.7	17.9	16.7
20	25.5	24.6	25.3	25.4
22	24.4	23.0	23.7	25.4
23	29.2	21.0	20.7	19.9
24	27.5	25.7	26.0	27.5
25	34.4	26.3	26.7	24.9
26	30.8	22.3	21.9	21.2
27	26.2	18.3	18.4	17.4
28	35.9	27.9	28.1	26.5
29	29.5	26.8	26.7	29.7
30	30.8	22.3	21.9	21.2
31	34.4	26.3	26.7	24.9
32	30.8	22.3	21.9	21.2
33	32.3	24.0	23.3	22.8
34	30.8	22.3	21.9	21.2
35	30.8	22.3	21.9	21.2
36	25.4	17.7	17.9	16.7
37	31.8	23.5	22.8	22.2
38	32.3	24.0	23.3	22.8
39	23.1	15.6	16.1	14.8
40	34.9	26.8	26.3	25.4
41	32.3	24.0	24.0	22.8
42	23.1	15.6	16.1	14.8
43	34.4	26.3	25.1	24.9
45	28.5	20.3	20.2	19.3
46	29.2	21.0	20.7	19.9
47	30.8	22.3	21.9	21.2
48	29.2	21.0	20.7	19.9

APPENDIX VI – DETAILED FIELD MEASUREMENTS

Tree Tagging

All trees greater than 9.0 cm DBH in the 11.28 m plot were measured and tagged at breast height.

Top Height Tree

The height and age of the largest diameter tree in the first quadrant was measured. This tree is the top height tree and was identified as the "T" tree. The CMI standard is to select this tree from the 5.64 m radius plot; however, selecting from the first quadrant better suits the 11.28 m radius plot design.

Site Trees

The height and age of the largest diameter suitable tree of all species in each quadrant were measured. These trees were noted as to whether or not they are suitable for estimating site index. Due to time restrictions on the plot, Leading trees (L trees), Second trees (S trees), and Other trees (O trees) were defined at the conclusion of the sampling.

Tree Heights

Tree heights were determined using two methods. On plots where all tree heights in the plot could be measured in one day, all heights in the plot were measured. In plots where all heights could not be measured, a 10-tree adjustment method was used. In this procedure, all tree heights were estimated first.[11] Once all heights in the plot were estimated, 10 trees were selected using the random table generator, and the heights of these trees were measured. A ratio of means between the 10 measured and estimated heights was applied to the estimated heights of all trees in the plot. In some cases, the crews did not have sufficient time to collect the measured heights on 10 trees so less than 10 randomly selected trees were measured.

Call Grade/Net Factoring

In plots where all tree heights were measured, the call grade/net factoring was done on all trees. On those plots that used the random height adjustment method, call grade/net factoring was done on the 10 randomly selected trees. In this case, the results of the call grade/net factor from these 10 trees were applied to the rest of the plot. Less than 75% of the plots are less than 40 years and so decay did not have a large impact on plot volumes.

[11] At the beginning of the project all heights were estimated using ocular estimates. In the second half of the project, heights were estimated using a Vertex.

APPENDIX VII – PLOT MODIFICATIONS FROM MSRM CMI STANDARD

Table 15. Comparison of Hope CMI and MSRM CMI data collected.

Attribute	MSRM CMI Standard	IFPA CMI Data
Plot Establishment		
Tree tags	Tags affixed at stump height	Tags affixed at breast height
Plot Measurements		
Range data	Collected	Not collected
Coarse woody debris data	Collected	Not collected
Ecology data	Collected	Visual estimation of site series
Tree Measurements		
Small-tree plot	Collected	Not collected
Regeneration plot	Collected	Not collected
Height	Always measured	Estimated, then statistically adjusted
Top Height	Chosen in 5.64-m plot	Northeast quadrant of 11.28-m plot
Second Species Height & Age	Collected	Not collected
Stem map	Collected	Not collected
Stumps	Collected	Not collected