Merritt TSA
Predictive Ecosystem Mapping:
Final Report

Prepared for

Nicola-Similkameen Innovative Forestry Society

Merritt, BC

Project: MTI-411

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1. INTRODUCTION

1.1 BACKGROUND

In 1997, Weyerhaeuser Company Limited, Tolko Industries Ltd., Aspen Planers Ltd., Ardew Wood Products Ltd., Riverside Forest Products Ltd., Nicola Tribal Association (NTA), Upper Similkameen Indian Band, and the Merritt Forest District Small Business Forest Enterprise Program presented a proposal to the Minister of Forests requesting Innovative Forestry Practices Agreements (IFPAs) for the licensees in the Merritt timber supply area (TSA). The Minister approved their proposal in November 1998. The IFPA's are designed to encourage holders to practice innovative forest management in return for corresponding gains in Allowable Annual Cut (AAC) as outlined in Section 59.1 (7) of the Forest Act.

To facilitate the implementation of the approved IFPAs, the five licensees, the NTA, the Upper Similkameen Indian Band, and the Merritt SBFEP formed the Nicola-Similkameen Innovative Forestry Society (NSIFS). The NSIFS is responsible for implementing this innovative forestry program for the Merritt TSA.

Forestry Plan #1[1] for the Merritt IFPAs was submitted to the Ministry of Forests (MOF) in July 2000 and approved by the Kamloops Regional Manager in January 2001. In Forestry Plan #1, the NSIFS committed to a cooperative approach with the MOF to develop a Predictive Ecosystem Map (PEM) for the TSA. The NSIFS, in consultation with Keystone Wildlife Research, the group entrusted with leading the Merritt environmental program, determined that pursuing PEM (instead of Terrestrial Ecosystem Map [TEM]) would reduce costs and timelines.

Ecosystem maps are integrated planning tools that provide the location and distribution of ecosystems within a management unit. The PEM approach predicts ecosystem occurrence on the landscape using basic inventory information and expert knowledge. Details on the history of the PEM project prior to March 2001 for the Merritt TSA are outlined in *Predictive Ecosystem Mapping (PEM) in the Merritt Forest District*.[2]

1.2 PROJECT HISTORY

The Merritt PEM project was initiated in 1998 and initially involved three consultants:

1. Keystone Wildlife Research Ltd. (KWR) to provide project management
2. Oikos Ecological Services Ltd. (Oikos) to provide the knowledge bases
3. J.S. Thrower & Associates Ltd. (JST) providing the Geographical Information Services (GIS) processing.

This project team worked closely with Dennis Lloyd, *RPF* (MOF, Kamloops Regional Ecologist) and Del Meidinger (MOF, Research Branch Ecologist) who provided guidance throughout the project.

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[1]Jointly prepared by J.S. Thrower & Associates Ltd., Timberline Forest Inventory Consultants Ltd., Keystone Wildlife Research Ltd., and the Nicola Similkameen Innovative Forestry Society. 2000. Nicola-Similkameen Innovative Forestry Society Forestry Plan #1, Merritt. July 14, 2000. 124 pp.

[2]Keystone Wildlife Research Ltd. 2001. Predictive Ecosystem Mapping in the Merritt Forest District Documentation Report. Contract Report to Nicola-Similkameen Innovative Forestry Society Merritt. March 2001. Unpublished.

When the Merritt PEM project began in 1998, PEM standards did not exist and so the methods used in TEM and previously completed PEM projects were followed. Since then, PEM standards have evolved with PEM standards being released in 1999[3] and digital standards in 2000.[4] The Merritt PEM project has adapted to these standards where possible.

In 2001, the NSIFS contracted EBA Engineering Consultants Ltd. to review the Merritt PEM for quality and accuracy. EBA's final report[5] recommended changes to the Merritt PEM process and suggested methods that would adhere to several published PEM standards. KWR, Oikos, and JST reviewed the EBA report, and modified the PEM process accordingly.

By 2002, KWR and Oikos had met their project objectives and JST remained in the process to manage the accuracy assessment, produce the final data set, and write the final report. In March 2002, JST wrote the *Predictive Ecosystem Mapping Input Data Documentation* and submitted it to the MOF.[6]

Subsequent work focused on preparing an accuracy assessment for the Merritt PEM. Existing plot datasets were analyzed for accuracy, but were not able to meet standards required in *Protocol for Quality Assurance and Accuracy Assessment of Ecosystem Maps.*[7] A meeting was held July 15, 2002 attended by key members of the Merritt PEM and timber supply analysis process to review progress to date and decide on a course of action to assess the accuracy of the Merritt PEM.

By September 2002, the accuracy assessment sample plan was approved by the MOF, and contract ecologists completed fieldwork. The final accuracy assessment report[8] was submitted to the MOF in December 2002 and recommended that the Merritt PEM be used for strategic purposes, such as timber supply analysis.

1.3 Problem Statement

The NSIFS requires an ecological map be developed to provide the ecological framework for strategic level planning including timber supply analyses, growth and yield information, wildlife suitability and capability, landscape analysis and First Nations values.

1.4 Objectives

The objective of this project is to provide the NSIFS with a MOF approved PEM for the Merritt TSA that meets MOF standards as outlined in the *Standards for Predictive Ecosystem Mapping*.[3]

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[3] Terrestrial Ecosystem Mapping Alternatives Task Force. 1999. Standards for Predictive Ecosystem Mapping. Prepared for the Resources Inventory Committee, Ministry of Forests. Victoria. November 1999. 40 pp.

[4] PEM Data Committee, 2000. Standards for Predictive Ecosystem Mapping (PEM) – Digital Data Capture, prepared for the Resources Inventory committee, Ministry of Forests. Victoria. April, 2000. 30pp.

[5] EBA Engineering Consultants Ltd. 2001. Quality and Accuracy Assurance for the Merritt PEM Project (Volume 1). Contract Report to the NSIFS. Merritt. November 2001. 30pp.

[6] J.S. Thrower & Associates Ltd. 2002. Predictive Ecosystem Mapping Input Data Documentation. Contract report to the Nicola-Similkameen Innovative Forestry Society. Merritt BC. March 25, 2002. 41 pp.

[7] Meidinger, D. 2000. Protocol for Quality Assurance and Accuracy Assessment of Ecosystem Maps. MOF Research Branch. Victoria. July 2000. 14 pp.

1.5 Terms of Reference

JST has been contracted by the NSIFS to complete the PEM for the Merritt TSA by:

- Ensuring the accuracy assessment was completed
- Submitting the final PEM digital data set
- Submitting the final report (this report).

The JST team who contributed to the Merritt PEM includes Ron Zayac, *BComm* (project manager), Frits Nijholt, *RPF* (project coordinator), and Wendy Creighton, *Dipl.Tech. GIS* (GIS analyst).

2. METHODS

2.1 Study Area

The Merritt TSA is located in the south-central interior of BC and covers approximately 1.13 million ha of the Kamloops Forest Region. The TSA is bordered to the north by the Kamloops TSA, to the west by the Lillooet and Fraser TSAs, and to the east by the Okanagan TSA. Manning Park, Cathedral Park, and the Canada-USA border to the south of the TSA.

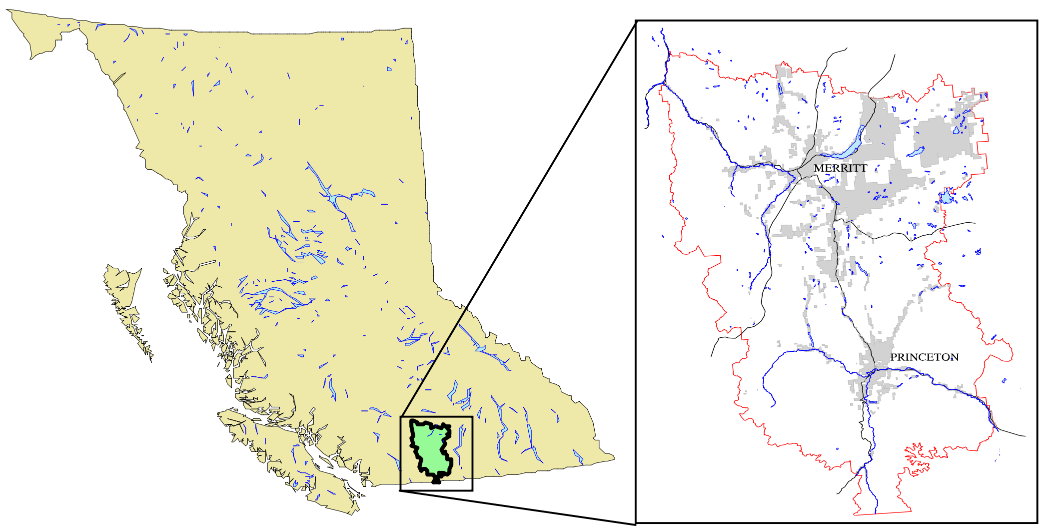

Figure 1. Merritt TSA location map.

2.1.1 Ecogen – PEM Model [9]

The Merritt PEM process utilized a computer software modeling application to assess the site characteristics of a resultant polygon to predict the most probable site series. At the start of the Merritt PEM project two applications were available, ELDAR (Alberta government product licensed to TFIC) and Ecogen (MoF product, license is free). KWR did a comparison analysis of both products the results are documented in the Merritt documentation report.[2] This comparison suggested that Ecogen was the best model for this project. The Ecogen model requires two inputs 1) Input data (section 2.2.2 of this report) built by the GIS section of JS Thrower & Associates with input from the MoF, Oikos and KWR and 2) Knowledge Base (section 2.2.3 of this report) build by the by Oikos.

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[8] The Merritt PEM accuracy assessment is described in more detail in Section 2.5 of this report.

[9] EcoGen site: http://www.for.gov.bc.ca/research/ecogen

2.1.2 Input Data

The PEM process uses existing data to produce a resultant GIS dataset that is the input for the PEM modeling exercise. The following data layers are described in terms of input quality and are discussed in the documentation report, submitted March 2002.[4] Ecosection map[10] lines have been added since the PEM input document was submitted, to comply with PEM standards.[6]

- Bioterrain map
- Forest cover inventory map
- Terrain resource inventory map (TRIM)
- Biogeoclimatic ecosystem classification (BEC) map

The bioterrain data is a map complex with up to three deciles containing terrain related information. When overlay analysis occurs using datasets with complex attributes, the potential that the thematic combinations actually occurred within a given resulting polygon is diminished. To reduce these unwanted effects, we chose to minimize the landform features intersecting with the bioterrain base rather than have unpredictable and uncontrollable results of cross-product correlation. The bioterrain coverage was intersected over the course of the PEM project by four coverages:

1. Creek buffer polygons
2. Non-productive forest type polygons
3. BEC polygons
4. Ecosection polygons.

The eliminate command was run in Arc/Info after each of the first two intersections to delete polygons less than one hectare in size. Each elimination was completed without deleting the original bioterrain lines, therefore preserving the integrity of the original bioterrain coverage.

2.1.3 Knowledge Bases

An advantage of creating the PEM using knowledge tables is the model is more flexible and does not limit the number of variables. Figure 2 shows area summaries of forested and non-forested biogeoclimatic (BGC) subzones in the Merritt TSA. Knowledge bases (KB) were created for each of the 26 BGC subzones in the TSA (Figure 3).

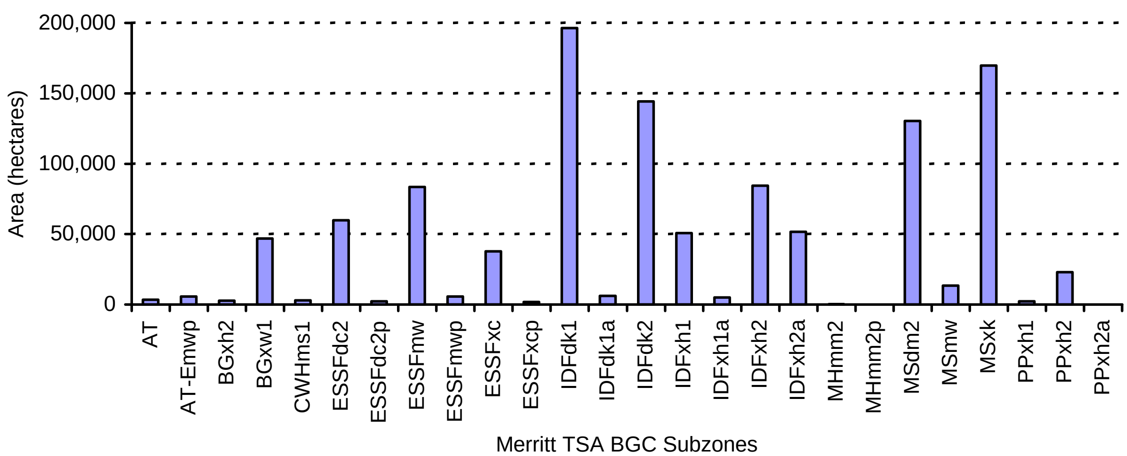

Figure 2. Merritt TSA biogeoclimatic subzone area summary.

[10] Digital file was downloaded from: ftp://ftp.elp.gov.bc.ca/dist/arcwhse/wildlife (qes_bc.zip).

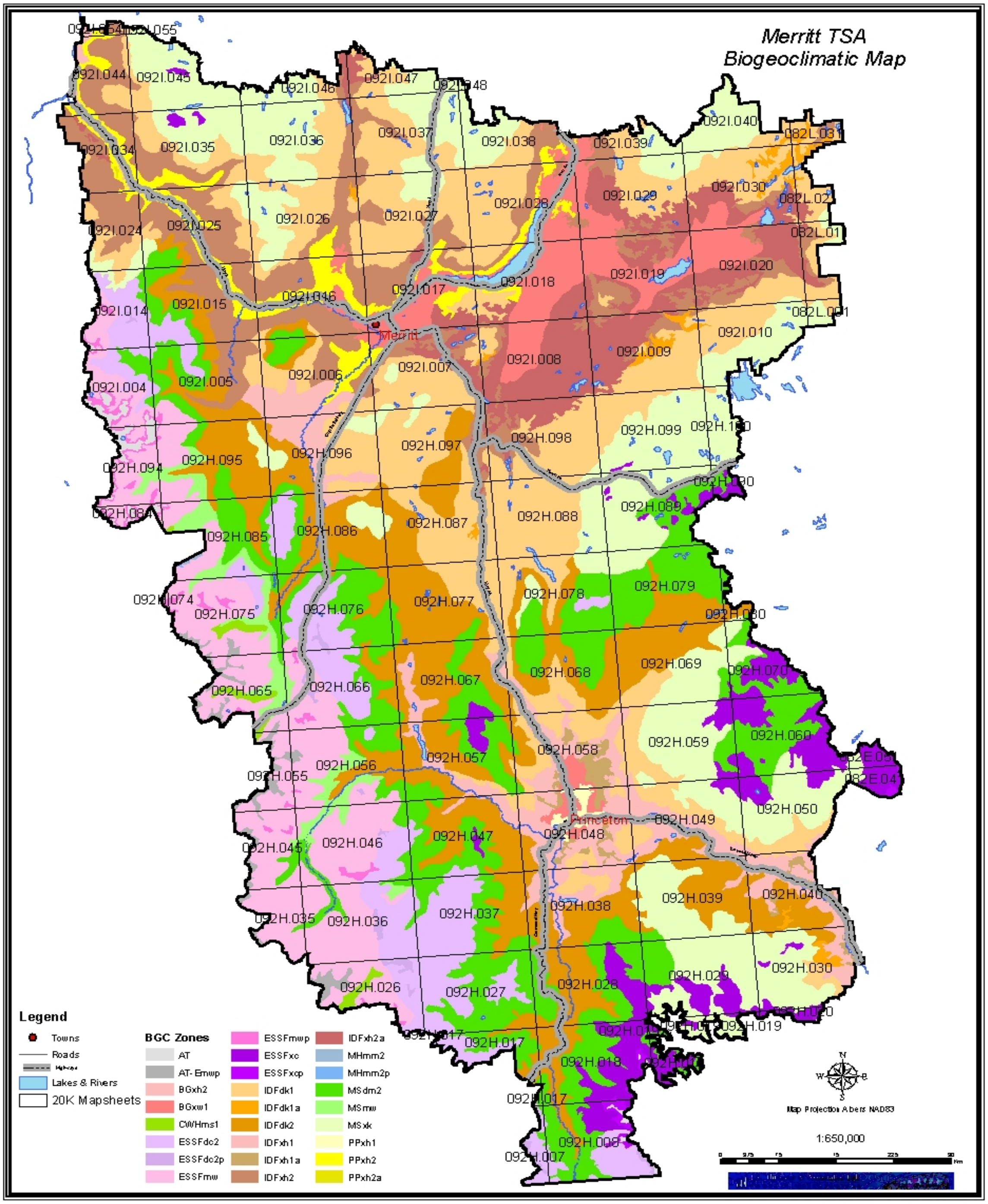

Figure 3. Merritt TSA biogeoclimatic subzone map.

Ecologists from Oikos derived the KB's using input data sources (Section 2.2) and their local knowledge (attributes are in Appendix II). Several iterations of the KB's were tested against existing field datasets suitable for testing the EcoGen process.[11] The limiting factor in using these datasets is that they are not random and did not sample the entire TSA population.

The EcoGen process provides a score for each site series decile within a polygon. The site series with the highest score has the highest potential of occurring in that polygon given the information used in creating the KB. Adjustments were made to the KB's and processed again to test the improvements. The final version of the KB's was submitted to JST, March 19, 2002.

2.1.4 GIS Processing

The Merritt PEM process has evolved since the November 6, 1999 workshop,[12] where it was decided that the input coverage's would be intersected to produce a final resultant and would be dissolved in the final stage to produce a site series maps. This process was revised following the EBA draft report[5] where four issues were identified and addressed. These include:

1. Retaining integrity of bioterrain polygons by minimizing splitting of polygons
2. Representing forest cover data more accurately by integrating attribute data with bioterrain polygons
3. Using seamless input data
4. Representing slope/aspect/elevation data more accurately by averaging across resultant polygons.

2.2 REVISED PEM DEVELOPMENT STEPS

The following is a description of the current revised PEM process (see Appendix I for flow diagram of the PEM process). All GIS processing was done using Arc/Info (version 7.2.1) and SAS software[13] was used for forest cover attribute weighting of resultant polygons. The scores for the resultant polygons were derived using EcoGen.[9] The original seamless bioterrain coverage contained approximately 58,000 polygons.

2.2.1 Step 1 – Stream Buffer Intersection

The TRIM digital elevation model (DEM) data was used to build a map of polygons with low slopes (slopes <20%). This coverage was intersected with the TRIM seamless single line creeks coverage, selecting only those creeks with low slopes. Twenty (20) meter buffers were created around the selected creeks and these polygons were intersected with bioterrain coverage. The intersection process produced sliver polygons, which were eliminated, preserving bioterrain arcs. The first resultant (Biobuf_elim) contains approximately 85,600 polygons.

2.2.2 Step 2 – Non-Productive Intersection

Non-productive (NP) polygons were extracted from the seamless forest cover dataset (e.g., open range or rock) to create a new NP coverage (Npdesc). The first resultant (Biobuf_elim) coverage was intersected

[11] Ground observations provided by Kamloops Regional Ecologist to Keystone, Oikos, and JST.
[12] KWR, JST, Oikos, Shearwater, Eco-Concepts, Shamaya Consulting, Mike Ryan, Alex Inselberg, and Dennis Lloyd were at the workshop.

with the NP forest (NpDesc) coverage and produced the second resultant (Biobufnp_Elim). New sliver polygons were removed while retaining bioterrain lines.

2.2.3 Step 3 – Slope/Aspect/Elevation Averaging Calculation

Slope/aspect/elevation polygon coverages can be derived from TRIM DEM data. Approximately 2.5 million polygons were created using the Arc/Info application software making it impossible to do further overlay analysis due to capability limitations with the software. Thus, the project area had to be split into eight "clip" coverages using BGC lines. The eight clipped TRIM coverages were intersected with the eight clipped second resultant coverages (Biobuf_elim). An area-weighted average for slope and aspect for each second resultant polygon was calculated using descriptive statistics. Elevation was calculated using a 50x50 m grid over the TSA, and then a weighted average of the elevation was calculated for each polygon. The eight clipped coverages were appended to produce the third resultant (biobufnp_final) comprising approximately 110,500 polygons.

2.2.4 Step 4 – Forest Cover Average Attribute Calculation

The attributes of a temporary coverage intersecting the forest cover and the third resultant coverage (biobufnp_final) were downloaded to SAS.[14] SAS calculated a weighted average for species, age, height, and crown closure for each resultant polygon. The SAS output was linked to the third resultant (biobufnp_final) and age, height, and crown closure classes were calculated (including species presence attributes) and added to the third resultant. This process did not add lines to the resultant.

The third resultant coverage was intersected with the BGC coverage provided by the Kamloops Forest Region. Note that there an elimination process was not done after this intersection, so slivers in this case are not errors. The fourth resultant (j_pem) resulted in 140,452 polygons.

2.2.5 Step 5 – Ecogen Process

The Ecogen process used the KB's provided by Oikos and the attributes from the fourth resultant coverage. The Ecogen process creates an output score for each site series decile by BGC subzone for every "j_pem" polygon. The output is processed to filter out top ranked site series for each polygon by decile and linked back to the fourth resultant (j_pem).

2.2.6 Step 6 – Ecosection Process

The Ecosection coverage was intersected with the fourth resultant. The fifth resultant again named "j_pem" contains approximately 144,000 polygons.

2.2.7 Step 7 – Post Ecogen Processing

During the accuracy assessment, we determined that many site series could not be distinguished using just computer attributes in the digital PEM process. Thus, many original site series were lumped together following consultation with the Kamloops Regional Ecologist and Biome (Appendix III describes these entities). The MOF then provided site series letter codes.[14] Both the entity numbers or letter codes and the latest series letter codes were added to the "j_pem" coverage. The PEM entities used in the Merritt PEM were developed in consultation with the regional research ecologist, both lumping and splitting using

[13] Statistical Analysis System software – Copyright 2002 SAS Institute Inc.

[14] Cory Erwin (Ministry of Sustainable Management, Wildlife and Habitat Inventory, Vegetation Ecologist, Victoria) provided final site series letter codes.

the 1990 field guide for site-series units.[15] The Kamloops Regional ecologist, Dennis Lloyd *RPF*, is conducting a redefinition of site series over the entire Kamloops Region including the Merritt TSA. He has proposed many new site-series for the BGC units in the Merritt TSA. PEM's by their nature must be generalized to lump site series units together when the original units cannot be distinguished apart. As a result, the Merritt PEM is a hybrid of the approved 1990 field guide[15] and the proposed site series modifications. Where resolution issues made units impossible to differentiate a new PEM entity unit was proposed.

2.3 ACCURACY ASSESSMENT[16]

The provincial Chief Forester requires that the accuracy of PEM be proven if the results are to be used in timber supply projections. The MOF states that "….the only way that the Ministry of Forests can accept the PEM for use in timber supply analysis is to have accuracy data."[17] The NSIFS, in consultation with the MOF, developed a plan to measure accuracy of the Merritt PEM[18] following principles outlined in the *Protocol for Quality Assurance and Accuracy Assessment of Ecosystem Maps*.[7]

The results of work completed by Biome were used to define the PEM map entities for the dominant BGC subzones/variants present in the TSA.[19] These 130 map entities are a hybrid of the 1990 site series classification and the 2002 revised classification system developed by the Regional Ecologist.

A revised PEM map was generated to reflect these new map entities, and formed the basis for PEM polygons to be classified in the field (Appendix III). The Merritt PEM accuracy assessment is based on four tests (as per the PEM Protocols) and includes:

1. Proportion of sampled polygons where the dominant PEM map entities are the same as determined in the accuracy assessment.
2. Percent overlap between PEM map entities and those determined in the accuracy assessment.
3. Percent acceptable overlap between PEM map entities and those determined in the accuracy assessment.
4. Chi-square test of the map entity distribution between PEM map entities over the TSA and sampled polygons from the accuracy assessment.

Map entity definitions for tests one and two were based on those map entities approved by the Regional Ecologist. Additional groupings of map entities for test three were based on the experience of the Regional Ecologist knowing these groupings should not constitute errors for this accuracy assessment. All three tests were completed in three groups (Table 1). Group one comprised ground samples, group two ground checks, and the third group combined both ground samples and checks. The results of the chi-squared test suggest that the distributions may be significantly different. However, since the polygon

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[15] D. Lloyd, K. Angove, G. Hope and C. Thompson. 1990. A guide to Site Identification and Interpretation for the Kamloops Forest Region. Ministry of Forests, Kamloops, B.C. February 1990. (Parts 1 and 2)

[16] J.S. Thrower & Associates Ltd, 2002. Merritt TSA Predictive Ecosystem Mapping: Accuracy Assessment Report. Contract Report to NSIFS Merritt , B.C. December 19, 2002. 16 pp.

[17] Meidinger, D. 2001, Ecosystem Mapping Accuracy and Timber Supply Applications. MOF Research Branch, Victoria, B.C. August 3, 2001. 4pp.

[18] J.S. Thrower & Associates Ltd. 2002. Merritt PEM Accuracy Assessment Sample Plan (Version 1.1) Contract Report to the Nicola-Similkameen Innovative Forestry Society. Merritt. August 27, 2002 17pp.

[19] These entities were agreed to by the Regional Ecologist on July 23, 2002.

was subjectively located (as opposed to a random sample), the results may not be entirely valid, and should be given less consideration in the overall evaluation of the PEM.

Table 1. Results of the four PEM accuracy assessment tests.

Group	Test	Ground samples (No.)	Non-weighted Scores (%)			Weighted Scores (%)		
			Average	Lower 95% CI	Upper 95% CI	Average	Lower 95% CI	Upper 95% CI
Ground Samples	1	202	70	64	76	74	68	80
	2	202	67	60	74	66	59	73
	3	202	77	71	83	82	77	87
Ground Checks	1	200	66	59	73	69	63	75
	2	200	65	58	72	70	64	76
	3	200	70	64	76	74	68	80
Combined	1	402	68	63	73	72	68	76
	2	402	66	61	71	68	63	73
	3	402	74	70	78	78	74	82

2. CONCLUSION

The Merritt PEM was the first provincial PEM to be completed on a landbase of this size (approximately 1.13 million hectares covering 26 BGC subzones). When the program began in 1998, there were few provincial standards, and only PEM pilot projects provided clues as to the deliverables.

The methods used in the final Merritt PEM have produced an ecosystem map that is supported by a database that is both flexible and standardized. The methods used have produced results that exceed all criteria outlined in the PEM standards, and met the provincial Chief Forester's requirement for a successfully completed accuracy assessment.

The methods used are described in the accuracy assessment sample plan and the results are reported in the PEM accuracy assessment report. The positive results of the accuracy assessment are:

- Biome states that, "We are confident that the Merritt TSA accuracy assessment provided a reasonable ecological verification of map accuracy, apart form potential bias introduced by the subjective approach."
- Shearwater states, " The Merritt PEM is an adequate tool for resource use analysis.".
- All three tests for accuracy exceed the 65% threshold as required by the MOF standards[20] for PEM use in timber supply.

The final digital Merritt PEM dataset as approved above is provided in Appendix IV in Arc/Info export (.e00) format.

[20] http://www.for.gov.bc.ca/research/becweb/pdf/PEM_accuracy_statement_3.pdf

APPENDIX I – PEM PROCESS

APPENDIX II – PEM ATTRIBUTES

BIOTERRAIN INPUT ATTRIBUTES

Table 2. Surficial materials. [21, 22]

Map Symbol	Material name	Material Description
A	Anthropogenic materials	Artificial materials, and materials modified by human actions such that their original physical appearance and properties have been drastically altered.
C	Colluvium	Products of gravitational slope movements; materials derived from local bedrock and major deposits derived from drift; includes talus and landslide deposits.
D	Weathered bedrock	Bedrock modified *in situ* by mechanical and chemical weathering.
E	Eolian sediments	Sand and silt transported and deposited by wind; includes loess.
F	Fluvial materials	Sands and gravels transported and deposited by streams and rivers; floodplains, terraces and alluvial fans.
FA	"Active" fluvial materials	Active deposition zone on modern floodplains and fans; active channel zone.
FG	Glaciofluvial materials	Sands and gravels transported and deposited by meltwater streams; includes kames, eskers and outwash plains.
I	Ice	Permanent snow and ice; glaciers.
L	Lacustrine sediments	Fine sand, silt and clay deposited in lakes, and beach gravels and sand.
L1	Alkali lake beds	Dried-up or partly dry lakes where white efflorescence is visible on air photos.
LG	Glaciolacustrine sediments	Fine sand, silt and clay deposited in ice-dammed lakes, and beach gravels and sand.
M	Till	Material deposited by glaciers without modification by flowing water. Typically consists of a mixture of pebbles, cobbles and boulders in a matrix of sand, silt and clay. Chiefly basal till, but may include small areas of ablation till.
M1	Ablation till	Material melted out on top of glacier ice. Contains less silt and clay and less dense than basal till.
O	Organic materials	Material resulting from the accumulation of decaying vegetative matter; includes peat and organic soils.
R	Bedrock	Outcrops, and bedrock within a few centimeters of the surface.
U	Undifferentiated materials	Different surficial materials in such close proximity that they cannot be separated at the scale of the mapping.
V	Volcanic materials	Unconsolidated pyroclastic sediments.
N	No surficial materials	Generally Non-productive types (e.g. Lakes, rivers, Rock.

Knowledge base heading = Sm, GIS-Pre-Ecogen heading = Sm_1,Sm_2,Sm_3, GIS-Post-Ecogen heading = surfm_1, surfm_2, surfm_3)

[21] Howes, D.E., Kenk, E., 1997. Terrain Classification System For British Columbia, Version 2.0, Res. Inv. Br. MoELP.
[22] http://www.for.gov.bc.ca/ric/Pubs/Earthsci/012/012t-34.htm#TopOfPage, Guidelines and Standards To Terrain Mapping in B.C., RIC January 1996.

Table 3. Surface expression.

Symbol	Surface expression name	Surface expression description
A	moderate slope(s)	predominantly planar slopes; 15-26° (27-49%).
B	Blanket	material >1-2m thick with topography derived from underlying bedrock (which may not be mapped) or surficial material.
C	Cone	a fan-shaped surface that is a sector of a cone; slopes 15° (27%) and steeper.
D	Depression	enclosed depressions.
F	Fan	a fan-shaped surface that is a sector of a cone; slopes 3-15° (5-27%).
H	hummocky	steep-sided hillocks and hollows; many slopes >15° (27%).
J	gentle slope(s)	predominantly planar slopes; 3-15° (5-27%).
K	moderately steep slope	predominantly planar slopes; 26-35° (49-70%).
M	rolling topography	linear rises and depressions; <15° (27%).
P	Plain	0-3° (0-5%).
R	Ridges	linear rises and depressions with many slopes >15° (27%)r.
S	steep slope(s)	slopes steeper than 35° (70%).
T	terrace(s)	stepped topography and bench lands.
U	undulating topography	hillocks and hollows; slopes predominantly <15° (27%).
V	Veneer	material <1-2m thick with topography derived from underlying bedrock (may not be mapped) or surficial material; may include outcrops of underlying material.
W	mantle of variable thickness	material of variable thickness infilling depressions in an irregular substrate (rock or surficial material).
X	thin veneer	a thin veneer, where material is predominantly 10-25 centimeters thick.

Knowledge base heading = Se, GIS-Pre-Ecogen heading = sf_1a, sf_2a, sf_3a, GIS-Post-Ecogen heading = surf_e1a, surf_e2a, surf_e3a[1,2]

Table 4. Geological processes and mass movement subclasses.

Symbol	Geological process name	Geological process description
A	Avalanches	Slopes modified by frequent snow avalanches.
Af	Avalanches: major tracks	In zones of coniferous forest: broad avalanche track(s) occupied by predominantly shrubby, deciduous vegetation.
Am	Avalanches: minor tracks	Similar to above, but generally narrower than the height of adjacent trees.
Aw	Avalanches: mixed	Includes both major and minor avalanche tracks.
Ao	Avalanches: old tracks	Clearly visible on air photos, but less well defined than active tracks because they are partly or completely occupied by young conifers.
B	Braiding channel	Channel zone with many diverging and rejoining channels; channels are laterally unstable.
C	Cryoturbation	Heaving and churning of soil and surficial materials due to frost action.
D	Deflation	Removal of sand and silt particles by wind action.
E	Glacial melt water channels	Areas crossed by melt water channels that are too small or too numerous to map individually.
F	Failing	Slope experiencing slow mass movement, such as sliding or slumping.
H	Kettled	Area includes numerous small depressions and/or lakes where buried blocks of ice melted.
I	Irregularly sinuous channel	Channel displays irregular turns and bends.
J	Anastamosing channel	Channels diverge and converge around semi-permanent islands.
K	Karst processes	Solution of carbonates (limestone, dolomite) resulting in development of collapse and subsidence features.
L	Surface seepage	Abundant seepage.
M	Meandering channel	Channel characterized by regular turns and bends.
N	Nivation	Surface modified by hollows developed around semi-permanent snow banks.
P	Piping	Subsurface erosion of silty sediments by flowing water resulting in the formation of underground conduits.
R	Rapid mass movement	Slope affected by processes such as debris flows, debris slides, and rock fall.
S	Solifluction	Slope modified by slow down slope movement of seasonally frozen regolith.
U	Inundated	Areas submerged in standing water from a seasonally high water table.
U1	Inundated due to beaver activity	Inundation or partial inundation resulting from the presence of beaver dams.
V	Gullying	Slope affected by gully erosion.
W	Washing	Winnowing of fines by flowing water resulting in development of lag deposits.
X	Permafrost processes	Processes related to the presence of permafrost and permafrost aggradation or degradation.
Z	Periglacial processes	Solifluction, nivation and cryoturbation occurring together in a single terrain polygon.

(Knowledge base heading = Gp, GIS heading = Geop_1, Geop_2, Geop_3) [1 2]

Table 5. Soil drainage classes. [23]

Drainage code	Drainage class	Drainage description
x	very rapidly drained	water is removed from the soil very rapidly in relation to supply. Water source is precipitation and available water storage capacity following precipitation is essentially nil. Soils are typically fragmental or skeletal, shallow, or both.
r	rapidly drained	water is removed from the soil rapidly in relation to supply. Excess water flows downward if underlying material is pervious. Subsurface flow may occur on steep gradients during heavy rainfall. Water source is precipitation. Soils are generally coarse textured.
w	well drained	water is removed from the soil readily but not rapidly. Excess water flows downward readily into underlying pervious material or laterally as subsurface flow. Water source is precipitation. On slopes, subsurface flow may occur for short durations, but additions are equaled by losses. Soils are generally intermediate in texture and lack restricting layers
m	moderately well drained	water is removed from the soil somewhat slowly in relation to supply because of imperviousness or lack of gradient. Precipitation is the dominant water source in medium- to fine-textured soils; precipitation and significant additions by subsurface flow are necessary in coarse-textured soils.
i	imperfectly drained	water is removed from the soil sufficiently slowly in relation to supply to keep the soil wet for a significant part of the growing season. Excess water moves slowly downward if precipitation is the major source. If subsurface water or groundwater (or both) is the main source, the flow rate may vary but the soil remains wet for a significant part of the growing season. Soils generally have a wide range of texture, and some mottling is common.
p	poorly drained	water is removed so slowly in relation to supply that the soil remains wet for a comparatively large part of the time the soil is not frozen. Excess water is evident in the soil for a large part of the time. Subsurface or groundwater flow (or both), in addition to precipitation, are the main water sources. AAA perched water table may be present. Soils are generally mottled and/ or gleyed.
v	very poorly drained	water is removed from the soil so slowly that the water table remains at or on the surface for the greater part of the time the soil is not frozen. Ground water flow and subsurface are the major water sources. Precipitation is less important, except where there is a perched water table with precipitation exceeding evapotranspiration. Typically associated with wetlands.

Where two drainage classes are shown:

if the symbols are separated by a comma, e.g., “w,i”, then no intermediate state is present;

if the symbols are separated by a dash, e.g., "w-i", then all intermediate classes are present.

(Knowledge base heading = D_1 or D_2 GIS heading = D_1 or D_2)

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23 http://www.for.gov.bc.ca/hfd/pubs/Docs/Lmh/Lmh025/02.soil.pdf Field Manual for Describing Terrestrial Ecosystems, Handbook 25, 1998.

Table 6. Ecological soil groups. [24]

Code	Group descriptions	Surficial material & surficial expression
NOSOIL	very thin to non-soil	Ru, Rk, Rs, Rh, Rr, Rm Rw, Ra, Rj
VTCSOIL	very thin (<20cm) coarse soils	Dx, Cx
VTMFSOIL	very thin (<20cm) medium/fine soils	Mx
MDCSOIL	moderately deep (20-100cm), coarse soils	Cv, FGv, Dv,Fv
MDMSOIL	moderately deep (20-100cm), medium soils	Mv, Mw
MDFSOIL	moderately deep (20-100cm), fine soils	Lv,Ev, LGv
DCSOIL	deep (>100cm) coarse soils	Ch, Cf, Cu, Cb, Cj, Ca, Ck, Cc, Cs, Cw, FGp, FGr, FGt, FGk, FGa, FGu, FGs, FGw, FGf, FGj, FGm, Fj, Ft, Fu, Ua, Us, Uk
DCSSOIL	deep (>100cm), coarse soils with subsurface seepage	FAf, FAp, Fp, Ff
DMSOIL	deep (>100cm), medium soils	Mb, Mm, Mp, Mu, Mw, Ma, Mr, Mt, Mk, Mj, Ms
DFSOIL	deep (>100cm), fine soils	Lp, Eu, LGp, LGu
MDOSOIL	moderately deep (20-100cm), organic soils	Ov
DOSOIL	deep (>100cm), organic soils	Op, Ob

1. Coarse Soils -S, LS; Medium soils - SL, L, SiL; Fine soils - Si and finer
2. Slope Se is not included
3. k table category is ECOSOILS
4. N = lake and water features and A = Urban road type features

(Knowledge base heading = ECOSOIL, GIS heading = ECOSOIL_1, ECOSOIL_2, ECOSOIL_3)

Table 7. Slope classes. [25]

Class	Slope %
1	0-10%
2	11-25%
3	26-45%
4	46-70%
5	>70%

(Knowledge base heading= S, GIS heading= S)

Table 8. Aspect classes.

Symbol	Aspect name	Aspect definition
k	Cold	285° to 60° (slope class is >2)
c	Cool	60° to 135° (slope class is >2)
h	Hot	135° to 240° (slope class is >2)
w	Warm	240° to 285° (slope class is >2)
n	Neutral	All aspects with slope class <3)

(Knowledge base heading = As GIS heading = AS) [3]

[24] An 'ecosoil' variable was developed to create soil groups with similar ecological properties. These were summarized using combinations of surficial material and surface expression that had similar overall soil textures and depths.

[25] The divisions of the 5 slope classes and the 5 aspect classes were discussed and approved at a Merritt Pem Project meeting held in Kamloops November 2, 2000. Which are different from those in the TEM standards.[2]

TRIM RESULTANT ATTRIBUTES

Table 9. Elevation classes.[26]

E1 Class	Elevation (m)	E2 Class	Elevation (m)	E3 Class	Elevation (m)
1	< 1300	1	< 1600	1	< 1400
2	> 1299	2	> 1599	2	> 1399

(Knowledge base heading = E1, E2, E3, GIS heading = E1, E2, E3)

Table 10. Riparian areas (creek banks). [27]

Symbol	Riparian Class	Riparian Description
CB	1	A resultant polygon containing a 20-meter buffer along a single line stream, where the slope is less than 20 percent.

(Kb = CB and GIS = CB)

FOREST COVER INPUT ATTRIBUTES[28]

Table 11. Tree species.

Tree species code	Tree species name
AC	Black Cottonwood
AT	Trembling Aspen
BL	Balsam
CW	Western Red Cedar
EP	Paper Birch
FD	Douglas-Fir
HW	Western Hemlock
PL	Lodgepole Pine
PY	Ponderosa Pine
YC	Yellow Cedar
S	White and Englemann Spruce

(12) Tree Species (Kb = SP_S,SP_PL,SP_PY,SP_AC,SP_AT, SP_FD, SP_CW,SP_HW,SP_EP SP_BL,SP_YC GIS = SP_S,SP_PL,SP_PY,SP_AC,SP_AT, SP_FD,SP_CW, SP_HW, SP_EP,SP_BL)

Table 12. Tree age grouping.

Age Class	Age (years)
1	1 – 20
2	21 – 40
3	41 – 60
4	61 – 80
5	81 – 100
6	101 – 120
7	121 – 140
8	141 – 250
9	251+

(Kb = AGEGRP GIS = AGEGRP)

Age Group	Age Class
1	5 - 9

[26] Elevation breaks were assigned by Oikos to further differentiate Site Series within a BGC zone.
[27] A creek bank attribute was assigned by Oikos to differentiate wetter riparian areas next to single line creeks.
[28] Relational Data Dictionary (RDD 2.0) MoF, RIC January 31, 1995, Source document for the forest cover attributes. Groupings were created by Oikos as distinguishing feature for the knowledge base.

Table 13. Tree height grouping.

Height class	Height (m)
1	0.1 to 10.4
2	10.5 to 19.4
3	19.5 to 28.4
4	28.5 to 37.4
5	37.5 to 46.4
6	46.5 to 55.4
7	55.5 to 64.4
8	64.5 +

(Kb = HTGRP GIS = HTGRP)

Height group	Height class
1	1-2

Table 14. Tree crown closure grouping.

Crown closure class	Crown closure
0	0-5%
1	6-15%
2	16-25%
3	26-35%
4	36-45%
5	46-55%
6	56-65%
7	66-75%

(Kb = CCGRP GIS = CCGRP)

CC group	CC class
1	1-2
2	3-4
3	5-6
4	7-10

Table 15. Non-productive forest codes.

FC-NP-Code	NPDESC used	Description
2	A	alpine
3	R	rock
6	G	gravel pit
10	Treated as normal	alpine forest with species
11	NPBR	non-productive brush
12	NP (without species) NP with species treated normally	non-productive forest (with or without species)
13	NPBU	non-productive burn
42	C	clearing
50	U	roads
54	U	urban
60	H	hayfield
62	M	meadow
63	OR	open range
35	SWAMP	swamp

(Kb = NPDESC GIS = NPDESC)

BIOGEOCLIMATIC INPUT ATTRIBUTES

Table 16. Biogeoclimatic input attributes.

AT	At-Emwp				
BGxh2	BGxw1				
CWHms1					
ESSFdc2	ESSFdc2p	ESSFmw	ESSFmwp	ESSFxc	ESSFxcp
IDFdk1	IDFdk1a	IDFdk2	IDFxh1	IDFxh2	IDFxh2a
MHmm2	MHmm2p				
MSdm2	MSmw	MSxk			
PPxh1	PPxh2	PPxh2a			

ATTRIBUTES AVAILABLE IN BIOTERRAIN/SLOPE/ASPECT RESULTANT COVERAGE

The following is a list of attributes from the bioterrain/slope/aspect resultant coverage that were not used in the Knowledge Base creation. As the Knowledge Bases are being developed it is possible for more attributes to be used. This list will be periodically updated.

Bioterrain Decile 1

PRTFLG_1 TTEX_1A TTEX_1B TTEX_1C SM_Q1 SURFM_ST1 SURF_E1C BEDROCK_1 STTEX_1A STTEX_1B STTEX_1C SSM_1 SSURFM_Q1 SSURFM_ST1 SSURF_E1A SSURF_E1B SSURF_E1C

Bioterrain Decile 2

PRTFLG_2 TTEX_2A TTEX_2B TTEX_2C SM_Q2 SURFM_ST2 SURF_E2C BEDROCK_2 STTEX_2A STTEX_2B STTEX_2C SSM_2 SSURFM_Q2 SSURFM_ST2 SSURF_E2A SSURF_E2B SSURF_E2C

Bioterrain Decile 3

PRTFLG_3 TTEX_3A TTEX_3B TTEX_3C SM_Q3 SURFM_ST3 SURF_E3A SURF_E3C BEDROCK_3 STTEX_3A STTEX_3B STTEX_3C SSM_3 SSURFM_Q3 SSURFM_ST3 SSURF_E3B SSURF_E3C

Bioterrain Geophysical Attributes

GEOP_Q1 GEOP_ST1 GEOP_SCM1A GEOP_SCM1B GEOP_SCM1C GEOP_Q2 GEOP_ST2 GEOP_SCM2A GEOP_SCM2B GEOP_SCM2C GEOP_Q3 GEOP_ST3 GEOP_SCM3A GEOP_SCM3B GEOP_SCM3C D_1 DRAIN_SEP1 DRAIN_SEP2 D_3

Bioterrain Aspect/Slope Attributes

MEAN_ASP LOWREL_FLG POLY_COM ASP_CLS1 ASP_SEP1 ASP_CLS2 ASP_SEP2 ASP_CLS3 SLPC_1 SLPC_REL1 SLPC_2 SLPC_REL2 SLPC_3 RELIABILIT

4.5. BEC ZONE ATTRIBUTES

QBEC_TAG_BECLABEL_REF_NO_ZONE_SUBZONE

APPENDIX III – PEM ENTITY DESCRIPTION

APPENDIX IV – PEM DIGITAL DATA