BULKLEY TSA
PREDICTIVE ECOSYSTEM MAPPING (PEM)
LEVEL 4 ACCURACY ASSESSMENT
SECOND ASSESSMENT

Final Report 2009

A Forest Investment Account (FIA) Project
Completed on Behalf of:
Pacific Inland Resources Ltd (PIR).
(a Division of West Fraser Mills Ltd.)
Smithers B.C.

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EXECUTIVE SUMMARY

Ecological land classification is recognized to be a valuable natural resources management tool with wide applications. Terrestrial ecosystem mapping (TEM) and predictive ecosystem mapping (PEM) have been completed for large portions of British Columbia. In order to increase and assess the usefulness of TEM and PEM it is important to know the accuracy the mapping product.

The following report is the second of two accuracy assessments completed in 2009 by Bio-Geo Dynamics Ltd on the 2009 PEM mapping of the Bulkley Timber Supply (TSA). The Bulkley TSA PEM and PEM accuracy assessments (PEM AAs) are Forest Investment Account (FIA) funded projects, coordinated by Pacific Inland resources Ltd. (A Division of West Fraser Mills Ltd). Both projects were administered by Jay Baker of Silvicon Services Inc. This second PEM AA was undertaken to assess the accuracy of the PEM after December 2009 revisions were undertaken after the first PEM report (Simonar and Migabo, 2009).

Bio-Geo Dynamics Ltd, along with the assistance of GIS specialists Digitec Consulting, completed this Bulkley PEM AA utilizing small area triangle sampling AA approach as outlined in "*Protocol for Map Accuracy Assessment of Ecosystem Maps*" (Meidinger 2003) and "*A protocol for assessing thematic map accuracy using small-area sampling*" (Moon *et. al,* 2005).

An important aspect of the Bulkley PEM includes its potential use for ecosystem based Timber Supply Review (TSR). Consequently the PEM AA focused on measuring the mapping accuracy of forested climatic units. Eight forested climatic units comprising the bulk of the commercial forest in the Bulkley TSA were audited. Twenty seven pairs of sample triangles were field surveyed. The survey utilized a stratified random sample design in rough proportion to the landscape representation of the eight largest climatic units.

Three different statistical analyses were used to assess map reliability. These included, percent overlap, dominant correct and entity proportions. In the field we recognized situations where ecosystems were transitional or were difficult to determine on the ground. In these instances we assigned an alternate ecosystem designation. These alternate designations were includes in our analyses.

The highest accuracy results included alternate ecosystem assignments. The highest accuracy score for dominant correct was 59.3% and percent overlap 68%. The dominant correct score is below the 65% minimum AA score required for using TEM or PEM mapping for ecosystem based TSR analysis. Recommendations for improving map reliability are included in the report.

Please find attached, in Appendix 1, a response letter to this accuracy assessment from the Ministry of Forests and Range, providing acceptance of the PEM and this PEM AA.

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Acknowledgements

We thank Jay Baker RFT of Silvicon Services Inc. and Gary Quanstrom RPF of PIR for their material assistance with the fieldwork logistics as well as their input on the report and report findings. Thanks to MOFR ecologists Allen Banner and Will Mackenzie for input and advice on data analysis and review of the draft report. We appreciated the safe, professional safe services of Highland Helicopters. We acknowledge the Forest Investment Account (FIA) for the funding of this important project.

1.0 INTRODUCTION

1.1 Background

Ecosystem mapping is a potentially useful management tool for forest harvesting, silviculture planning, forest yield prediction, wildlife habitat assessment, and measuring and reporting out on ecological indicators. However, for ecosystem mapping to be useful, the relative accuracy or reliability of the final map product must be known.

In 2002-2003 Pacific Inland Resources Ltd. (a division of West Fraser Mills Ltd.) coordinated a Forest Investment Account (FIA) funded, Predictive Ecosystem Mapping (PEM) project of the Bulkley Timber Supply Area (TSA). A PEM Accuracy Assessment (PEM AA) was completed on this project in 2004. The PEM thematic accuracy was below the minimum threshold of the 65% required for approval for use for ecosystem based timber supply analysis. Subsequently, Silvicon Services Inc., on behalf of Pacific Inland Resources Ltd. and the Wetzin'Kwa Community Forest Corporation, administered a follow-up project to improve on the mapping accuracy of the existing PEM. This new PEM project was completed by Timberline Resource Group in 2009.

A second PEM accuracy assessment was tendered by Silvicon Services Inc. in 2009. Bio-Geo Dynamics Ltd (Bio-Geo) was chosen to undertake the second accuracy assessment. Fieldwork for the 2009 field season was completed by, Ken Simonar and Saphida Migabo, senior terrestrial ecologists at Bio-Geo Dynamics Ltd. Field data collection was completed in August of 2009. The field data was then analysed with the assistance of Digitec Consulting. A PEM AA report was completed in October to November 2009, by Ken Simonar and Dr Saphida Migabo of Bio-Geo Dynamics Ltd. (Simonar and Migabo 2008). The results were much improved from the 2004 PEM. Accuracy scores however were still lower than the minimum threshold required by ecosystem based timber supply analysis. Subsequently, improvements to the 2009 PEM were completed by the mappers. This second 2009 PEM AA report describes the results of these last PEM improvements as well as providing suggestions for future improvement of the PEM product.

1.2 Study area

The Bulkley TSA PEM comprises 762,733. The 2009 Bulkley PEM AA was specifically designed to provide a measure of accuracy for ecosystem based Timber Supply Review (TSR) purposes. Therefore only climatic units with commercial forests were appraised. Nine forested biogeoclimatic (BGC) units are found within Bulkley TSA these are: the SBSdk, SBSmc2, ESSFmc, ESSFwv, ESSFmk, ICHmc1, ICHmc2, MHmm2 and CWHws2. One climatic unit, the ESSFmk comprises only 2288.8 ha of the Bulkley TSA land base. Because of its small size this climatic unit was excluded from the accuracy assessment. The remaining eight forested climatic units comprise 563,434 ha. See Table 1 below showing the areas within each climatic unit stratified by landscape designation. Within the remaining eight forested climatic units the areas of private land, private woodlots, agricultural lands and lakes were excluded from the PEM AA leaving a net study area of 485,204 ha.

Table 1. Bulkley TSA PEM AA Climatic Unit Summary.

Climatic Unit	Total Area Ha.	Woodlots Ha	Private Ha.	Agriculture Ha.	Lakes Ha.	Net Sample Area Ha.
SBSmc2	230,947	5,631	5,057	2,804	4,420	**213,035**
SBSdk	70,557	987	42,155	5,474	1,995	**19,946**
ESSFmc	140,639	8	369	0	1,129	**139,133**
ESSFwv	44,124	110	6	0	527	**43,481**
ICHmc1	32,751	995	386	30	168	**31,172**
ICHmc2	21,419	1156	2208	1,970	431	**15,654**
CWHwc2	10,668	0	0	0	157	**10,511**
MHmm2	12,329	0	0	0	57	**12,272**
TOTAL	563,434	8887	50,181	10,278	8884	**485,204**

2.0 METHODS

2.1 Field Sampling

2.1.1 Brief Overview of Ecosystem Field Sampling and Identification

A level 4 accuracy assessment was conducted according to methods outlined in the following documents:

- A Protocol for Assessing Thematic Map Accuracy Using Small-Area Sampling. Moon et al. (2005)

- Protocol for Accuracy Assessment of Ecosystem Maps. Meidinger (2003).

The primary field assessment technique we employed was the small area sampling protocol employed by Moon et al (2005). The sampling protocol involves establishment of randomly placed equilateral triangle traverses, 1500m long and 500m per side. This is similar to the polygon based line intersect method employed in Meidinger et al (2003) except that the small area method is independent of PEM polygon boundaries while line intercept traverses are entirely within individual polygon boundaries. For more detail on the field methodology for both techniques, please refer to Moon et al (2005) and Meidinger et al (2003)

Each ground traverse was completed with the aid of GPS units as well as compass and hip chain. Ecosystem boundary changes were recorded on GPS units as well as in field note cards. Ecosystem descriptions for each ecosystem were recorded on GIF forms according to methods outlined in the "Field Manual for Describing Terrestrial Ecosystems" (Province of British Columbia 1998). This information was used to assign a site series to the traverse segments.

Both senior ecologists, listed in the introduction, completed the work as one two person field crew. This insured consistency of interpretation as well as maintaining a rigorous internal quality control with each ecosystem call being corroborated between the two senior ecologists.

2.1.2 Sampling in 2009 Field Season

Previous samples from 2004 had been used to help to build the 2009 PEM knowledge base, therefore a complete new set of audit samples was required. We used our experience in the 2007-2008 audits of the neighbouring Lakes and Morice TSA PEMs in designing a sample pan for the Bulkley PEM AA. The intra-climatic unit variability in the Morice TSA was quite variable and required almost double the number of samples as the Lakes TSA in order to acquire a statistically reliable sample set. The adjoining Morice TSA shares many of the same climatic units as the Bulkley TSA. It shares some of the same physiography as well. In the Morice we required 52 samples to complete a statistically accurate enough sample set to pass minimum reliability objectives.

Based on this forgoing information, we estimated that a set of 54 samples might be adequate for the Bulkley PEM AA. Field sampling is time consuming and expensive. In order to maintain statistically reliable sampling, while insuring cost efficiency, we were allowed by NIFR regional and provincial ecologists to complete the triangle samples in pairs 500 metres apart. Twenty seven triangle pairs were chosen from the net sample area in a stratified random sample roughly proportionate to the area of each of the eight targeted climatic units. Each climatic unit featured a minimum of one triangle sample pair. The samples were chosen as illustrated in Table 2 below.

Table 2. Stratified Random Sampling Design for the Bulkley PEM AA.

BEC Unit	Area (ha)	%	Sample (Y or N)	Samples per BEC	Sample Pairs
SBSmc2	213,035	44	**Y**	24	12
SBSdk	19,946	4	**Y**	2	1
SBS	**231,981**	**48**		**26**	**13**
ESSFmc	139,113	29	**Y**	14	7
ESSFwv	43,481	9	**Y**	4	2
ESSF	**182,594**	**38**		**18**	**9**
ICHmc1	31,172	6	**Y**	4	2
ICHmc2	15,654	3	**Y**	2	1
MHmm2	12,272	2	**Y**	2	1
CWHws2	10,511	2	**Y**	2	1
Cedar - Hemlock	**69,609**	**14**		**10**	**5**
Total	**485,204**	**100**		**54**	**27**

Samples were rejected and another one chosen if one or more of the sample pair set was outside the study area, or less than 50% forested or if the sample pair was divided by an impassable river or steam An additional set of replacement 13 sample pairs were chosen as replacements for the original sample set in the event the one or more of the sample triangle in a pair were unsafe to traverse due to water or terrain hazards or if the sample pair was not able to be completed by either ground or helicopter access during the course of an entire field day.

Ultimately only three triangle pairs required replacing and the field work was completed before the end of August 2009. This allowed enough time for a quick preliminary assessment of sample size adequacy in time for completing extra sampling in September 2009, if that was required. As described below in the office analysis section, we found that the initial 54 samples collected met the minimum sampling intensity required for TSR based PEM AA standards.

2.2 Office Analysis

2.2.1 Data Table creation

Data table creation is the first step in data analysis Field data from these transect notes were summarized and analysed according to methods outlined in Meidinger (2003). Data from the field assessment (**observed**) was juxtaposed with map entities (**expected**) based on PEM polygon designation, the information was further grouped according to biogeoclimatic (BGC) unit to determine accuracy within a BGC unit and for illuminating error trends. Comparison tables were produced in Database spreadsheets which enabled us to carry out statistical analyses on our results.

For creation of comparison tables using the small area protocol, the basic unit used for comparison is the triangle transect and pure ecosystem sections (segments) within it. A 30 m buffer is established around each traverse to create small areas. The basic PEM map units are 20X20 meter raster polygons, each identified by a unique ecosystem site series label of up to three site series. Contiguous 20X20 meter square raster polygons sharing the same ecosystem label can be combined into "super polygons". The buffered audit triangle is overlain over top the PEM map raster based polygons. The overlap of individual ecosystem audit small areas with the corresponding area of PEM map areas within a triangle transect is appraised. As well we compared the sum of total area of individual ecosystems along with the entire transect, with the sum of the individual ecosystem area being overlapped on the PEM map. Comparison tables are created to allow comparison of overlap triangle and map units. A hypothetical comparison table is outlined in Table 3 below. Details of specific statistical analyses in relation to comparison tables are described below.

2.2.2 Statistical Analyses

2.2.2.1 STATISTICAL METHODS AND ENTITY PROPORTION

Three analysis methods were utilized to assess accuracy of the mapped units on these two datasets. The first of these methods consisted of a comparison of dominant unit between observed and expected. Dominant unit (ecosystem site series) was scored as being either right (100%) if the expected dominant site series unit was the same as the dominant observed or wrong (0%). In the instance of the small area triangles this equals the sum of individual site series segment areas actually encountered for each triangle, compared with the sum of the areas represented by each individual site series overlapped on the PEM map. Each entire triangle is therefore awarded either a 100% or a 0% dominant correct score. The dominant correct score for the project is the sum of dominant right score triangles divided by the total number of assessed triangles. An example calculation of dominant correct for triangle is presented below.

The second method consisted of assessing the direct percent overlap of expected versus observed triangle proportions. The following Table 3 presents an EXCEL table example condensed from our Dbase analysis tables employed for the project.

Table 3. Example of PEM Data and Evaluation of Percent Overlap and Dominant Correct

Triangle "plot"	bec	Side "edge id"	Field Section "stn #"	MAP Site Series	Field Alt Site Series	Section Length/ Area	Field Site Series	Field / Field Alt SS
B1-1	MHmm2	1	1	01		200	01	01
B1-1	MHmm2	1	1	03		100	01	01
B1-1	MHmm2	1	2	01		200	03	03

This table represents one 500m side of a triangle traverse. It can be seen above that there are two site series field audit sections identified along the first arm (side/edge) of the triangle traverse. The first one is 300 metres long and is comprised of the MHmm2-01 (zonal) site series. The overlapping PEM map area traveled by that 300 metre field traverse section is comprised of 1/3 (100m) MHmm2-03 and 2/3 (200m) MHmm2-01. The next field section, Field Section 2, 200m in length was identified to be MHmm2-03 in the field and predicted to be MHmm2-03 on the PEM map.

From the table we can calculate that along the entire triangle side there actually exists a total of 300m of 01 and 200m of 03 in the field, while the PEM map predicts 400m of 01 and 100m of 03. To simplify analysis and to apply our analysis to a whole sample triangle, assume that the above proportions hold true for the entire triangle traverse.

To determine the percent dominant correct statistic for this triangle we compare the field ecosystem with the largest representation with the PEM ecosystem with the largest representation. In this instance site series 01, at 300/500 (60%) in the field and 400/500 (80%) in the PEM, is the dominant ecosystem. Therefore the sample is awarded a dominant correct score of 100%.

To calculate the percent overlap statistic for our sample triangle we compare the cumulative overlapping percentage for all (forest) site series within the triangle. Unless the percentages are the same, we chose the lesser percent score to represent the overlap. For the 01 the PEM achieves 80% while the field achieves 60% representation, therefore the percent overlap between the two is 60%. Similarly the 03 achieves 40% presence in the field compared to 20% in the PEM. Therefore the percent overlap for between the two for the 03 is 20%. The cumulative percent overlap representing the entire triangle, considering all forest ecosystems (01 and 03), is 60% plus 20% which equals 80%.

The third method, entity proportions graphing, consists of graphically depicting the proportions of each site series found in the sampled data compared with that predicted by the PEM mapping. This can help point out possible error trends in the PEM mapping, which may be useful in making mapping rule adjustments.

2.2.2.2 USING ALTERNATE CALLS

If there are ecosystem transitions in the field or if it is impossible to distinguish between two ecosystems on the ground, then the ecosystem proportions score for the traverse can be amended to reflect this uncertainty. If overlapping of the PEM ecosystem attributes with this amended traverse dataset gives a higher score for dominant correct and percent overlap, then that score is allowed to stand. The benefit of the doubt is then accorded to the PEM mapping product.

2.2.2.3 AREA WEIGHTING

TSR analysis is based on area. In PEM polygon based accuracy assessment methods, area is relevant. Area weighting recognizes the effect of larger than average polygons which may represent a significant area of the landscape. Hypothetically, if the whole landscape consisted of the two polygons and if the first one represented 90% of the area (or 90% of the sample set) and remaining sample polygon represented only 10% of the area (or 10% of the sample set) then one can easily see the effect that this would have on the relevance of the dominant correct and percent overlap scores regarding the true map accuracy over the entire landscape. As a consequence area weighting of dominant correct and percent overlap scores is a very important component of the mapping assessment score, particularly for TSR purposes. Note however, in the case of our small area triangle sampling methodology, that all our sample entities (equilateral triangles of approximately 500m per side) are essentially all the same size. Therefore the weighted and non-weighted dominant correct and percent overlap statistics are identical as well.

3.0 RESULTS AND DISCCUSSION

The results and discussion section it divided into five sections. The first section presents results of percent overlap and dominant correct statistics. The second section shows the calculation of the reliability of the audit sample set. The third section displays forested ecosystem entity proportions. The fourth section is a discussion of the results in relation to the possible combining of similar ecosystems as PEM map entities. Section five is a brief introduction to error trends in PEM mapping.

3.1 Bulkley TSA PEM Audit Accuracy Assessment Scores

Two different sets of analyses were carried out on the PEM database. One analysis included the mapped accuracy of all ecosystems encountered within the Audit sample transects. The other analyses appraised only the accuracy of the portion of the traverse populated by potentially merchantable forest ecosystems. Non-forest ecosystems and non-commercial ecosystems were netted out before this analysis was completed. The results are presented separately below.

3.1.1 All Ecosystems: Accuracy Assessment Scores

3.1.1.1 OVERALL AREA STATISTICS - ALL ECOSYSTEMS

The overall map area results of the small area sampling method are shown in Table 4. The results of the first and second 2009 PEM audits are presented. Percent overlap exhibited a substantial leap in accuracy from the mapping improvements completed in December 2009. The first score for alternate ecosystem percent overlap was 61.7%. The percent overlap score on the December 2009 revised database jumped to 68%. The alternate dominant correct score changed from 57.4% to 59.3. The relatively low dominant correct scores relative to percent overlap scores and compared with other PEM maps is likely a function of terrain/ecosystem pattern complexity in the Bulkley TSA. Please note that area weighted scores are identical to the non-weighted scores since all triangles were essentially identical in size. Climatic unit statistics are shown in Table 5.

Table 4. Bulkley TSA, Small Area Method, Dominant Correct and Percent Overlap Summary - All Ecosystems.

Statistical Operation	% Basic/Area Weighted Score First Audit 09	% Alternate Ecosystem/ Area Weighted Score First Audit 09	% Basic/Area Weighted Score Second Audit 09	% Alternate Ecosystem/ Area Weighted Score Second Audit 09
Dominant Correct	51.9 (CI:43-61)	57.4 (CI:48-66)	44.4 (CI:35-53)	59.3 (CI:50-68)
Percent Overlap	56.6 (CI:52-61)	61.7 (CI:57-66)	59.9 (CI:55-64)	68.0 (CI:64-73)

3.1.12 CLIMATIC UNIT STATISTICAL SUMMARY - ALL ECOSYSTEMS

Second audit dominant correct scores from Table 5 reveal the ESSFwv, ICHmc1 and SBSdk with scores over 65%. Both the ESSFmc and the SBSmc2 had drops in dominant correct score, while their percent overlap scores rose to a respectable 67% each. Dominant correct score is clearly not as indicative of map accuracy as percent overlap as noted in the preceded section 3.1.1.1. While the Dominant correct scores did not get a significant boost from the most recent PEM, every climatic unit experienced increases in the percent overlap accuracy score. The ESSFmc alternate percent overlap score rose 8% while the SBSmc2 alternate percent score increased by 6%. Statistics for climatic units with a small number of plots should not be considered a reliable indication of the accuracy for that particular unit

Table 5. Bulkley TSA, Small Area Method, Dominant Correct and Percent Overlap by Subzone (Variant) - All Ecosystems.

Statistical Operation	n	BGC Unit	% Basic/ Area weighted Score 2009 First Audit	% Alternate Ecosystem/ Area weighted Score 2009 First Audit	% Basic/ Area weighted Score 2009 Second Audit	% Alternate Ecosystem/ Area weighted Score 2009 Second Audit
Dominant Correct	14	ESSFmc	64	64	42	57
	4	ESSFwv	75	75	75	75
	4	ICHmc1	50	50	75	75
	2	ICHmc2	50	50	0	50
	2	MHmm	50	50	0	50
	2	SBSdk	50	50	50	100
	24	SBSmc2	46	58	42	54
	2	CWHws2	50	50	50	50
Percent Overlap	14	ESSFmc	56	59	59	67
	4	ESSFwv	67	71	67	74
	4	ICHmc1	53	59	57	67
	2	ICHmc2	45	50	57	63
	2	MHmm	57	67	65	78
	2	SBSdk	75	84	74	89
	24	SBSmc2	56	61	58	67
	2	CWHws2	53	57	58	60

3.1.2 Forest Ecosystems: Accuracy Assessment Scores

3.1.2.1 OVERALL AREA STATISTICS - FOREST ECOSYSTEMS

The overall map area results of the small area sampling method are shown in Table 6. The results of the first and second 2009 PEM audits are presented. Percent overlap and dominant correct scores for forested ecosystems are mostly about 2% lower than the corresponding statistics for all ecosystems listed in the section3.1.1. The reason for forested ecosystems being slightly lower is probably because non forest or sparsely forested ecosystems are easier to distinguish. Percent overlap exhibited a substantial leap in accuracy from the mapping improvements completed in December 2009. The first score for alternate ecosystem percent overlap was 59.4%. The percent overlap score on the December 2009 revised database jumped to 65.5%. The alternate dominant correct score remained the same at 57.4%. The relatively low dominant correct scores relative to percent overlap scores and compared with other PEM maps is likely a function of terrain/ecosystem pattern complexity in the Bulkley TSA. Please note that area weighted scores are identical to the non-weighted scores since all triangles were essentially identical in size. Climatic unit statistics are shown in Table 7.

Table 6. Bulkley TSA, Small Area Method, Dominant Correct and Percent Overlap Summary - Forest Ecosystems.

Statistical Operation	% Basic/Area Weighted Score First Audit 09	% Alternate Ecosystem/ Area Weighted Score First Audit 09	% Basic/Area Weighted Score Second Audit 09	% Alternate Ecosystem/ Area Weighted Score Second Audit 09
Dominant Correct	51.9 (CI:43-61)	57.4 (CI:48-66)	40.7 (CI:35-53)	57.4 (CI:50-68)
Percent Overlap	54.3 (CI:50-59)	59.4 (CI:55-64)	57.6 (CI:53-62)	65.5 (CI:61-70)

3.1.2.2 CLIMATIC UNIT STATISTICAL SUMMARY - ALL ECOSYSTEMS

Second audit dominant correct scores from Table 7 reveal the ESSFwv, ICHmc1 and SBSdk with scores with scores over 65%. Both the ESSFmc and the SBSmc2 had drops in dominant correct score, while their percent overlap scores rose 9% for the ESSFmc and 6% for the SBSmc2. While the Dominant correct scores did not get a significant boost from the most recent PEM edits, every climatic unit experienced increases in the percent overlap accuracy score between the first and second audits in 2009.

3.2 Calculation of Appropriate Sample Size

Calculation of appropriate sample size, for satisfying 90% confidence limits for percent overlap, using the small area sampling protocol, was completed using the appropriate formula listed in Moon et al. (2005). Based on the evaluation of the first 54 sample triangles, the conclusion is that 46 samples would have been adequate.

The formula for calculating sample size (Meidinger 2003 and Moon et al 2005) is as follows:

$n = (t^2 \text{ x } SD^2)/SE^{2= 45}$

Where;

n = sample size = 54

t = t table value at n-1 number degrees of freedom where n = sample size 54 = (1.679)

SD = standard deviation of transect matching lengths expressed as percentage. = 19.9%

SE = standard error expressed as a percentage, in our case 5%.

The confidence interval at confidence level (90%) for sample size = 4.53 on either side of the mean.

Table 7. Bulkley TSA, Small Area Method, Dominant Correct and Percent Overlap by Subzone (Variant) Forest Ecosystems.

Statistical Operation	n	BGC Unit	% Basic/ Area weighted Score 2009 First Audit	% Alternate Ecosystem/ Area weighted Score 2009 First Audit	% Basic/ Area weighted Score 2009 Second Audit	% Alternate Ecosystem/ Area weighted Score 2009 Second Audit
Dominant Correct	14	ESSFmc	50	52	36	50
	4	ESSFwv	75	75	75	75
	4	ICHmc1	75	75	75	75
	2	ICHmc2	0	0	0	50
	2	MHmm	50	50	0	50
	2	SBSdk	50	50	50	100
	24	SBSmc2	50	62.5	38	54
	2	CWHws2	50	50	50	50
Percent Overlap	14	ESSFmc	50	52	54	61
	4	ESSFwv	63	68	64	71
	4	ICHmc1	53	60	58	67
	2	ICHmc2	41	46	53	59
	2	MHmm	52	62	61	74
	2	SBSdk	77	86	74	89
	24	SBSmc2	57	60	58	66
	2	CWHws2	52	56	56	57

3.3 Forested Entity Proportions

Figures 1 through 8 display ecosystem entity proportions for the eight major forested climatic units of the Bulkley TSA. The entity proportions for non-forested and non-vegetated ecosystems have been assembled into three groups: AN for anthropomorphic (landings roads fields etc); HS for herb shrub - ecosystems and NV for non-vegetated ecosystems that are not water bodies.

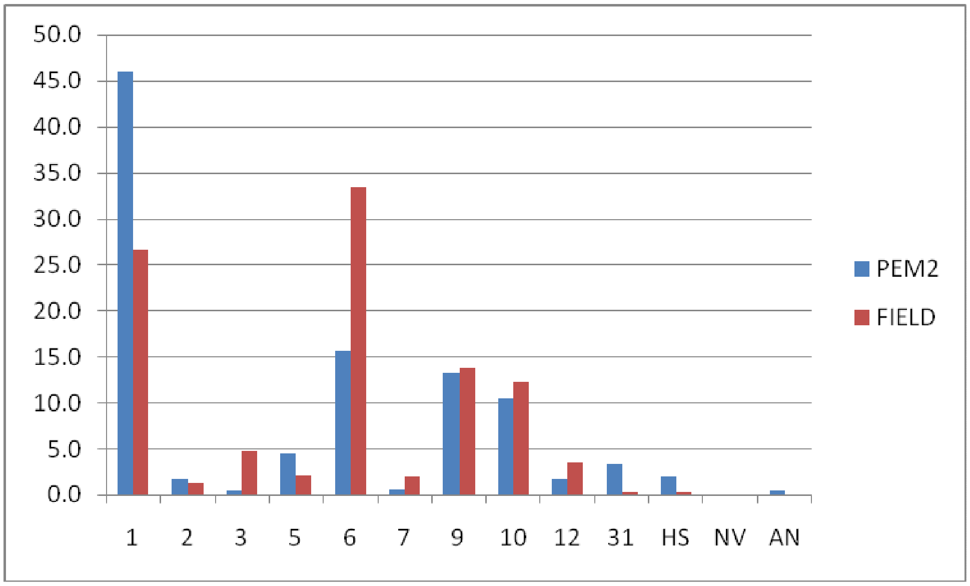

Figure 1. Forested Entity Proportions for the SBSmc2 in the Bulkley TSA

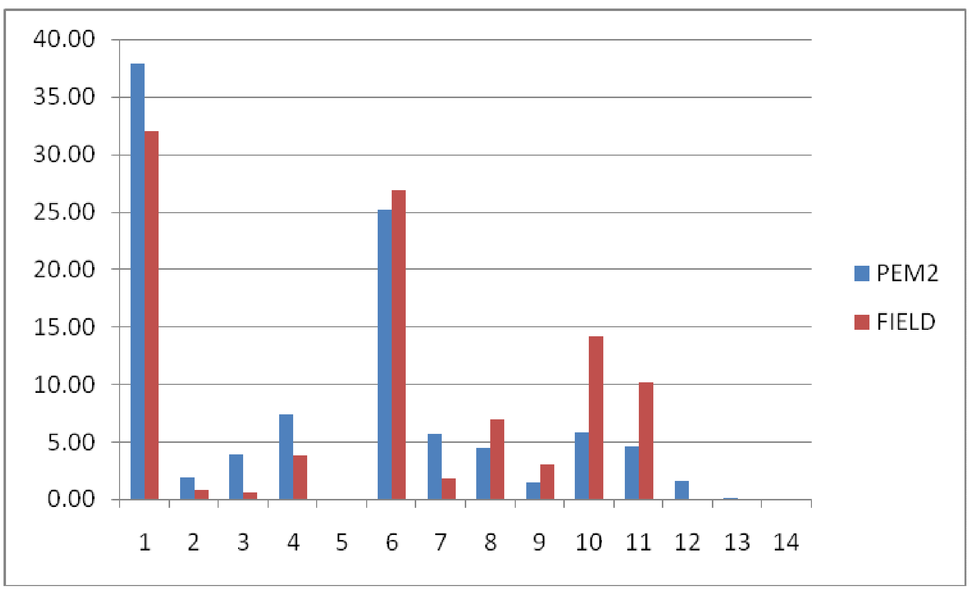

Figure 2. Forested Entity Proportions for the ESSFmc in the Bulkley TSA

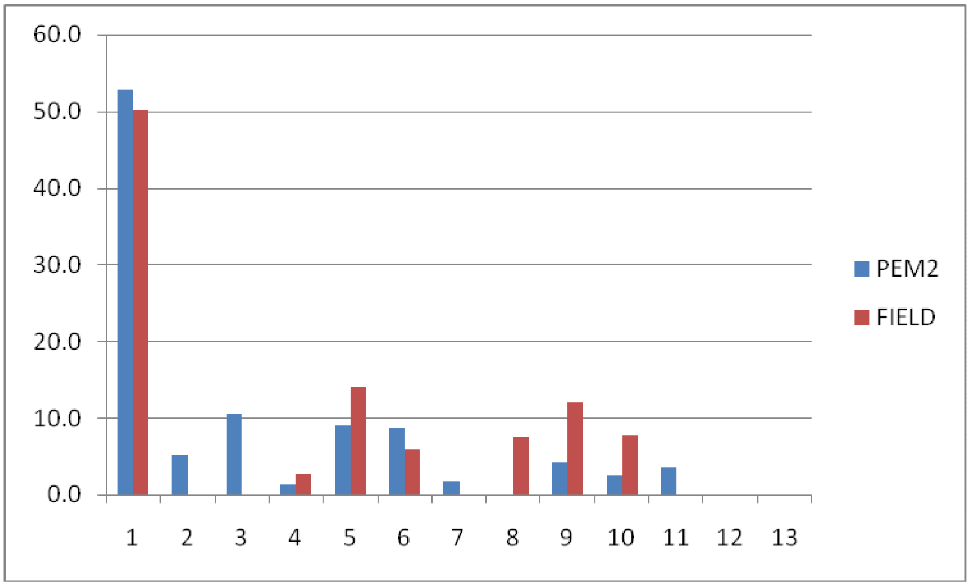

Figure 3. Forested Entity Proportions for the ESSFwv in the Bulkley TSA

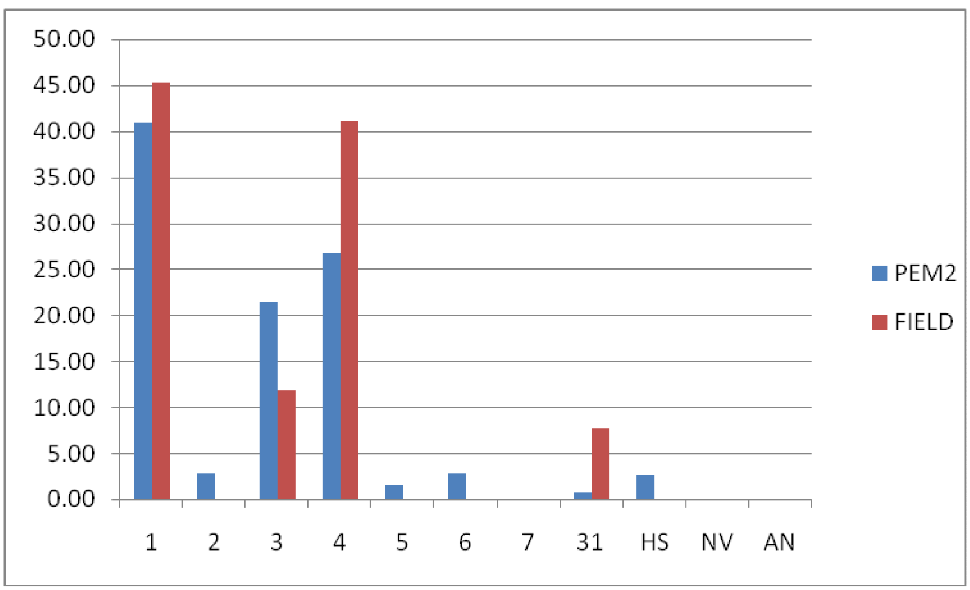

Figure 4. Forested Entity Proportions for the ICHmc1 in the Bulkley TSA

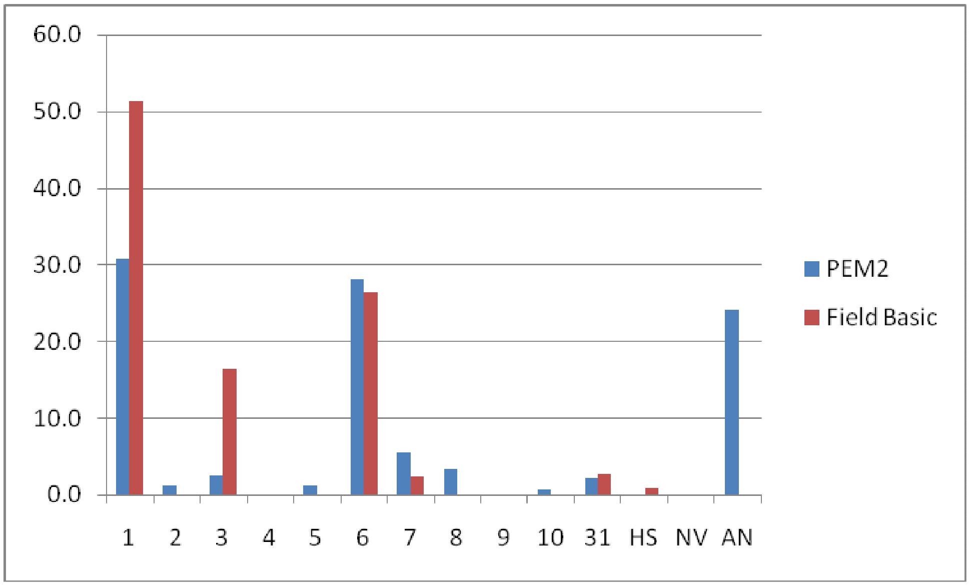

Figure 5. Forested Entity Proportions for the SBSdk in the Bulkley TSA

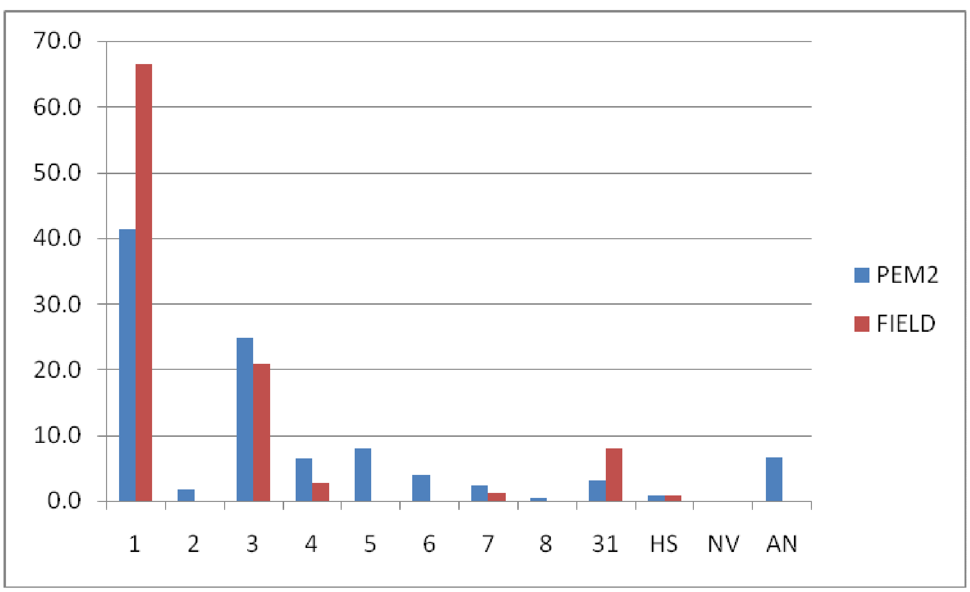

Figure 6. Forested Entity Proportions for the ICHmc2 in the Bulkley TSA

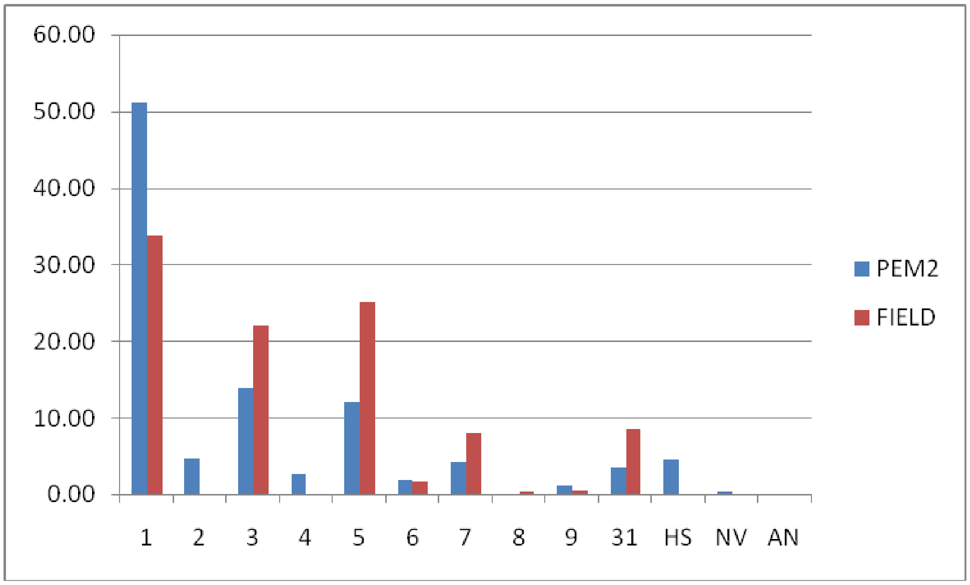

Figure 7. Forested Entity Proportions for the MHmm2 in the Bulkley TSA

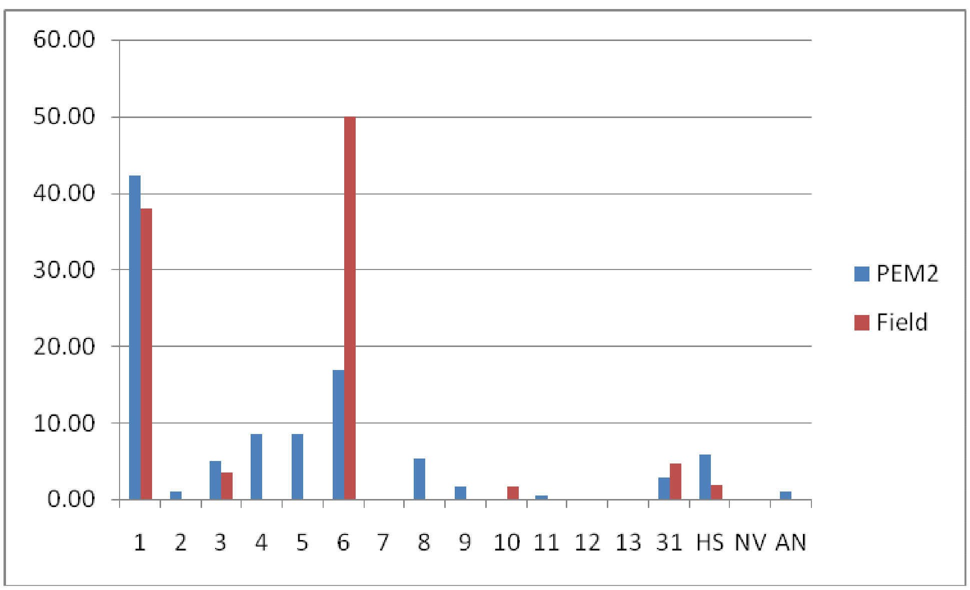

Figure 8. Forested Entity Proportions for the CWHws2 in the Bulkley TSA

Forested ecosystem entity graphs depict PEM estimates of site series in relation to those sampled on the ground by our audit. Audit site series proportions generated from a limited number of sample plots should not be considered totally definitive of actual proportions. These graphs may point to general error trends in dominant correct statistics and have limited usefulness for identifying error trends in percent overlap scores. For example, the SBSmc2 shows that the 09 and 10 site series proportions have been mapped/predicted quite close to what we observed in the field. This does not mean that they were mapped spatially correct in the landscape. Only a detailed, spatially explicit, error analysis will reveal that. There does seem to be an error trend based on the results of the SBSmc2 and ESSFmc entity proportions, (climatic units with fairly numerous audit samples) that still shows an underestimation of generally wetter site series and an overestimation of zonal site series. This might be rectified by a slight skewing of moisture models towards the wetter side by adjusting aspect and drainage parameters.

3.4 Merging Ecosystems in the Bulkley TSA

Combining closely allied site series, which cannot be differentiated by PEM knowledge bases, has been considered in other PEM mapping projects in order to improve PEM map accuracy. Often there are great difficulties in differentiating between subhygric site series with identical or closely overlapping positions on the edatopic grid. In order to merge them for TSR purposes, the ecosystems should share similar SIBEC site indices. There are several subhygric site series worthy of consideration for merging in this project.

3.4.1 Overview of Combining Ecosystems in SBSmc2 and ESSFmc

Two climatic units, the SBSmc2 and ESSFmc make up the vast majority of the forested crown lands in the Bulkley TSA with 44% and 29% representation respectively. At 71% representation in the landscape, combining ecosystems in these two climatic units could have a significant impact on map reliability and on forest management considerations including TSR calculations.

It has been observed that the subhygric ecosystems in the SBSmc2 and ESSFmc are impossible to distinguish apart except by understory shrub and herb plant indicators, visible only from the ground.. These ecosystems include the SBSmc2 05 (Sxw-Twinberry –Coltsfoot), 06 Sxw-Oak fern) and 09 (Sxw-Devil’s club) and ESSFmc 06 (Bl-Oak fern – Heron’s bill and 07(Bl- Devil’s club Lady fern).

The SBSmc2 05 and 06 occupy the same edatopic grid location (4)5/C-E. Both lack devils club and are differentiated from another by the presence of oak fern on the 06. The 09 overlap both the 05 and 06 on 5/D-E sites. The 09 also overlaps with 10 (horsetail type on hygric sites but this is much more rare than the subhygric situation. The 09 is distinguished from the 05 and the 06 by prominence of devils club. All of these site series occupy similar sites, tree species are similar and they all exhibit good growth.

The ESSFmc has two subhygric units which are very difficult to differentiate. The two site series are the 06 and the 07. The 06 and 07 overlap on 5/D-E sites on the edatopic grid. The 07 occurs on hygric sites as well. They both occur on mid to lower slopes and have good growth and feature the same tree species. The 07 is differentiated from the 06 by abundant devil’s club and greater prominence of lady fern.

3.4.2 Combining Ecosystems in other climatic units

The effect of combining similar ecosystems in the remaining 21% of the landscape, represented by the other six climatic units that we audited, will have less effect on overall map accuracy and on TSR. However there are several valid combinations which can be considered. These in include: The ESSFwv 05 and 06, ESSFwv 08 and 09, ICHmc1 03 and 04 and ICHmc2 03 and 04. The above combinations of ecosystems have been sanctioned for consideration for PEM mapping within the old Prince Rupert portion of the NIFR by Banner et el 2003. The MHmm2 is a small climatic unit not much utilized by the commercial harvest. Consideration could be made of combining the MHmm2 01 and 03, the 04 and 05 and the 06 and 07. The results on increasing PEM map accuracy are shown in the following section.

3.4.3 Effect of Combining Subhygric Site Series on PEM Map Accuracy.

The effect of combining subhygric site series in the Bulkley TSA is illustrated in Table 6.

Table 6. Effect of Combining Ecosystems on PEM Accuracy.

SUBZONE	SITE SERIES COMBINATIONS	ALTERNATE SITE SERIES PERCENT OVERLAP EFFECT		ALTERNATE SITE SERIES DOMINANT CORRECT EFFECT	
		individual	total	individual	total
ESSFmc	01 AND 05 09 AND 10 05 AND 06	+.4 +.43 +1.23	+2.5	0 -1.8 +1.9	0
ESSFwv	05 AND 06 08 AND 09	+0.2 +.6	+0.8	0 +1.9	+1.9
ICHmc1	03 AND 04	+1.1	+1.1		
ICHmc2	03 AND 04	0	0	0	0
MHmm2	01 AND 03 04 AND 05 06 AND 07	+.4 +0.2 0	+0.6	+1.9 0 0	+1.9
SBSmc2	01 AND 05 05 AND 06 06 AND 09 05, 06 AND 09	0 +1.0 + 3.0 +4.1	+4.1	+3.7 +1.9 -4.3 0	0% if all Subhygric added. +3.7% if 01 and 05 combined

Individual Ecosystems: Alternate Site Series Percent Overlap Score is 68%
Individual Ecosystems: Alternate Site Series Dominant Correct Score is 59.3%

<u>The most effective outcome towards achieving a near 65% accuracy threshold score involves combining:</u>
ESSFwv 08 and 09, MHmm2 01 and 03 and SBSmc2 05 and06, with an outcome of % Overlap Score 70.0% and dominant correct score of 64.8%. Combining the zonal and 05

site series in the SBSmc2 and ESSFmc is shown as well. Combining these site series should be a last resort.

Note that for the Dominant Correct statistic it is possible for the combination of two ecosystems to have a negative result (SBSmc2- 05/06 and ESSFmc 09/10) because an ecosystem which was slightly subdominant could now become dominant when combined with another subdominant ecosystem.

3.5 Brief Introduction to Error Trend Analysis

General observations of the data show errors in differentiating between different subhygric units. For example The SBSmc2 05 06 and 09 are the most common subhygric site series to be confused for one another, judging from the negative swing in dominant correct when SBSmc2 05 and 06 and 09 are combined. As well, it appears that significant errors occur in distinguishing between the SBSmc2 01 with the 05 and 06 site series. A detailed error trend analysis is beyond the scope of this present report and should be undertaken if the PEM requires knowledge base improvements to achieve minimum standards. An error trend analysis will pinpoint the magnitude and direction of errors between one site series and another. If there are distinct trends, then this can help to further calibrate and improve moisture models and other knowledge base inputs.

4.0 RECOMENDATIONS FOR IMPROVING PEM ACCURACY

4.1 Improve PEM knowledge Base

Improving PEM accuracy will be facilitated by detailed error trend analysis followed by improvements to the existing PEM knowledge base. The fairly low percent overlap scores for the SBSmc2 and ESSFmc still indicate the need to differentiate better between ecosystems in those climatic units. The SBSmc2 05, 06 and 09 should be better differentiated. In addition it appears that improvements could be made to the SBSmc2 moisture model to improve resolution between 01 and subhygric units. An improvement here could make an impact on map accuracy. Differentiating better between ESSFmc 08 and other subhygric ecosystems could improve map accuracy. Identifying the SBSmc2 03 and 07 better could also improve map accuracy.

4.2 Consider Merging Some Subhygric Ecosystems

Combining very similar site series with similar site indices has been judiciously used in other PEMs. We have observed that it is virtually impossible, except on the ground, to distinguish between several subhygric site series in the study area. Among others, these include the SBSmc2 05 and 06 ESSFwv 08 and 09 and MHmm2 01 and 03. The inability to distinguish between these ecosystems has a significant impact on map accuracy. We recommend consideration be made of the effect on map accuracy on combining these and other ecosystems. Combining the above ecosystems will result in a marginal pass for the Bulkley PEM.

5.0 SUMMARY AND CONCLUSIONS

This Bio-Geo Dynamics Ltd. Bulkley PEM AA report is a follow up to PEM mapping and PEM AA reports completed in 2004 and earlier in 2009. A small area triangle sampling AA approach was completed for this project. Eight forested climatic units were analyzed employing 27 pairs of small area triangles, for a total of 54 samples.

Office analysis revealed that sampling intensity met the minimum requirements for ecosystem based TSR analysis. The PEM AA analyses yielded alternate ecosystem accuracy scores of 59.3 and 68% for dominant correct and percent overlap respectively. The dominant correct score is lower than the 65% minimum threshold required for ecosystem based TSR purposes. Regarding percent dominant correct statistics please note that this statistic is not as relevant or sensitive to map accuracy as percent overlap. For the Bulkley TSA PEM this is particularly true. Part of the reason for this is landscape and ecosystem pattern complexity. Often two or more ecosystem site series can vie for dominance within a landscape unit, rendering calculation of percent dominant correct a poor indicator of true map accuracy. As a consequence we recommend that a shortcoming in percent dominant correct be overlooked when the percent overlap score passes comfortably passes the 65% minimum threshold required for TSR. Please refer to Appendix 1 for MOFR commentary and response to this issue.

Investigation into improving PEM accuracy reveals that combining various similar ecosystems leads to improvement in map reliability. Combining similar ecosystems results in a percent overlap score as high as, or higher than, 70%. The dominant correct score improved to as high as 64.8% by combining the ESSFwv 08 and 09, MHmm2 01 and 03 and the SBSmc2 05 and 06. While these combinations improve dominant correct score, they have a neutral or slightly negative impact on accuracy of TSR statistics particularly regarding some tree species in the SBSmc2 05 and 06. If the current PEM is allowed for TSR purposes without combining, as recommended in the above paragraph, then combining of ecosystems will serve no useful TSR purpose and is not recommended. Please refer to Appendix 1 for MOFR commentary and response to this item.

Recommendations for increasing PEM accuracy could include several further steps. These steps include completion of a detailed error trend analysis, followed by further fine tuning of the existing knowledge base. In future, additional sampling could be completed in lightly sampled climatic units in order to improve reliability of the audit and to help calibrate future PEM improvements. Please refer to Appendix 1 for MOFR commentary and recommendations regarding this issue.

6.0 LITERATURE CITED

Banner A. C. Jones, R. Trowbridge, A Trobridge, G. Cushon, D. Yole, B. Bance and L. McCulloch. 2003. *Ecogen Site Unit Interpretation Tables for the Prince Rupert Forest Region (updated March 2003).*

Meidinger, Del. 2003. *Protocol for Quality Assurance and Accuracy Assessment of Ecosystem Maps.* Research Branch, B.C. Ministry of Forests, Victoria, BC.

_________. 2001. *Ecosystem Mapping Accuracy and Timber Supply applications.* Research Branch, B.C. Ministry of Forests, Victoria, BC.

Moon, D. D. Dunlop, K. Isles and N. Philips. 2005. *A Protocol for Assessing Thematic Map Accuracy Using Small-area Sampling.* B.C. Min. For., Res. Br. Victoria, B.C. Tech Rep. 23.

Simonar, K and S. Migabo. 2009. *Bulkley TSA Predictive Ecosystem Mapping (PEM) Level 4 Accuracy Assessment*. A FIA sponsored consultants report for PIR (A division of West Fraser Mills Ltd), Smithers B.C.

7. APPENDIX 1: MOFR approval letter for 2009 Bulkley PEM and PEM AA

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01/21/2010 09:47 AM

To "Lloyd-Smith, Jane FOR:EX" <Jane.LloydSmith@gov.bc.ca>
cc "Gary Quanstrom" <Gary.Quanstrom@westfraser.com>, "Jay Baker" <Jay.Baker@silvicon.com>, "MacKenzie, Will H FOR:EX" <Will.MacKenzie@gov.bc.ca>
Subject

To: Jane Lloyd-Smith, Skeena Stikine District Manager

Dear Jane,

Will MacKenzie and I have reviewed the recent accuracy assessment for the Bulkley PEM and our decision is provided below:

Allen Banner and Will MacKenzie have reviewed the BULKLEY TSA PREDICTIVE ECOSYSTEM MAPPING (PEM) LEVEL 4 ACCURACY ASSESSMENT report as prepared by Bio-Geo Dynamics Ltd. to evaluate the revised PEM that was completed for the Bulkley TSA portion of your District by TimberLine Natural Resource Group. The accuracy assessment followed the provincial ecosystem mapping accuracy protocol to ensure that the ecosystem mapping is of sufficient quality to be used in conjunction with Site Index Biogeoclimatic Ecosystem Classification (SIBEC) data for base-case timber supply analysis.

Based on the second Bulkley TSA PEM by Timberline and a subsequent accuracy assessment undertaken in 2009, the PEM can now be confirmed to be of sufficient quality for use in SIBEC-based timber supply analysis.

However, there are some issues that should be noted in using this PEM for TSR:

1) The PEM meets the minimum accuracy assessment standard of 65% only when alternate site series calls are used.

2) The requirement for a "dominant correct" statistic has been waived by us, as it is clear that the statistic is not well suited to a raster based PEM and the type of AA protocol applied

3) When accuracy assessment results, for forested ecosystems only, are summarized by BGC unit, subzones/variants covering one third of the area (34%) do not meet the standard required for TSR. Confidence in site productivity estimates for these units (ESSFmc, ICHmc2, CWHws2) will generally be lower than for those BGC units with scores in excess of the standard. Note that when results are summarized for all ecosystems (non-forested and forested), the ICHmc2 and the CWHws2 are the only two BEC units that do not meet the standard.

4) In several BEC units the PEM appears to be under-representing sybhygric site series while often over-mapping mesic site series (as determined by the AA statistics). This occurs in the SBSmc2, SBSdk, ICHmc1, CWHws2, and the MHmm2, which cover a combined 54% of the study area. This statistic contradicts our (MacKenzie and Banner) field observations/impressions and it is believed that the PEM map is likely a better representation of subhygric site series distribution than the AA.

5) The PEM AA report includes statistics for combined forested site series which was undertaken as part of the AA to increase the overlap statistics. We recommend using the original non-combined PEM for TSR; however for some purposes, using the post-mapping combination site series with their higher accuracy but broader definitions may be of value.

While the current PEM is acceptable for current timber supply review purposes, we recommend the following improvements be addressed prior to the next TSR:

1) When considering just forested ecosystems, the ESSFmc did not pass the minimum accuracy assessment threshold and should be improved prior to the next TSR.

2) Most BGC units did not individually receive enough AA transects to statistically determine their accuracy. These include the ESSFwv, ICHmc1, ICHmc2, MHmm, SBSdk, and CWHws2. Additional accuracy assessment transects may be necessary to provide a better assessment of results for these units.

If you would like further information on the mapping, contact Jay Baker (Silvicon). For further information on its evaluation for use in timber supply analyses, contact Allen Banner, NIFR Regional Ecologist, Smithers or Will MacKenzie, Provincial BEC Correlator, Smithers.

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