CRANBROOK TSA AND DOMINION COAL BLOCK

Predictive Ecosystem Mapping (PEM) Final Report

FIA project 07-RIP-FIA-102

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Field personnel for the PEM field data sampling project were, Kim Everett, Peter Richardson, Sherri Elwell and Jacob Bapty of Timberline Natural Resource Group Ltd. Thanks to them for their meticulous attention to detail in all aspects of field sampling and data handling. The entire sampling crew worked hard and long hours under often difficult circumstances. Generalized materials mapping was completed by Maureen Ketcheson, Kim Everett and Sherri Elwell, knowledge bases were compiled and tested by Maureen Ketcheson and Sherri Elwell. Internal accuracy assessments were completed by Maureen Ketcheson and Iain Smith. Data entry and final report compilation was completed by Sherri Elwell. Final reporting was completed by Maureen Ketcheson and Kim Everett (year one).

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I would like to extend a sincere thank you to Kevin Misurak for his work on filling the gaps in the ortho photo coverage and for many years of a great working relationship.

We appreciate Dennis Lloyd, Research Ecologist, Southern Interior Region for his input into early discussions of the nature of mapping entities and for his ongoing work on the new BGC classification in the subzones of the study area and to Deb McKillop, Research Ecologist whose input was encouraged and appreciated.

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March 31, 2008

File number: 4061613

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Reference: Cranbrook TSA and Dominion Coal Block Predictive Ecosystem Mapping (PEM) Final Report

Dear Marcie;

Please accept this final report for the above-mentioned project.

Thank you, it has been a pleasure working with you over the past two years.

Yours truly,

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EXECUTIVE SUMMARY

The Biogeoclimatic subzone variants of the Cranbrook TSA modeled in this project include the Ponderosa Pine Bunchgrass, dry hot (PPdh2), Interior Douglas-fir, dry mild (IDFdm2), Montane Spruce, dry cool (MSdk1,2), Interior Cedar Hemlock, dry warm (ICHdw), Interior Cedar Hemlock, dry mild (ICHdm), Interior Cedar Hemlock, moist cool (ICHmk4), Engelmann Spruce Subalpine Fir , wet mild (ESSFwm), Engelmann Spruce, dry mild (ESSFdm), and Engelmann Spruce, dry cool (ESSFdk1,2) variants. Parkland, Woodland, and Alpine areas were not addressed by this version of the Cranbrook TSA PEM model. The project area covers approximately 1.48 million hectares in a landscape that varies from the undulating Rocky Mountain Trench to the steep valleys of the Purcell and Rocky Mountains, with a wide variety of terrain shaped by post glacial deposition and climatic influences from the Moist Interior Climate to the north and west to Dry Continental influences to the east and south. A Predictive Ecosystem Mapping (PEM) model was developed to allocate ecosystem based mapping entities over the land base for 11 BEC variants (Ecological Data Committee 2000; Ministry of Sustainable Resource Management 2004). Within each variant the model predicts the distribution of map entities based on the site series classification recently presented by Dennis Lloyd, Regional Ecologist, Southern Interior Forest Region (Lloyd 2006). Every effort was made to retain the detail of the site series classification for each BEC variant, however, in some cases, lumping of site series into map entities was necessary, especially in areas of flat or gently sloping terrain with the same general landscape shape and in diverse rocky areas. All lumped map entities were approved by Dennis Lloyd.

Field data was collected using a random sampling regime that combines point data and line intercept transect data to generate a "measure" of the distribution of site series within each variant. The field data was also used to assist in the determination of relationships between the physical and GIS related spatial attributes of the data point and the site series it represented. Lloyd's classification of site series is strongly based on floristics and it was difficult to derive anything other than very general relationships between site and GIS features and site series. However, the field data was very useful for determining the "expected" proportion of site series within the variant and to test the thematic accuracy of each run of the model.

The goal of the model is to accurately predict the distribution of site series over each variant. Our objective was thematic accuracy of at least 65%, the final run of the model scored an internal accuracy of 67% overlap between field transects and model predictions. Field transect locations were marked with hand held GPS and may be subject to spatial error, more so than independent AA transects. The model was developed to run in a raster environment using a 25 meter pixel as the basic unit for prediction. It is important to note that the final raster based result of this model could be rolled up to any polygon provided at a later date, consequently ultimately the model could accommodate any polygons from a variety of sources including the final VRI and provide a prediction of site series within those polygons.

Our internal measure of the success of the model was achieved through a combination of statistical analysis and visual observation of the result. The model was run through as many as six iterations per variant until a satisfactory distribution of map entities was achieved. Each iteration of the model was tested with field data using the Moon (2005) protocol, as well as, visual assessment of the model result at a variety of scales. This facilitated the determination of appropriate distribution of map entities relative to the shape of the landscape and position of the predicted map entity. The comparison of site series proportions between the model and the field data was also useful and was the criteria through which the overall area of each map entity was assessed. Field data collection was biased to one kilometer from TRIM roads, consequently, an assessment of overall landscape shape was also used to temper the final result of the model and prevent the result from being “over trained” to the field data.

The final result has yet to be tested independently for accuracy. We expect that some modifications to this model will be necessary after that is completed owing to the strong bias towards vegetation over site features in the revised BEC classification.

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1.0 INTRODUCTION

1.1 History of the project

Predictive ecosystem mapping (PEM), for the Cranbrook TSA and Dominion Coal Block was initiated by the Tembec Enterprises Inc. in June of 2006 as year one of FIA project 07-RIP-FIA-102. The contract was awarded to Timberline Natural Resource Group Ltd. Over the winter of 2006/2007 generalized materials mapping to support the Cranbrook TSA PEM was completed along with the preparation of spatial input layers depicting slope, aspect, landscape position, buffered water features, buffered BEC variants, TRIM water features, elements of forest cover, including leading species and top three species. The quality of the input data was assessed. A field sampling plan was prepared. In March 2007 a progress report and an input data quality assessment report were submitted to the client.

In preparation of the 2007 field season a sample plan was developed. The sample plan consisted of randomly selected points that would make the location of line intercept transects within the crown forested land base, Tembec's Managed Forest 27 and the Dominion Coal Blocks.

A preliminary PEM was completed for March 31, 2007 using a 25m raster-based modeling approach to support the prediction of ecosystems. The preliminary PEM depended largely on the digital elevation model (DEM) and four valuable layers which were developed from it: TauDEM wetness index, slope position/shape (Zimmerman 2000), slope gradient, and aspect. Data layers derived from the DEM were combined with specified forest cover attributes, extracted from the VRI, and TRIM wetland features. Expert-based knowledge tables were developed specifying site series for unique combinations of the input layers. The 2007/2008 fiscal year runs of these knowledge bases used additional information from the field work, generalized materials mapping and the sensitive ecosystem inventory (SEI) mapping to further identify specific site series.

This report documents the results of 2007 field data collection, field data base preparation, site series modeling and field data analysis activities for the BEC variants of the Cranbrook TSA that were undertaken between June 2007 and March 2008 and reports on Tasks and Deliverables required for PEM under FIA project 07-RIP-FIA-102.

2.0 DESCRIPTION OF THE AREA

The Cranbrook TSA is located in southeastern corner of B.C. and covers approximately 1.48 million hectares of the former Nelson Forest Region (Figure 1). The TSA is bound by the Skookumchuck Valley to the north, the Canada-US border to the south, the Alberta border to the east, and the southern Purcell Mountains height of land to the west.

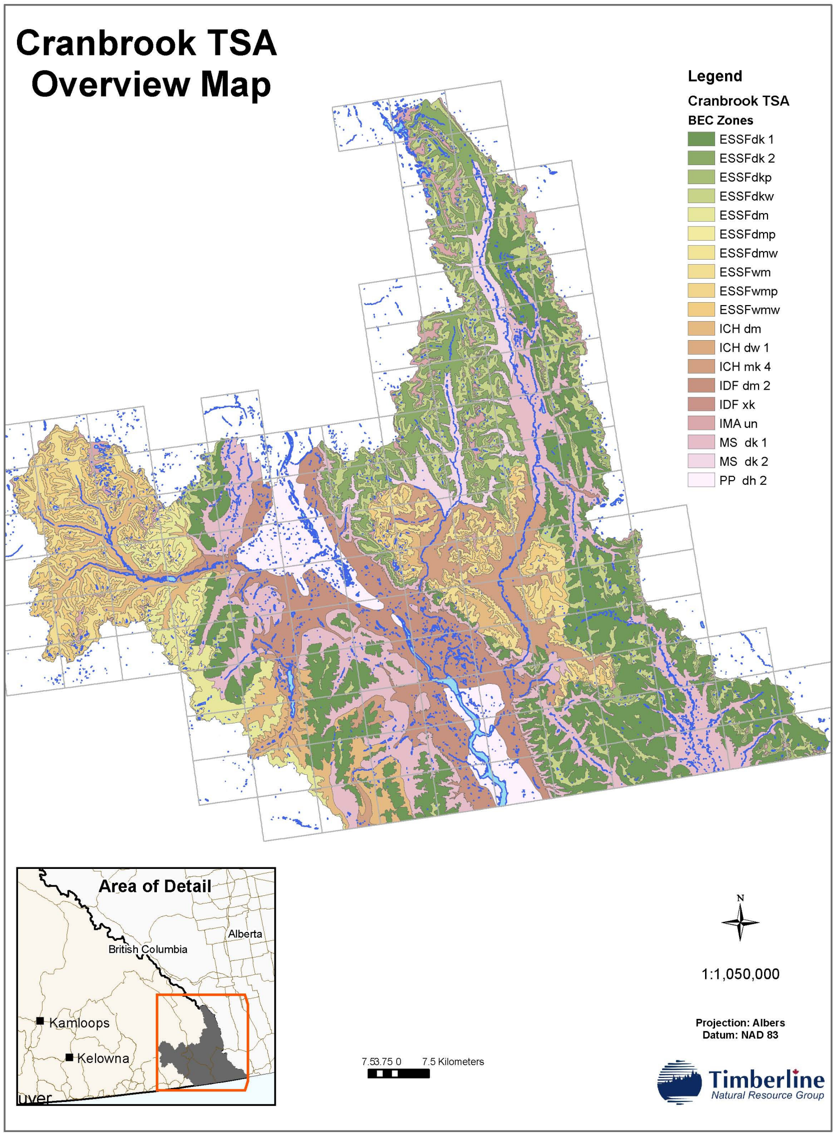

Figure 1. Overview of the Cranbrook TSA

Three major physiographic regions characterize the varied terrain of the Cranbrook TSA: the Rocky Mountains in the east, the Purcell Mountains in the West, and the Rocky Mountain Trench in the Middle. The major drainage in the TSA includes the Kootenay River, which flows southward through the Rocky Mountain Trench. Its major tributaries are the Moyie, St. Mary, Wildhorse, Bull and Elk Rivers.

The climate in the Cranbrook TSA is best described by Biogeoclimatic (BGC) units, which include six BGC zones and 19 BGC subzone/variant/phases (Table 2). The Ponderosa Pine (PP) BGC Zone occurs at low elevations (700-900 m) in very dry valleys of the Rocky Mountain Trench (Lloyd et al. 2006). The climate is characterized by very dry summers and cool winters with light snow cover. Interior Douglas fir (IDF) BGC Zone also occurs in the Rocky Mountain Trench, generally between the PP zone and the Montane Spruce (MS) Zone (800-1200 m). The climate is characterized by warm, dry summers, a fairly long growing season and cool winters. The Montane Spruce BGC Zone is found at mid-elevations, often between the IDF and the Engelmann Spruce-Subalpine Fir (ESSF) BGC Zone (1200-1600 m) (Lloyd et al. 2006). This zone is characterized by cold winters and moderately short, warm summers. The Interior Cedar-Hemlock (ICH) BGC zone occurs at low to middle elevations (700-1500 m) in the wetter portions of the Purcell and Rocky Mountains. This zone has a climate dominated by easterly moving air masses that produce cool wet winters and dry warm summers. Snow melt minimizes soil moisture deficits in the summer. This zone is considered the most productive zone in the interior of B.C. and also has the highest diversity of tree species of any zone in B.C (Lloyd et al. 2006). The ESSF BCG zone is the uppermost forested zone, lying below the Alpine Tundra (IMA) from 1600-2200 m. Growing seasons are cool and short, while winters are long and cold. Forests are continuous at the lower elevations but become more patchy in higher elevation where islands of heath, meadow and grassland exist (Lloyd et al. 2006). The Alpine Tundra (IMA) zone lies above the ESSF and is by definition treeless although stunted, or krummholz trees are common at the lower elevations of this zone. Overall rock, ice, and grassy meadows dominate this zone.

Forests in the Cranbrook TSA have the distinction of being among the most productive in the interior of the province. In addition, lower elevation forests have a wide diversity of tree species. The forests of the Cranbrook TSA are dominated by lodgepole pine, Douglas-fir, western larch, Engelmann spruce, and subalpine fir or balsam. Ponderosa pine, western hemlock, western red cedar, whitebark pine, western white pine, trembling aspen, paper birch and black cottonwood are less common in the TSA. Table 1 provides a summary of areas by status within the Cranbrook TSA and table 2 provides a summary of the BGC units and areas in the Cranbrook TSA.

Table 1. Area Statistics for Cranbrook TSA

Category	Areas (ha)	Category	Areas (ha)
Gross	1,483,891	Alpine	35,695
Private Land	237,827	Parkland	81,445
Parks & Protected	72,902	Woodland	178,208
Productive Land	760,590	THLB	416,196

Table 2. Summary of BGC Units and Areas in the Cranbrook TSA

BGC Unit[1]	Areas (ha)	BGC Unit	Areas (ha)
ESSFdk1	273,575	ESSFwmw	64,737
ESSFdk2	82,642	ICHdm	76,168
ESSFdkp	45,555	ICHdw1	4,124
ESSFdkw	143,113	ICHmk4	77,168
ESSFdm	43,399	IDFdm2	151,548
ESSFdmp	3,662	IDFxk	892
ESSFdmw	15,489	IMAun	34,402
ESSFwm	90,127	MSdk1	224,364
ESSFwmp	27,139	MSdk2	43,482
		PPdh2	82,305
Total	**1,483,891**		

Table 3. Summary of BGC Units and Areas in the Dominion Coal Block

BGC Unit[2]	Areas (ha)	BGC Unit	Areas (ha)
ESSFdk1	9,927	ESSFwmw	1,236
ESSFdkw	3,736	ICHmk4	1,883
ESSFwm	3,248	MSdk1	196
Total	**20,226**		

[1] Lloyd 2007 BEC coverage result

[2] Lloyd 2007 BEC coverage result

3.0 SUMMARY OF 2006/07 PROJECT

The 2006/07 year saw a number of components of this project being completed.

- Areas of relatively homogenous slope, aspect and landscape position were generated using a variety of routines including Taudem, Toposcale and Spatial Analyst.
- Sensitive Ecosystem Inventory Mapping (delineations and polygon attribution) were completed on the Crown Forested Land Base and the Dominion Coal Blocks.
- Generalized/Exceptional materials mapping was completed on the Crown Forested land base and the Dominion Coal Blocks.
- Input data layers were compiled and put into GRID formats for use in the PEM.
- Input data quality assessments were completed on each of the input data layers which tests them against existing field data in the Cranbrook TSA.
- Expert-based knowledge tables were developed for the preliminary BGC classification.
- Draft runs of the PEM were completed.
- A sample plan was developed for the 2007 field season.

4.0 INPUT DATA LAYER OVERVIEW

Input data originated in several thematic input layers. Here the input data layers and how they were derived are described in detail.

The tasks required of this phase of the project included;

- The assessment of thematic input layers for use in the PEM process
- The creation of PEM input layers
- The assessment of PEM input layers for use in the mapping process

For purposes of clarification it should be stated here that this phase of the project involved the use of four sources of thematic input layers for assessment against collected field data.

- Ministry of Forests and Range Biogeoclimatic Mapping (Lloyd 2007)
- Ministry of Sustainable Resource Management TRIM II mapping
- Ministry of Forests and Range VRI/FC1 Data
- Existing field data from the Cranbrook TSA

From these four layers the preliminary PEM utilized 28 input layers:

- Biogeoclimatic Mapping
- TRIM II
  - TRIM II Water Layer Feature
    - Lakes
    - Rivers
  - TRIM II Wetland Layer Feature
    - Marshes
    - Swamps
    - Reservoirs
  - Digital Elevation Model
    - TauDEM Wetness Index
    - Toposcale (Landscape shape/Slope position)
    - Aspect
    - Slope gradient

- VRI/FC1 Forest cover attributes
  - Douglas-fir leading or in the top three species
  - Ponderosa pine leading or in the top three species
  - White spruce leading or in the top three species
  - Western Red Cedar leading or in the top-three species
  - Lodgepole pine leading or in the top-three species
  - Trembling aspen leading or in the top three species
  - Black cottonwood leading or in the top three species
  - Open Range
  - Urban
  - Rock

  - Non-productive Brush
- Generalized Materials Mapping
  - Non-Forested Features
  - Seepage
  - Soil texture
- Sensitive Ecosystem
  - Grasslands
  - Sparsely vegetated areas (i.e.- rock, talus, cliffs)
  - Riparian
  - Coniferous Woodlands
  - Broadleaf Woodlands

4.1 Biogeoclimatic Ecosystem Mapping

The most current version of the BGC unit mapping (Lloyd 2007) was provided in August 2007 as the BGC to be utilized in this project. It should be noted that additional BGC boundary revisions and site unit refinement in the Cranbrook TSA are still a possibility as the new Research Ecologist Deb McKillop finalizes and publishes classifications for the Region.

The BGC unit line input source was generated on a TRIM base and used TRIM elevations in the development of BGC rules. The mapping is seamless and there are generally no issues regarding the positional accuracy of this layer of information.

The revised BGC mapping is completed and quality assured by MoFR. The mapping represents the best effort given the current knowledge and information availability. Thematic accuracy assessment is generally beyond the scope of this project. Since the BGC forms the base for ecosystem (site series) mapping, it is normally recommended for use in PEM with the approval of the MoFR Regional Ecologist. In this case, the Regional Ecologist does encourage the use of the revised BGC mapping in the upcoming PEM (Lloyd, pers. com. March, 2007).

Citation: Ministry of Forest Research Branch

Consultant/Department: Ministry of Forests Research Branch

Publication Scale: 1:20,000

Period of Compilation: August, 2007.

Base Map Projection: UTM NAD83, Zone 11

The Biogeoclimatic mapping was projected from the government standard Albers Equal Area projection.

4.2 TRIM II

TRIM has been the standard as a base for new land base inventories during the past two decades and directly forms the basis of the wetland polygons (marshes, swamps, rivers and lakes) and the Digital Elevation Model (DEM) in the PEM. In addition, TRIM data such as road locations was used in creating the sample plan for the upcoming field season.

Citation: n/a

Consultant/Department: Geographic Data BC Branch, Ministry of Sustainable Resource Management

Publication Scale: 1:20,000

Period of Compilation: 1992-2000

Base Map Projection: UTM NAD83, Zone 11

TRIM mapping was projected from the government standard Albers Equal Area projection to Universal Transverse Mercator (UTM) zone 11 NAD83.

4.2.1 TRIM Water Feature Layer

TRIM water was received as a single precision export (e00) file in Albers projection. All TRIM data was placed in the corresponding map sheet directory and imported, projected to UTM Zone 11 as a double precision coverage and finally appended into a seamless single line stream network. No edge mapping issues were discovered here. All AMLs associated with process can be found in Appendix 1.

In order to transform the single line water features into a double line water coverage the following process was completed. The single line coverage (twtr) was copied to a coverage named twtrfill to be used as our working coverage. Next, double line water features were selected using the feature code attribute (FCODE = 'GA90000'). All other arcs were deleted. The outer boundary of the mapsheets that comprise the TSA was added to the double line water features and the arcs were extended to match up the external boundary. This is done in order to classify the land separate from the water features. At this stage arcs were extended to help eliminate dangles, and any remaining dangles were eliminated manually. Finally, polygon topology was built, labels created and a surface attribute was added to the PAT. The AML used to complete this task is listed in Appendix 1.

Once a topologically sound water feature polygon layer was created we could begin classifying each polygon based upon the feature code of the ARC. The right hand rule is used in coding feature codes so we know to which side each arcs feature code refers. A relate was created between the AAT and the PAT and polygons were selected based upon the feature code listed in the AAT (Table 4). The following table highlights the codes used to assign polygon features. The final step in classifying the water feature coverage was to select out only lakes and double line rivers and place them in a new coverage.

Table 4. Classification of the TRIM feature codes

Feature Code	Classification
GA	Rivers
GB	Lakes
GC	Swamps
GE25850	Sandbars
GE *	Land
GD	Glaciers
GG	Ocean

4.2.2 TRIM Wetland Layer

The steps used to define the wetland layer were exactly the same as those used to define the lake layer. The last step differed in that all polygons defined as swamps or wetlands were removed. All relevant AML's can be found in Appendix 1. The wetlands delineations by TRIM were classified as part of the SEI process.

4.3 Digital Elevation Model (DEM)

The DEM was generated from 1:20,000 TRIM II arc generate files. The source projection was Albers. In order to create the DEM the TOPOGRID command in ARC/INFO was used. All relevant AML's can be found in Appendix 1. The TOPOGRID command required:

- a point coverage of elevation sources;
- a lake coverage used to flatten out lake elevations;
- a sink coverage of known sink locations; and
- a buffered boundary coverage defining the outer boundary of the TSA plus 5000 meters.

Point Coverage of Elevation Values: The point elevation coverage was generated by creating a TIN from the TRIM generate files and using the hardlines contained within the TRIM package. Once the TIN was generated a lattice was created using the tinlattice command. The spatial resolution of the source data points was approximately 75 m. The gridpoint command is used to translate the lattice to a point coverage. Once the point coverage was generated it was projected to UTM Zone 11, Nad 83.

Lake Coverage: The creation of the lake coverage is described above in the TRIM Water Feature Layer section. The purpose of this coverage is to ensure that all elevation values within the lake are averaged to the same height. This ensures consistent elevation values across lakes.

Existing Sinks: Sinks are topographic depressions and the TOPOGRID command tries to eliminate as many sinks as possible. However, some of these sinks are valid and the sinks layer defines all known sinks across the landscape. Sinks can be extracted from the twtr file point features. They are feature coded as HB27550000. *5000 m Buffered Boundary*: The boundary of the TSA was buffered by 5000 m in order to ensure consistent analysis across the TSA boundary.

The TOPOGRID Command: Once all the input layers are in place the TOPOGRID command was issued allowing the DEM to be processed.

4.3.1 TauDEM Wetness Index (Soil Moisture Model)

The TauDEM soil moisture model was developed by Tarboton (2005). This model allows estimation of soil moisture through analysis of a specific catchment area. The moisture contributing area for each grid cell is taken as its own contribution plus the contribution from upslope neighbors that drain into it. This is evaluated recursively starting from points in the outlets shapefile, or when this is not input at each point in the grid. The landscape was classified into five categories of soil moisture: subhydric to hygric, subhygric, mesic, submesic to subxeric, and very xeric to subxeric (Figure 2).

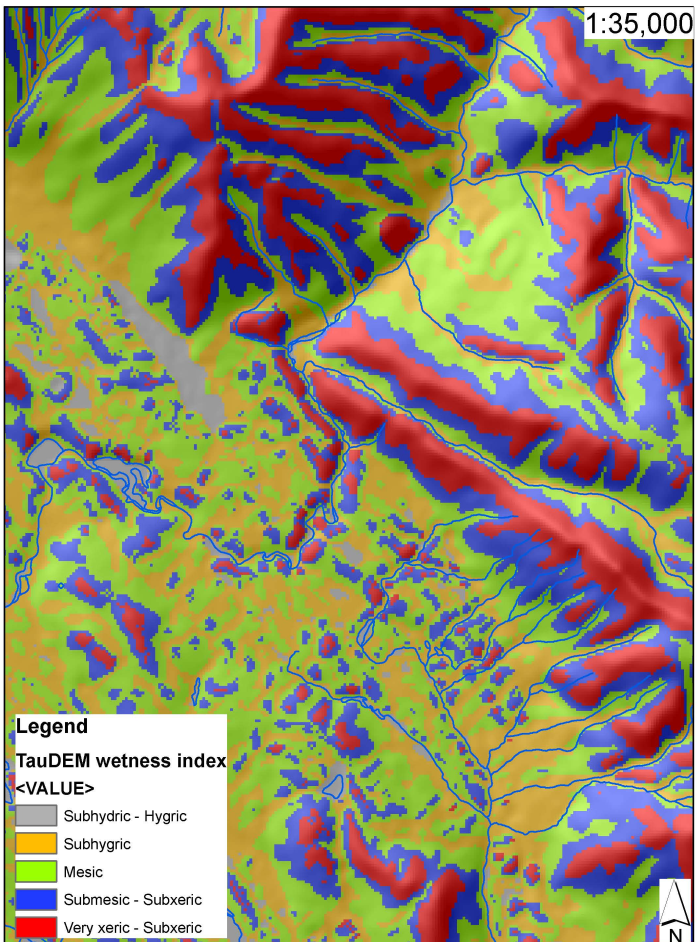

Figure 2. An example of the spatial output from the TauDEM wetness index

4.3.2 Slope position

The slope position layer describes the position of an area relative to the overall landscape shape. This process was designed to characterize the landscape into six classes: Crest, Upper Slope/Convex, Mid Slope – Straight, Mid Slope - Concave, Lower Slope, Toe Slope (Figure 3, Table 5). This layer was modeled using an AML downloaded from the Swiss Federal Research Institute WSL (Zimmermann 2000).

This AML is used to identify topographic exposure (ridge, slope, toe slope, etc) at various spatial scales, and to hierarchically integrate these features into a single grid (Zimmermann 2000). Topographic position can be calculated using a hierarchically nested approach. In this AML, circular moving-windows with increasing radii are applied to a DEM, and the difference between the average elevation of the window and the center cell of the window is calculated and written to temporary output grids (Zimmermann 2000). The user is prompted for the number search radii, for which the temporary grids are generated. The resulting (temporary) maps are interpreted as relative topographic exposure at different spatial scales. The exposure can be interpreted as a ridge or peak if the center cell in the moving window has a higher elevation than the average elevation of the cells in the window. Contrarily, if the center cell is of lower elevation than the average elevation of the window, then the center pixel can be interpreted as "toe slope" or "valley bottom".

The DEM was smoothed twice using a low pass filter using a focal mean with a 3 by 3 kernel. This generalized the overall values of the DEM, effectively reducing the elevation value range. After the smoothing process, the AML was run on the DEM. The number of pixels for the smallest search radius was set to 3, with increments of 3 up to the maximum of 12 pixels for the largest search radius.

Values derived from the AML were classified according to natural breaks in the data to produce the six slope position classes. The AML does not distinguish between midslope and valley bottoms, therefore the slope grid was then applied, and areas with a slope of 5% or less were classified as 'flat' or 'valley bottoms'.

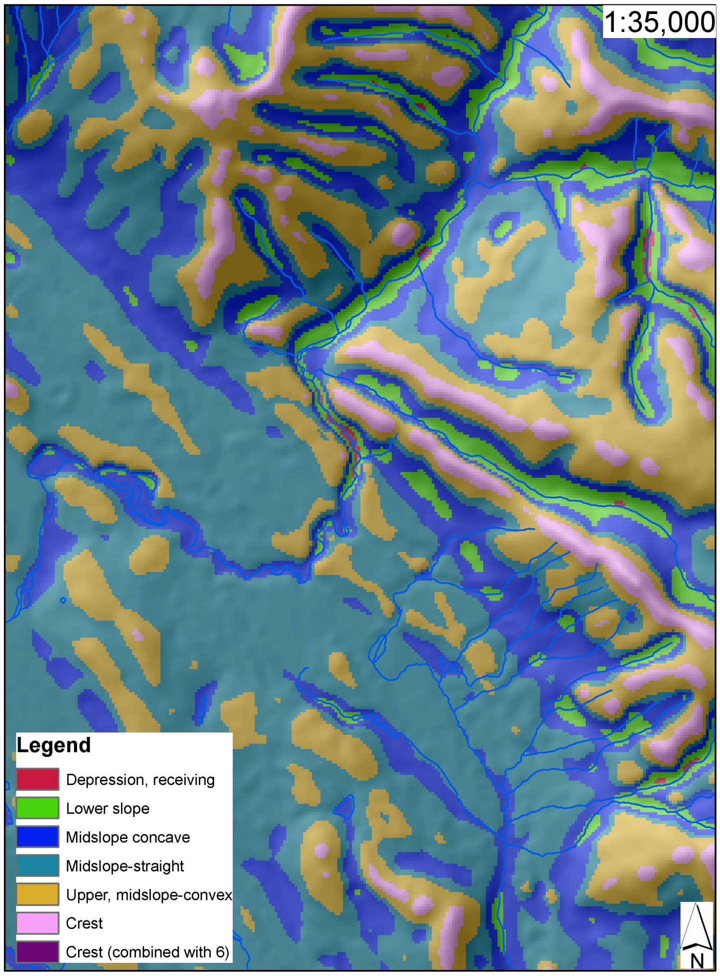

Figure 3. An example of the spatial output from the slope position model

Table 5. Slope Position Classes

Min Value	**Max Value**	**Slope Position**	**Slope Position Code**
-3887.923	-249.919	Toe slope	1
-249.919	-127.907	Lower slope	2
-127.907	-36.2	Midslope concave	3
-36.2	24.938	Midslope straight	4
24.938	147.215	Upper Slope /Midslope convex	5
147.215	1001.021	Crest	6

4.3.3 Aspect

The ArcInfo Grid Aspect command was applied to the elevation grid. Aspect identifies the down-slope direction of the maximum rate of change in value from each cell to its neighbors. Aspect can be thought of as the slope direction and is expressed in positive degrees from 0 to 360, measured clockwise from the north.

The Slope grid was then applied to the Aspect grid. Aspect classes with a slope in slope class 1 (<5% slope) were considered to be level and have no significant aspect. The grid was then reclassified into discrete classes (Table 6).

Table 6. Aspect Classes

Aspect Class	Description (degrees)
1 - Cool	0-45, 315-360
2 - Warm	135-270
3 - Neutral	45-135, 270-315
4 - Level	Less than 5% slope

4.3.4 Slope gradient

ArcInfo Grid Slope Command was used on the Elevation Grid. Slope identifies the maximum rate of change in value from each cell to its neighbors. An output slope grid can be calculated as percent slope or degree of slope. The direction the plane faces is the aspect for the processing cell. The slope for the cell is calculated from the 3 x 3 neighborhood using the average maximum technique. If there is a cell location in the neighborhood with a no-data z value the z value of the center cell will be assigned to the location. At the edge of the grid, at least three cells (outside the grid's extent) will contain no-data as their z values. These cells will be assigned the center cell's z value. The result is a flattening of the 3 x 3 plane that is fit to these edge cells, which thus usually leads to a reduction in the slope. The grid was then reclassified into discrete classes (Table 7).

The actual algorithm that is used to calculate slope is (*ESRI 2001*):

rise_run = SQRT(SQR(dz/dx)+SQR(dz/dy))degree_slope = ATAN(rise_run) * 57.29578

where the deltas are calculated using a 3x3 roving window.a through i represent the z_values in the window:

a b cd e fg h i

(dz/dx) = ((a + 2d + g) - (c + 2f + i)) / (8 * x_mesh_spacing)(dz/dy) = ((a + 2b + c) - (g + 2h + i)) / (8 * y_mesh_spacing)

Table 7. Slope Classes

Slope Class	Description
1	0 to 5%
2	5% to 20%
3	20% to 50%
4	50% to 65%
5	65% +

4.4 VRI/FC1

The VRI was derived from existing FC1 based on VRI data format (i.e., it is not a true VRI based on VRI Inventory Standards). GRIDS were created for the following attributes:

- Douglas-fir leading or in the top three species
- Ponderosa pine leading or in the top three species
- White spruce leading or in the top three species
- Western Red Cedar leading or in the top-three species
- Paper birch leading or in the top-three species
- Trembling aspen leading or in the top three species
- Black cottonwood leading or in the top three species
- Urban
- Non-Productive Brush
- Open Range
- Rock

Citation: Rollover Forest Cover to VRI

Consultant/Department: Ministry of Sustainable Resource Management

Publication Scale: 1:20,000

Period of Compilation: Rollover VRI 2000- 2005

Base Map Projection: UTM NAD83, Zone 11

4.5 Terrain and Soil Mapping

For the PEM purpose, the assembled sources of terrain and soil maps were considered valuable information for identifying areas of 'exceptional' ecology and surficial material. For this reason this layer was used solely as a guide when delineating areas for generalized or exceptional materials mapping and no GRIDS for direct input into the PEM were created. Areas typically characterized by exceptionally coarse textures, as would be expected in glaciofluvial deposits, or exceptionally fine textures, as would be expected in glaciolacustrine areas were visually identified and delineated using this data layer.

Level D Terrain

Citation: n/a

Consultant/Department: Ministry of Forests, Nelson

Publication Scale: Unknown

Period of Compilation: Unknown

Base Map Projection: UTM NAD83, Zone 11

Compiled into one seamless coverage both B and D level mapping.

Level B Terrain

Citation: n/a

Consultant/Department: Ministry of Forests, Nelson.

Publication Scale: Unknown
Period of Compilation: Unknown

Base Map Projection: UTM NAD83, Zone 11

Compiled into one seamless coverage both B and D level mapping.

Soil Mapping

Citation: See Table 8

Table 8. Citation of terrain and soil mapping sources

Mapsheet	Map Name	Citation	Map Type	Year	Scale	Agency
82F/4	ROSSLAND-TRAIL	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/5	CASTLEGAR	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/12	PASSMORE	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/13	BURTON	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82K/4	NAKUSP	U. WITTNEBEN & P.N.	SOILS &	1980	50000	MOE

Mapsheet	Map Name	Citation	Map Type	Year	Scale	Agency
		SPROUT	LANDFORMS			
82K/5	ST. LEON CREEK	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/12	BEATON	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/13	CANBORNE	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82F/3	SALMO	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/6	NELSON	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/11	KOKANEE PEAK	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/14	SLOCAN	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82K/3	ROSEBURY	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/6	POPLAR CREEK	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/11	TROUT LAKE	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/14	WESTFALL RIVER	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82F/2	CRESTON	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/7	BOSWELL	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/10	CRAWFORD BAY	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/15	KASLO	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82K/2	LARDEAU	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/7	DUNCAN LAKE	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/10	HOWSER CREEK	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/15	BUGABOO CREEK	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82F/1	YAHK	P.N. SPROUT & J.R.	SOILS &	1980	50000	MOE

Mapsheet	Map Name	Citation	Map Type	Year	Scale	Agency
		JUNGEN	LANDFORMS			
82F/8	GRASSY MOUNTAIN	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/9	ST. MARY LAKE	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82F/16	DEWAR CREEK	P.N. SPROUT & J.R. JUNGEN	SOILS & LANDFORMS	1980	50000	MOE
82K/1	FINDLAY CREEK	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/8	TOBY CREEK	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/9	RADIUM HOT SPRINGS	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82K/16	SPILLIMACHEEN	U. WITTNEBEN & P.N. SPROUT	SOILS & LANDFORMS	1980	50000	MOE
82G/4	YAHK RIVER	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/5	MOYIE LAKE	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/12	CRANBROOK	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/13	SKOOKUMCHUCK	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/3	LAKE KOOCANUSA	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/6	FERNIE	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/11	FERNIE	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/14	QUINN CREEK	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/2	LOWER FLATHEAD	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/7	UPPER FLATHEAD	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/10	CROWSNEST	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/15	TORNADO MOUNTAIN	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE

Mapsheet	Map Name	Citation	Map Type	Year	Scale	Agency
82G/1	SAGE CREEK	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE
82G/8	BEAVER MINES	L. LACELLE & H. LUTTMERDING	SOILS	1978	50000	MOE

Consultant/Department: Ministry of Environment Energy and Mines

Publication Scale: 1:50,000

Period of Compilation: Various, 1977 – 1990. See Table Above

Base Map Projection: UTM NAD83, Zone 11

5.0 INPUT DATA QUALITY ASSURANCE

Input data quality assessments were derived from two main methods. First, when possible, input data layers were compared against field plot data that had been collected over a number of years. When this data was incomplete or missing critical spatial information or potential inconsistent data was present, data quality assessment was acquired from the *PEM Requirements Analysis for the Cranbrook Timber Supply Area* (2005). An input data quality report for the Cranbrook PEM can be found in Appendix II.

6.0 FIELD SAMPLE PLAN

The field sample plan was developed for the 2007 field season. Potential field sample points (1500) were randomly selected within the Crown Forested land Base and the Dominion coal Blocks and within a 1000 m buffer of TRIM roads, excluding alpine, woodland and parkland ecosystems.

The existing BEC field data for the Cranbrook TSA can definitely be used to internally assess the model, but because it was not collected using a random sampling approach, it cannot be used to determine site series prediction success with any statistical confidence.

Enough new field data was collected within the boundaries of the study area to verify, internally, the results of each run of the PEM model. The data was collected from randomly chosen start points based on twice the number of forested site series within the variant, This mimics the protocol for independent accuracy assessment and gives a good internal measure of the success of the model for the applicable variants.

Field data in VENUS formats for plots and Excel format for transects can be found in Appendix III.

6.1 Location of Field Sampling Points

Field access maps were derived that showed the access routes, potential sample point location, ortho image, TRIM contours and initial predictions. Data was collected from three different sources.

1. Transects were at least 500 m long, crossed a random point somewhere along their length and were oriented in a random bearing along which line intercept measurements of site series were taken.
2. Along each transect a minimum of one full GIF plot was completed describing the transect segment in detail, the gps location recorded, and the site occasionally photographed.
3. Everywhere a crew travelled, either along roads or trails detailed notes were taken comparing the draft PEM result to features on the ground.
4. Each GIF plot and line segment was classified to site series when the final site series classification was made available to us. By September 2007 all BEC variants, with the exception of the ESSFwm were available.

7.0 GENERALIZED MATERIALS MAPPING

Generalized materials mapping and a sensitive ecosystem inventory (SEI) were completed on the Crown Forested Land Base and the Dominion Coal Blocks. The sensitive ecosystem inventory is reported separately and delivered to its own set of standards (Ketcheson et al. Unpublished 2008). Generalized materials mapping was carried out in order to better identify areas characterized by traits that tend to effect site level ecology but are difficult to model in the PEM (Figure 4). Such areas frequently include coarse textured glaciofluvial terraces that occur on valley bottoms that the model would tend to predict as wetter but are actually drier due to coarse textured soils.

7.1 Mapping Legend

The generalized/exceptional materials mapping and SEI legends can be found in Appendix IV. Mapping was completed to the woodland/parkland boundary throughout the TSA.

7.2 Issues identified during mapping

Some minor issues were identified during the mapping process. When possible issues identified during mapping were reviewed while in the field and mapping was adjusted where deemed necessary. The issues identified are listed below;

- When resolution of the orthophotos was poor talus slopes, rock and shallow soils were sometimes difficult to clearly distinguish. In these cases polygon attribution relied heavily on professional experience.
- Small pockets of shallow, talus or rock (less than 0.5 ha) often can't be practically delineated but will be able to be identified on the ground. These areas may be identified in the accuracy assessment but cannot be completely mapped at the 1:20,000 scale.
- Permanent Grasslands tended to be difficult to identify clearly in areas where there has been significant harvesting in the past (ie- is it open due to natural conditions / ecology or because of selective harvesting). Attention was paid to this in the 2007 field season and mapping was adjusted where necessary.

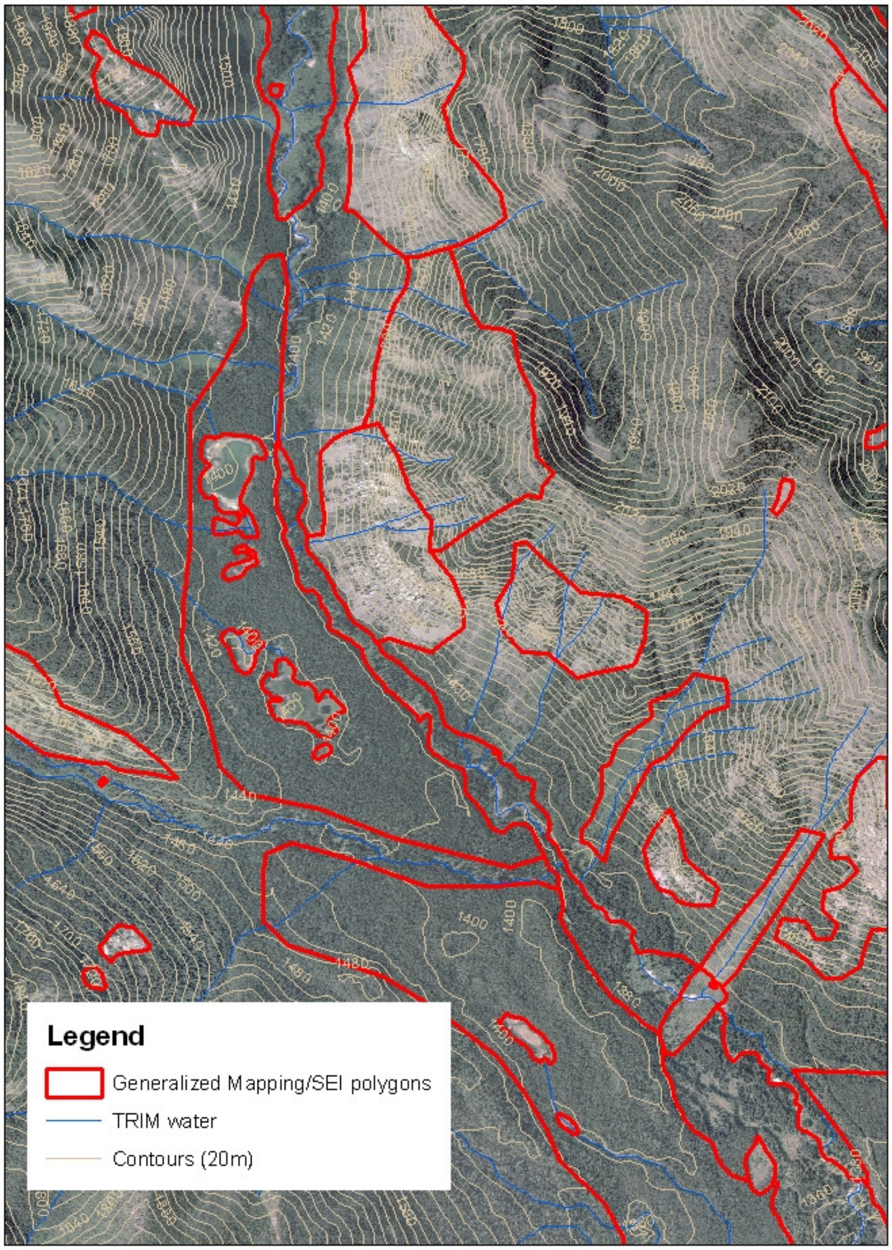

Figure 4. An example of generalized materials mapping in the Cranbrook TSA. Polygons are delineated by the red lines and denote areas of specific texture, shallow soils, floodplain, seepage, avalanche paths and wetlands.

8.0 KNOWLEDGE BASE DEVELOPMENT

Knowledge bases were developed for the following BGC subzones/variants: ESSFdk1, ESSFdk2, MSdk1, MSdk2, ESSFdm, ESSFwm, ICHdm, ICHdw, ICHmk4, IDFdm2 and PPdh2. Knowledge bases for the majority of the BGC subzones were based on Lloyd et al. (2007). The ESSFdm and ICHdm were based on Braumandl and Dykstra (2005) and the ESSFwm based on Lloyd (2008). This site classification is still deemed to be in its draft stages and has yet to be finalized.

All knowledge tables are implemented through sequenced query language (SQL) defining unique combinations of the input layer variables to define site series or map entities. Knowledge tables are initially developed in Excel worksheets. The Excel format knowledge bases can be found in the Appendix V.

Knowledge bases were finalized using an SQL approach drawing upon expert knowledge, field data relationship to input layers, combined with Lloyd et al. (2007) descriptions of the units. A query was created using a combination of the available variables listed in Section 4.0 resulting in a single site series prediction per pixel, these were compared to the orthophotos for a qualitative assessment of the results. The queries were modified several times per BEC variant until a satisfactory result was obtained. The result was visually assessed relative to the orthophoto superimposed with the input layers on screen, it was deemed satisfactory if the distribution of the site series emulated the description in the field guide, as depicted on the topo-sequence. The goal is to have the model predict site series in landscape positions where the expert may expect, this was verified, tested in the field and modified for the final PEM.

Each run of the knowledge based was tested against field data transects using the Moon (2005) protocol and percent overlap was calculated. Once the percent overlap was acceptable (generally over 65%) and the model's prediction of site series proportions by BEC was similar to that measured in the field a BEC variant was considered final. That knowledge base became the final knowledge base.

In general, the knowledge bases were the most successful in the ESSF, ICH and PP variants. Site series classifications in the IDFdm2 and MSdk1,2 were difficult to model, as there is considerable site series overlap in the circum mesic portion of the landscape. Overall site series proportions were acceptable in these variants, but transect field observation relative to pixel prediction did not have acceptable overlap. In these variants it may be appropriate to consider creation of map entities of two strongly related site series. A record of the attempt to maximize the accuracy of the model result for each BEC variant can be found in Section 9.0. On average the model was run four times before acceptable overlap was achieved. Where acceptable overlap was not achieved the model was run until an acceptable site series proportion relative to field data was achieved.

9.0 PEM MODEL RESULTS

The final run of the model is reported for eleven BEC subzones/variants, ESSFdk1, ESSFdk2, ESSFdm, ESSFwm, MSdk1, MSdk2, ICHmk4, ICHdm, ICHdw, IDFdm2, and PPdh2. Each BEC subzone/variant is described in its own section where model history, strengths and short comings, classification issues, and final overlap scores are reported. A complete list of site series mapped can be found in Appendix VI.

The overall internal score of accuracy using the Moon (2005) protocol was 67.4% based on the percentage overlap between the final model result and field transects. It is critical to note that this score is based on GPS field transect locations from hand held units, which can be in error, more so than the differentially corrected GPS methodology used in independent accuracy assessments. Owing to this, we were less concerned with spatial accuracy over thematic accuracy, we used a combination of the internal AA score and the proportional similarity between field data and the model result to temper our view of the success of the model.

Some BEC variants were modelled more successfully than others (see Table 9). In general the ESSF all scored greater than 65%, PPdh2 scored greater than 90%, ICH was moderately successful, and the IDF and MS were not as successful. The success or failure of this model seems to be related to the nature of the landscapes that the lower elevation BEC variants occur in. This, in combination, with revisions to the BEC classification that have resulted in a more floristic, versus formerly site based classification, with overlapping site series differentiated by a few herbaceous species and occurring in areas of very similar terrain, slope position and soil moisture. Revisions to the MS and IDF, which occur in rolling terrain and valley floors have proved difficult to successfully model.

Table 9. Mean Percentage Overlap Scores for Internal Accuracy Assessment of the Cranbrook PEM. Transect number includes both complete and partial transects.

BEC variant (Lloyd 2007)	% Overlap	Number of transects
ESSFdk1	65.78	11
ESSFdk2	79.13	5
ICHmk4	54.32	13
IDFdm2	48.26	12
MSdk1	56.52	21
MSdk2	48.98	18
ICHdm	63.59	8
PPdh2	91.12	4
ICHdw	84.06	2
ESSFdm	69.23	2
ESSFwm	80.19	3
Mean Overlap	**67.4%**	

9.1 ESSFdk1

The internal measure of thematic accuracy for this variant is 65.78%. The model adequately represents the distribution of site series over the landscape. The short coming of training the model to achieve optimal internal AA based on 11 randomly located transects is that the 03 is under represented over the entire landscape relative to its abundance in the field sampling data. Lloyd (2007) suggests that this site series is limited to the southern portion of the former Nelson Forest Region and is not common elsewhere. In order to achieve an accuracy of greater than 65% the model over represents the 01 relative to the field data, however, the field data was collected within 1000 m of TRIM roads and may be biased to coarser materials in the valley floors resulting in an under representation of the true extent of 01 and over representation of the abundance of 03 over the entire variant.

Table 10. Mapped Site Series for the ESSFdk1

Subzone	Site Series Number	Map Code	Site Series Name
ESSFdk1	01.1/01.2	01	Bl – Azalea – Feathermoss/ Bl – Grouseberry – Arnica
ESSFdk1	02		Bl – Selaginella
ESSFdk1	03		BlPl – Grouseberry – Beargrass
ESSFdk1	04		PlBl – Juniper – Soopolallie
ESSFdk1	05		PlBl – Azalea – Beargrass
ESSFdk1	06		SeBl – Gooseberry
ESSFdk1	82/83	XG	Bluebunch wheatgrass – Silky lupine/ Idaho fescue – Sulphur buckwheat
ESSFdk1	07/08	XM	SeBl – Horsetail/ Pl – Bluejoint – Horsetail
ESSFdk1	Av04	AV	Alder – Hellebore
ESSFdk1	Av06	GT	Thimbleberry – Cow parsnip
ESSFdk1		FE	Herb/ graminoid dominated wetland
ESSFdk1	Me03	ME	Leatherleaf saxifrage – Horsetail
ESSFdk1		OS	Shrub dominated wetland
ESSFdk1		RO	Rock outcrop
ESSFdk1		RT	Talus
ESSFdk1		MD	Dry Meadow

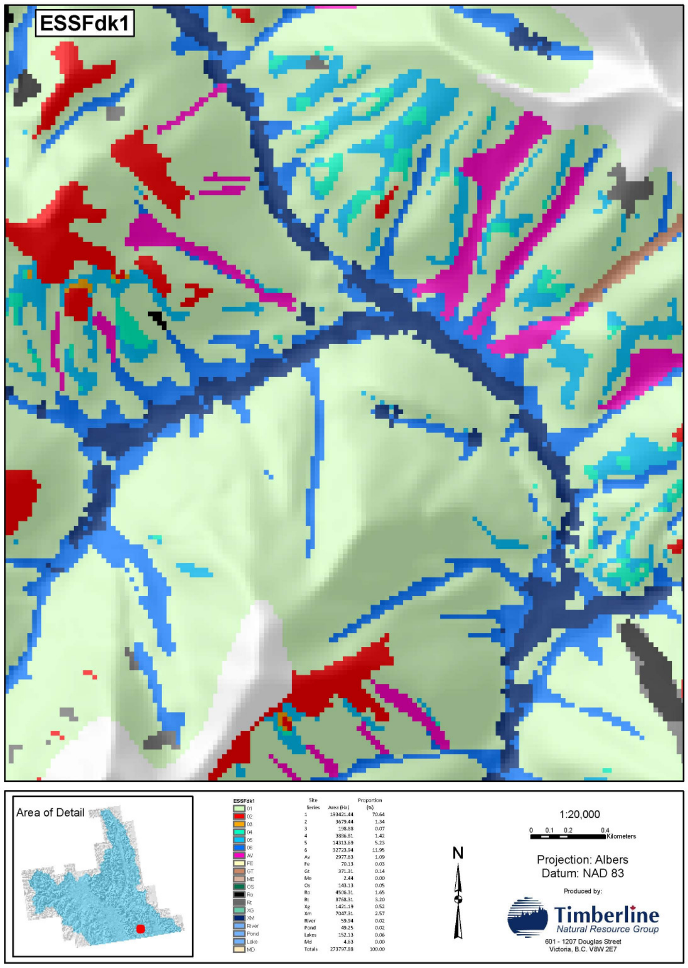

Figure 5. An example of the spatial output of the final PEM for the ESSFdk1.

Table 11. Comparing field site series percentages and model run history for the ESSFdk1, including percent overlap of site series between field transects and model output.

Site Series	FIELD PERCENTAGES	MODEL PERCENTAGES							
	Field	Run1	Run2a	Run2b	GenMat (Lakes)	Run3	Run4	Run5	Final
XG (82/83)	-	0.00	0.00	0.00	0.52	0.52	0.52	0.52	0.52
02	2.0	10.33	10.36	10.33	0.99	0.99	1.34	0.80	1.34
03	12.0	1.22	1.22	1.22	0.00	0.00	1.14	7.64	0.07
04	4.0	(04/05) .92	(04/05) 6.06	(04/05) 5.96	0.06	0.06	1.58	9.14	1.42
05	9.0	-	-	-	6.71	6.70	15.95	6.94	5.23
01 (01.1/01.2)	57.0	72.65	71.00	66.55	70.99	70.95	56.92	52.43	70.64
06	9.0	14.88	11.36	13.34	11.96	11.95	11.00	11.05	11.95
XM (07/08)	5.0	0.00	0.00	2.61	0.52	2.57	5.29	5.25	2.57
Transect / Model Overlap (%)						66.00	58.11	57.19	65.78

9.2 ESSFdk2

The model was very successful in predicting the distribution of site series relative to field data with an internal accuracy score of 79% over five randomly located transects. The model over predicts the 06,07 map entity (XM) relative to the field data and under predicts the 08 relative to the field data. However, based on the field data the 08 (SeBl Horsetail) occurs over 11% of the area and the XM (SeBl False Azalea Foamflower/Bl Valerian Foamflower) occurs 4.5% of the transect area. We believe that this is not a good representation of the true distribution of 08 (SeBl Horsetail) over the entire variant nor of the XM. We believe that the model is more realistic in its predictions than what is represented in the transect data.

Table 12. Mapped Site Series for the ESSFdk2

Subzone	Site Series Number	Map Code	Site Series Name
ESSFdk2	01.1/01.2	01	Bl – Azalea – Feathermoss/ Bl – Grouseberry – Arnica
ESSFdk2	03		Bl – Dicranum
ESSFdk2	08		SeBl – Horsetail
ESSFdk2	04/05	XJ	Pl(SxwBl) – Juniper – Grouseberry/ FdPl – Soopolallie - Juniper
ESSFdk2	06/07	XM	SeBl – Azalea – Oak fern – Foamflower/ Bl – Valerian - Foamflower
ESSFdk2		AV	Shrub dominated avalanche track
ESSFdk2		GT	Herb dominated avalanche track
ESSFdk2		OS	Shrub dominated wetland
ESSFdk2		FE	Herb/graminoid wetland
ESSFdk2		MM	Moist meadow
ESSFdk2	RO/02	RO	Rock outcrop/ PlBl – Juniper - Kinnikinnick
ESSFdk2		RT	Talus

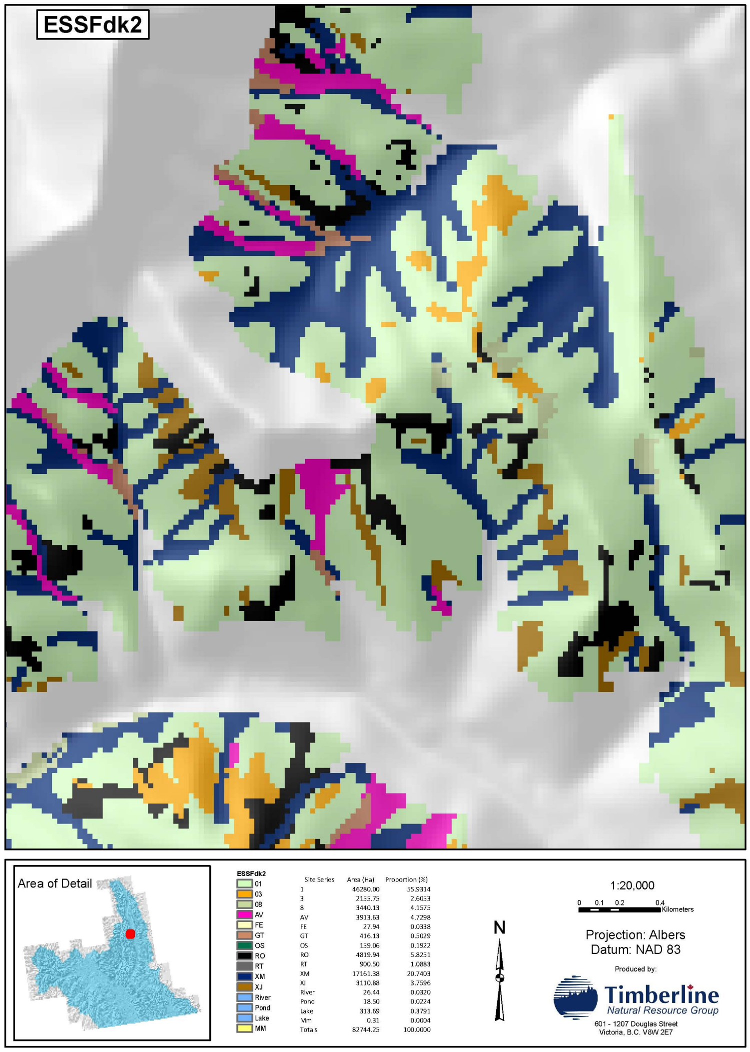

Figure 6. An example of the spatial output of the final PEM for the ESSFdk2.

Table 13. Comparing field site series percentages and model run history for the ESSFdk2, including percent overlap of site series between field transects and model output.

	FIELD PERCENTAGES	MODEL PERCENTAGES			
Site Series	**Field**	**Run1**	**Run2 (GenMat)**	**Run3 (Lakes)**	**Final**
02 (includes in RO)	6.0	0.00	5.83	5.83	5.83
03	-	2.56	2.61	2.61	2.61
XJ (04/05)	21.0	4.39	3.76	3.76	3.76
01 (01.1/01.2)	57.0	64.40	56.25	55.93	55.93
XM (06/07)	4.5	25.07	20.77	20.74	20.74
08	11.0	3.58	4.19	4.16	4.16
Transect / Model Overlap (%)				79.13	79.13

9.3 ESSFdm

The model for this variant is based on Braumandl and Dykstra (2005) and based on two field transects scored 69% internal accuracy. The distribution of the site series in the model is similar to that measured in the field, although the field data is completely lacking representation of several site series (02,67,72,73,62). The model did predict these units in proportions that seem appropriate based on the experience of the author.

Table 14. Mapped Site Series for the ESSFdm

Subzone	Site Series Number	Map Code	Site Series Name
ESSFdm	01		Bl – False azalea – Beargrass
ESSFdm	02		BlPl – Spirea – White hawkweed
ESSFdm	03		BlPl – Black huckleberry – Grouseberry
ESSFdm	04		BlSe – False azalea – Foamflower
ESSFdm	05		BlSe – Gooseberry – Oak fern
ESSFdm	06		SeBl – False Azalea – Horsetail
ESSFdm	72/RO	72	Fescue – Awned haircap moss/ Rock outcrop
ESSFdm	73		Black huckleberry – Pinegrass
ESSFdm		AV	Shrub dominated avalanche track
ESSFdm		FE	Herbaceous wetland
ESSFdm		GT	Herb dominated avalanche track
ESSFdm		ME	Non-wetland permanent herb meadow - moist
ESSFdm		OS	Shrub dominated wetland
ESSFdm		MD	Dry meadow
ESSFdm		RT	Talus

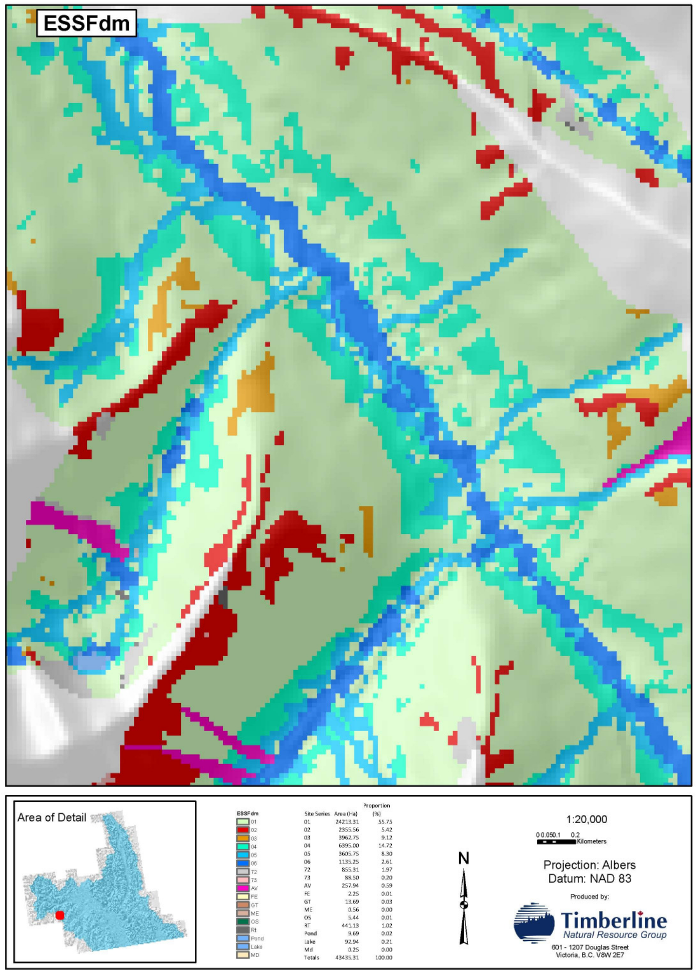

Figure 7. An example of the spatial output of the final PEM for the ESSFdm.

Table 15. Comparing field site series percentages and model run history for the ESSFdm, including percent overlap of site series between field transects and model output.

	FIELD PERCENTAGES	MODEL PERCENTAGES						
Site Series	**Field**	**Run1**	**Run2**	**GenMat**	**Run3 (Lakes)**	**Run4**	**Run5**	**Final**
72 (includes RO)	-	0.00	0.00	1.97	1.97	1.97	1.97	1.97
73	-	0.57	0.57	0.20	0.20	0.20	0.20	0.20
62	-	0.00	17.90	0.00	0.00	0.00	0.00	0.00
02	-	1.88	1.88	3.60	3.60	5.16	5.40	5.42
03	7.0	9.35	9.35	9.12	9.12	12.03	9.12	9.12
01	56.0	64.61	46.70	53.85	53.63	59.97	44.83	55.75
04	17.0	19.22	19.22	18.78	18.78	7.86	25.67	14.72
05	27.0	4.38	4.38	8.16	8.15	8.30	8.30	8.30
06	-	0.00	0.00	2.65	2.65	2.61	2.61	2.61
Transect / Model Overlap (%)					34.19	43.45	-	69.23

9.4 ESSFwm

The ESSFwm classification is provisional and based on a draft classification provided by Lloyd (2008). There are three field transects and when used to assess the internal accuracy of the model the score was 80%. The distribution of site series measured by the transects are similar to those of the model.

Table 16. Mapped Site Series of the ESSFwm

Subzone	Site Series Number	Map Code	Site Series Name
ESSFwm	01/04	01	Bl – Rhododendron – False Azalea – Brachyt/ BlSe – Azalea – Oak fern
ESSFwm	02		Bl – Juniper – Lichen
ESSFwm	03		Bl – Black huckleberry – One-sided wintergreen
ESSFwm	05		SeBl – Trollius – Senecio
ESSFwm		AV	Shrub dominated avalanche track
ESSFwm		FE	Herb/graminoid dominated wetland
ESSFwm		GT	Herb dominated avalanche track
ESSFwm		OS	Shrub dominated wetland
ESSFwm		RO	Rock outcrop
ESSFwm		RT	Talus
ESSFwm		MM	Moist meadow

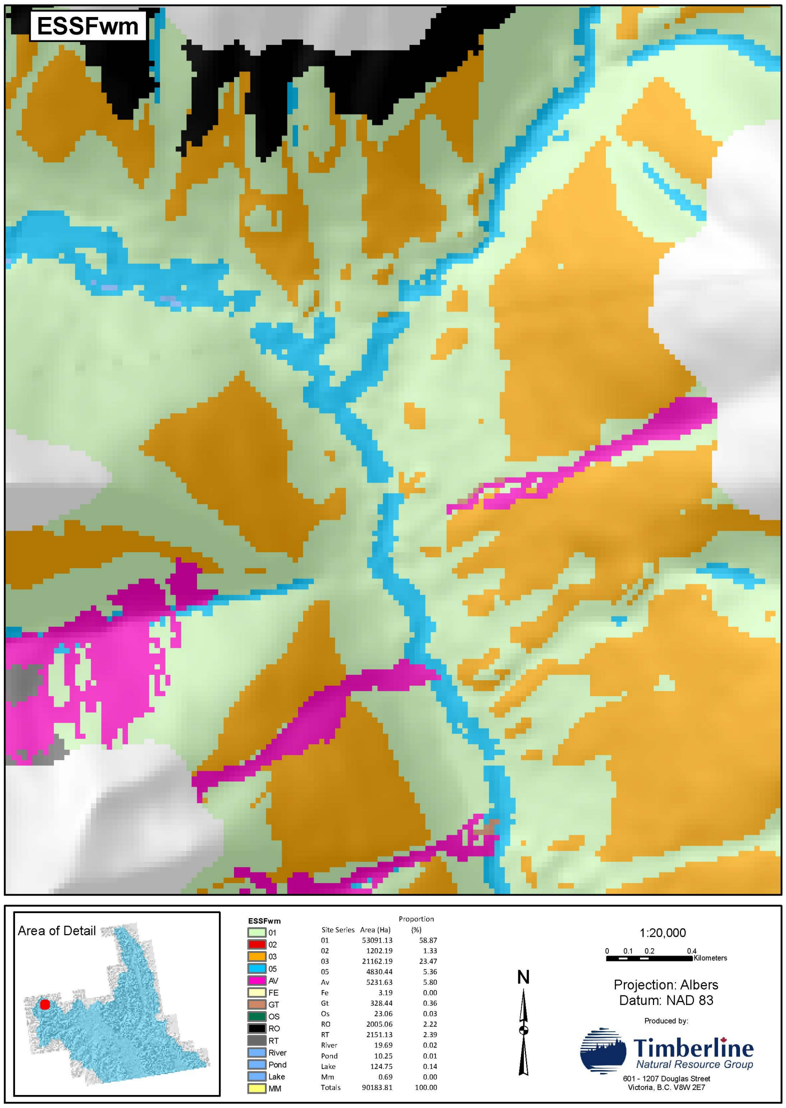

Figure 8. An example of the spatial output of the final PEM for the ESSFwm.

Table 17. Comparing field site series percentages and model run history for the ESSFwm, including percent overlap of site series between field transects and model output.

	FIELD PERCENTAGES	MODEL PERCENTAGES			
Site Series	**Field**	**Run1 (GenMat/ Lakes)**	**Run2**	**Run3**	**Final**
02	3.0	1.33	1.33	15.42	1.33
03	21.2	6.54	23.47	22.44	23.00
01 (01/04)	65.6	75.80	58.87	46.08	58.00
05	3.0	5.36	5.36	5.30	5.36
Transect / Model Overlap (%)			80.19	-	80.19

9.5 MSdk1

This model, when compared to field data scored an internal accuracy of 56% over 21 transects. The nature of the site series classification, landscape shape and similarity between sites in the field supporting the 01 and the 05 site series and the 03 and 04 site series resulted in the model confusing these sites relative to the field data. Most of this confusion occurred in level or gentle sites where micro sites were more likely controlling the local distribution of these site series rather than features that can be modelled in a 25 meter pixel. In the future a more sophisticated DEM from something like a LIDAR inventory may be able to solve this modelling dilemma. Another approach may be to determine relative percentage of each site series based on field data within these landscape areas and report that as a probability by site series in landscape positions where there is strong site series overlap.

Table 18. Mapped Site Series of the MSdk1

Subzone	Site Series Number	Map Code	Site Series Name
MSdk1	01		SxwPl – Arnica – Feathermoss
MSdk1	02		Fd(Pl) – Bluebunch wheatgrass – Pinegrass
MSdk1	03		FdLwPl – Juniper – Pinegrass
MSdk1	04		Pl – Soopolallie – Pinegrass
MSdk1	05		Sxw – Gooseberry – Foamflower
MSdk1	82/83/84	XG	Saskatoon – Bluebunch wheatgrass/ Idaho fescue – Bluebunch wheatgrass/ Idaho fescue – Oatgrass
MSdk1	06/07	XM	Sxw – Horsetail/ Sxw – Trapper's tea – Peat moss
MSdk1		AV	Avalanche track
MSdk1		GW	Herb dominated wetland
MSdk1		WE	Shrub dominated wetland
MSdk1		RO	Rock outcrop
MSdk1		RT	Talus

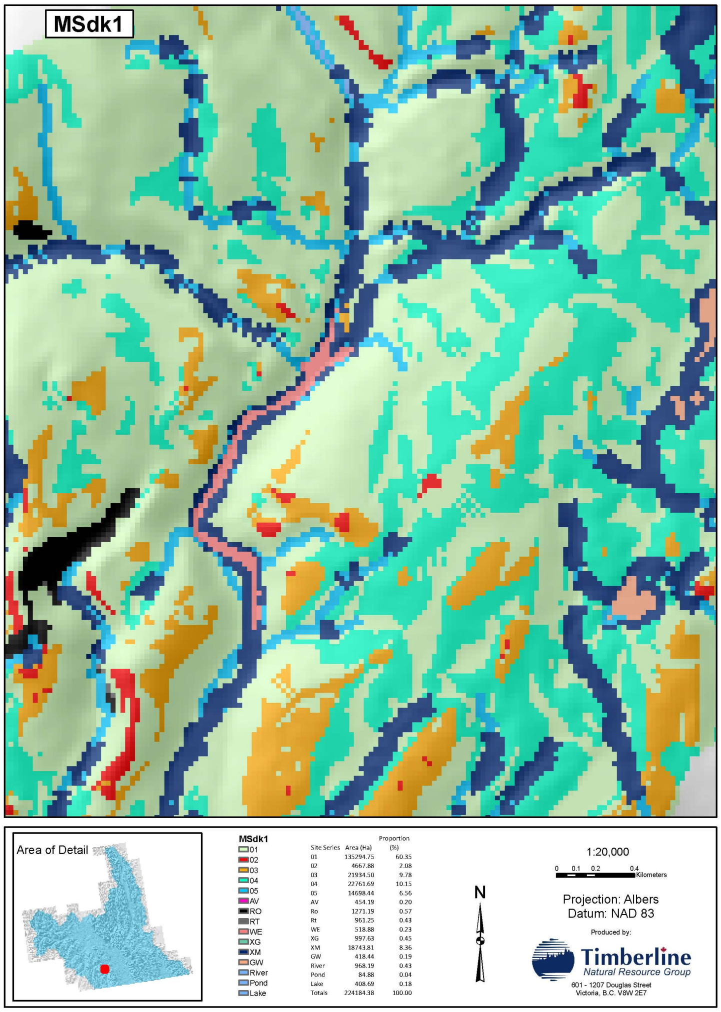

Figure 9. An example of the spatial output of the final PEM for the MSdk1 variant.

Table 19. Comparing field site series percentages and model run history for the MSdk1, including percent overlap of site series between field transects and model output.

	FIELD PERCENTAGES	MODEL PERCENTAGES			
Site Series	**Field**	**Run1**	**Run2 (GenMat)**	**Run3 (Lakes)**	**Final**
XG (82/83/84)	-	0.39	0.52	0.52	0.45
02	4.0	1.17	2.10	2.10	2.08
03	16.0	3.09	11.64	11.59	9.78
04	23.0	2.28	12.50	12.41	10.15
01	40.0	78.87	56.58	56.11	60.35
05	11.0	7.30	6.64	6.63	6.56
XM (06/07)	5.0	6.90	8.39	8.36	8.36
Transect / Model Overlap (%)				58.33	56.53

9.6 MSdk2

This variant is a new BEC unit identified in the north end of the Elk Valley that was formerly classified as MSdk1. The model based on Lloyd's 2007 classification scored 49% relative to 18 field transects. This variant has a complex site series classification with eight forested site series drier than mesic. The model frequently confused 01 and 08, the 08 occurs on a wide variety of sites on mid slopes, as does the 01, it also occurs on materials that are medium, as well as coarse textured. The 08 has more pinegrass and soopolallie than the 01, but the features controlling the distribution of these species occur locally and may be maintained by disturbance history, especially that of fire. The sites these map units occur on are strongly overlapping. The model also had difficulty distinguishing between 01 and 09 on level sites, especially in level areas whose overall shape was considered concave by the model. This is also a situation where micro sites are likely controlling the distribution of the 09. The main difference between the 01 and 09 are the relative abundance of soopolallie, highbush cranberry, and a suite of moist herbs. The subtle difference in soil moisture that controls the distribution of these sites is difficult to model, as the minor changes in landscape position and shape are difficult to model to a 25 meter pixel. Again, a more sophisticated DEM may be the answer to this problem or adopting a probabilistic approach to modelling in these landscape areas.

Table 20. Mapped Site Series of the MSdk2

Subzone	Site Series Number	Map Code	Site Series Name
MSdk2	01		Sxw – Arnica – Feathermoss
MSdk2	02		Fd – Juniper – Kinnikinnick
MSdk2	03		Fd – Rocky Mountain Juniper – Bluebunch wheatgrass
MSdk2	04		Fd(Pl) – Juniper – Pinegrass – Kinnikinnick
MSdk2	05		FdPl – Soopolallie – Pinegrass – Twinflower
MSdk2	06		SxwPl – Labrador tea – Bunchberry – Feathermoss
MSdk2	07		Pl – Soopolallie – Velvet-leaved blueberry
MSdk2	08		PlSxw – Soopolallie – Feathermoss
MSdk2	09		Sxw – Dogwood – Feathermoss
MSdk2	10/11/12	XM	Sxw – Horsetail/ PlSxw – Labrador tea/ Sxw – Sedge
MSdk2		AV	Shrub dominated avalanche track
MSdk2		GT	Herb dominated avalanche track
MSdk2		FE	Herb/graminoid dominated wetland
MSdk2		OS	Shrub dominated wetland
MSdk2		RO	Rock outcrop
MSdk2		RT	Talus

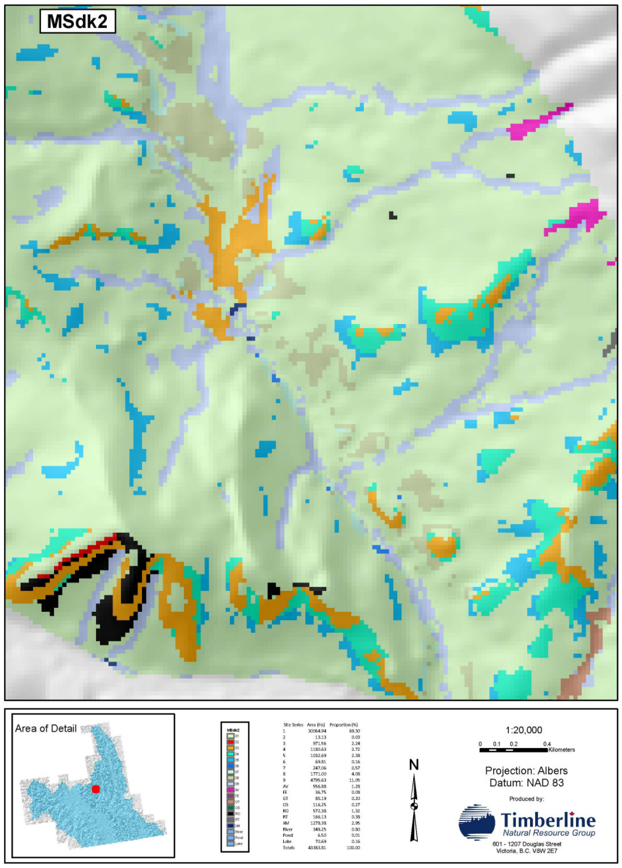

Figure 10. An example of the spatial output of the final PEM for the MSdk2.

Table 21. Comparing field site series percentages and model run history for the MSdk2, including percent overlap of site series between field transects and model output.

Site Series	FIELD PERCENTAGES	MODEL PERCENTAGES						
	Field	Run1	Run2	GenMat	Run3 (Lakes)	Run4	Run5	Final
XD (03/04)	-	1.24	1.24	0.00	0.00	0.00	0.00	0.00
02	1.0	0.00	0.00	0.05	0.05	0.05	0.03	0.03
03	2.0	0.00	0.00	0.00	0.00	28.26	2.24	2.24
04	6.0	0.00	0.00	1.47	1.47	1.47	2.72	2.72
05	1.0	1.61	1.61	1.55	1.55	1.55	4.26	2.38
06	2.0	(06/08) 2.33	(06/08) 3.19	0.00	0.00	0.61	0.46	0.16
07	8.0	4.55	6.06	1.73	1.72	1.64	2.30	0.57
08	13.0			2.44	2.44	8.06	0.25	4.08
01	48.0	72.92	70.56	46.92	46.26	26.68	34.52	69.30
09	15.0	9.88	9.88	30.47	30.22	23.63	45.87	11.05
XM (10/11/12)	4.0	7.47	7.47	11.23	11.17	2.95	2.95	2.95
Transect / Model Overlap (%)					38.05	-	31.01	48.98

9.7 ICHmk4

The ICHmk4 was modelled to an internal accuracy of 54% when compared to 13 transects. The model had difficulty distinguishing between 01 and 03 in submesic midslope neutral locations. The two site series are distinct floristically but field data noted that the 01 can occur on some coarse textured sites that are not cool. The model also reversed the XM and XW, in some instances, in gentle and level terrain, although the overall proportional distribution of all sites was very similar to that measured in the field.

Table 22. Mapped Site Series of the ICHmk4

Subzone	Site Series Number	Map Code	Site Series Name
ICHmk4	01/01-YC	01	CwSxw – Falsebox – Knight's plume/ Cw – Nudem
ICHmk4	02		Fd – Juniper – Pinegrass
ICHmk4	03		FdPl – Soopolallie – Pinegrass
ICHmk4	04/04-MS	04	SxwCwAct – Dogwood/ ActSxw – Snowberry
ICHmk4	05/06	XM	CwSxw – Oakfern – Ladyfern/ CwSxw – Devil's club – Lady fern
ICHmk4	07/08/09	XW	Sxw – Horsetail/ BlSxw – Labrador tea – Peatmoss
ICHmk4		AS	Shrub dominated avalanche track
ICHmk4		GT	Herb dominated avalanche track
ICHmk4		FE	Herb/graminoid dominated wetland
ICHmk4		OS	Shrub dominated wetland
ICHmk4		RO	Rock outcrop
ICHmk4		RT	Talus
ICHmk4	Rt02	T2	Feathermoss – Clad lichens

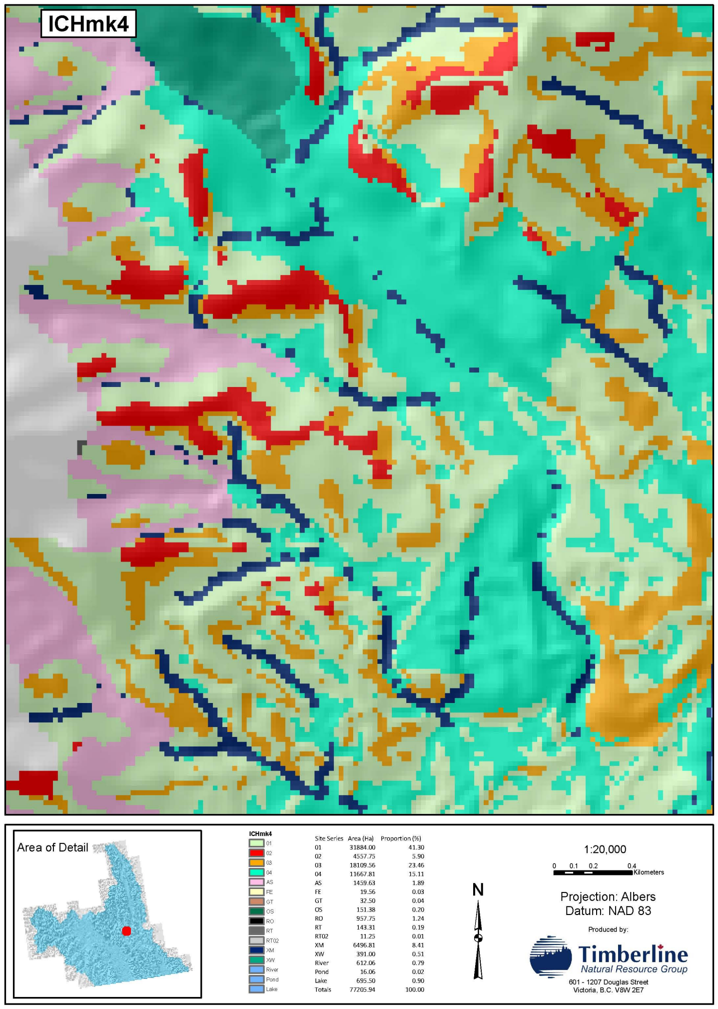

Figure 11. An example of the spatial output of the final PEM for the ICHmk4.

Table 23. Comparing field site series percentages and model run history for the ICHmk4, including percent overlap of site series between field transects and model output.

	FIELD PERCENTAGES	MODEL PERCENTAGES							
Site Series	**Field**	**Run1**	**Run2**	**GenMat**	**Run3 (Lakes)**	**Run4**	**Run5**	**Run6**	**Final**
02	1.0	5.15	5.48	5.57	5.57	0.50	0.50	0.50	5.90
03	23.0	2.70	2.67	21.79	20.49	15.46	18.70	24.07	23.46
01 (01/01-YC)	48.0	71.61	64.76	47.77	47.47	49.06	47.82	46.08	41.30
04 (04/04-MS)	17.0	14.39	12.55	8.14	8.08	15.49	13.54	15.11	15.11
XM (05/06)	8.5	6.16	5.40	8.25	8.24	8.53	8.48	8.41	8.41
XW (07/08/09)	2.0	0.00	9.15	5.88	5.84	5.65	5.65	0.51	0.51
Transect / Model Overlap (%)					51.30	52.86	52.80	53.44	54.32

9.8 ICHdm

The classification used for this variant is that of Braumandl and Dykstra (2005). It achieved an internal accuracy score of 64% based on eight field transects. In low scoring transects the model was predicting 01where field calls were 03. The two sites are distinct floristically, but overlap on sloping submesic midslope sites. The model over predicts 01 in concave level areas where field calls indicated 04 or 05. Again, a more sophisticated DEM may assist in improving the result. The overall proportions of sites predicted by the model are similar to those measured in the field.

Table 24. Mapped Site Series of the ICHdm

Subzone	Site Series Number	Map Code	Site Series Name
ICHdm	01		HwCw – Falsebox – Twinflower
ICHdm	02		Kinnikinnick – Bluebunch wheatgrass
ICHdm	03		PlLw – Birch-leaved spirea – Pinegrass
ICHdm	04		HwCw – Black huckleberry – Oak fern
ICHdm	05		CwHw – Devil's club – Lady fern
ICHdm	06		Sx – Thimbleberry – Meadowrue
ICHdm		AS	Shrub dominated avalanche track
ICHdm		GL	Herb dominated avalanche track
ICHdm		FE	Herb/graminoid dominated wetland
ICHdm		OS	Shrub dominated wetland
ICHdm		RT	Talus
ICHdm		RO	Rock outcrop

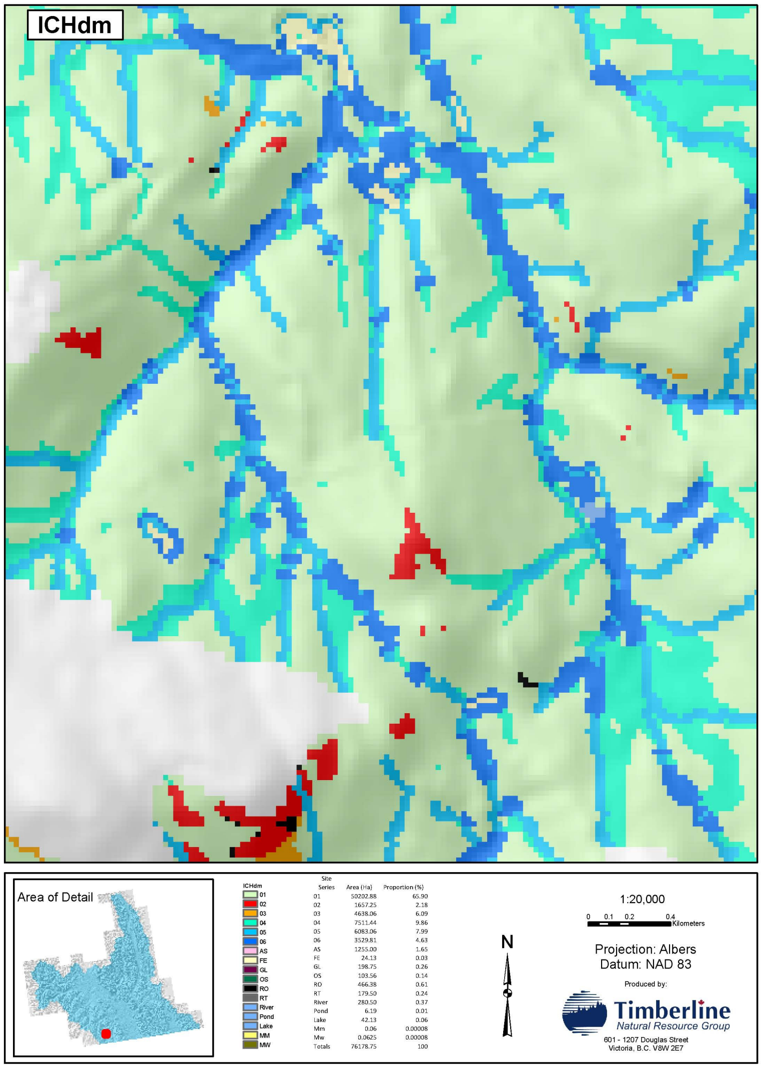

Figure 12. An example of the spatial output of the final PEM for the ICHdm.

Table 25. Comparing field site series percentages and model run history for the ICHdm, including percent overlap of site series between field transects and model output.

	FIELD PERCENTAGES	MODEL PERCENTAGES			
Site Series	**Field**	**Run1**	**Run2**	**GenMat**	**Final (Lakes)**
02	1.6	26.70	26.70	2.18	2.18
03	33.0	6.61	6.61	6.09	6.09
01	43.0	19.78	19.78	66.12	65.90
04	6.0	33.59	33.38	9.98	9.86
05	14.5	8.83	9.04	8.04	7.99
06	1.6	4.49	4.49	4.68	4.63
Transect / Model Overlap (%)					63.59

9.9 ICHdw1

The ICHdw1 is of limited distribution in the Cranbrook TSA. The site series classification used was the original Nelson Region version by Braumandl and Curran (1992). It is a simple classification that is easily modelled. The model scored 84% internal accuracy when compared to two field transects. This is an interim BEC classification that will eventually by revised.

Table 26. Mapped Site Series of the ICHdw1

Subzone	**Site Series Number**	**Map Code**	**Site Series Name**
ICHdw1	01a	1A	CwFd – Falsebox – sx sm phase
ICHdw1	01b	1B	CwFd – Falsebox – m shg phase
ICHdw1	02		FdPy – Oregon grape – Parsley fern
ICHdw1	03		CwHw – White pine – Devil's club
ICHdw1	04		CwHw – Devil's club – Lady fern
ICHdw1		OS	Shrub dominated wetland
ICHdw1		FE	Herb/graminoid dominated wetland
ICHdw1		RO	Rock outcrop
ICHdw1		RT	Talus

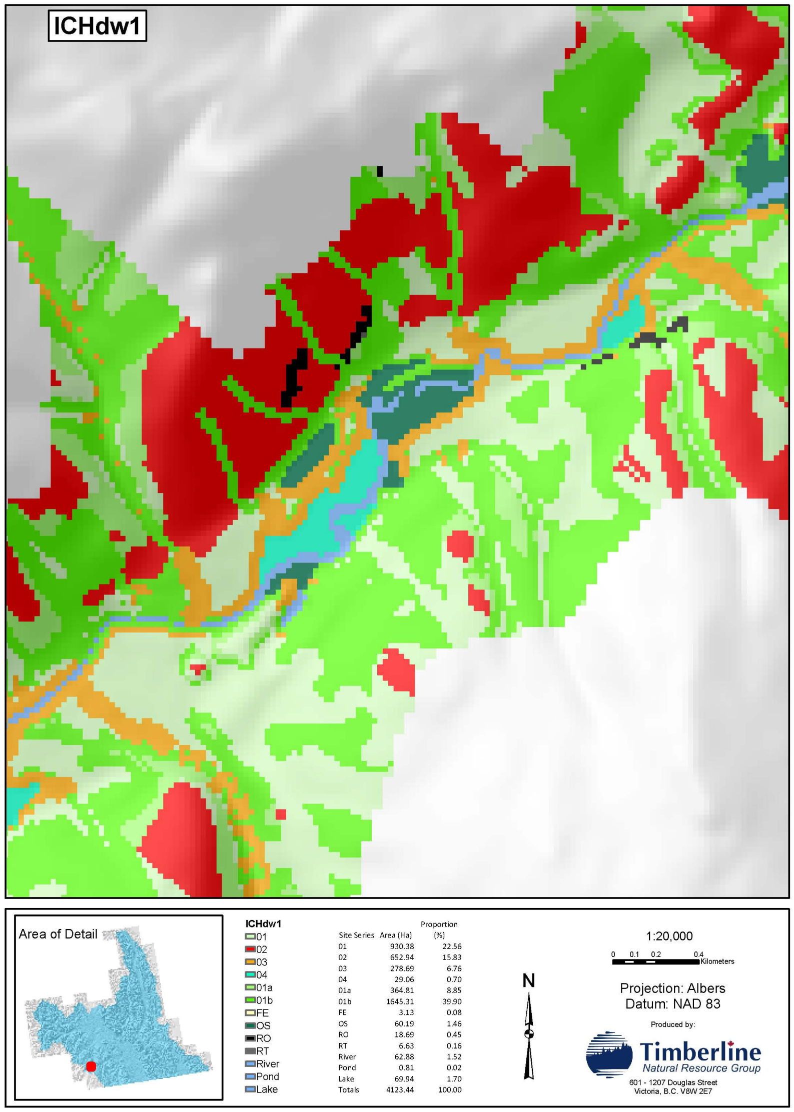

Figure 13. An example of the spatial output of the final PEM for the ICHdw.

Table 27. Comparing field site series percentages and model run history for the ICHdw, including percent overlap of site series between field transects and model output.

	FIELD PERCENTAGES	MODEL PERCENTAGES		
Site Series	**Field**	**Run1**	**GenMat**	**Final (Lakes)**
02	-	0.76	15.84	15.83
1A (01a)	23.7	18.07	8.87	8.85
1B (01b)	68.9	64.88	65.51	62.46
03	7.6	11.00	6.88	6.76
04	-	5.29	0.75	0.70
Transect / Model Overlap (%)				84.06

9.10 IDFdm2

This variant was revised by Lloyd (2007). The model scored an internal accuracy of 48% when compared to twelve randomly located field transects. The model had difficulty distinguishing between the 01 and 05. The two sites have very similar floristics and overlapping site characteristics. In the rolling gentle terrain micro site features are controlling the distribution of 01 and 05, small hollows, versus small hummocks, disturbance history and terrain texture are factors that seem to distinguish between the two site series. In the East Kootenay glaciofluvial materials can be medium textured and the 01 also seems to appear on some coarse textured sites. Field data demonstrates that the two sites series are inconsistent in their relationship to site features.

Table 28. Mapped Site Series of the IDFdm2

Subzone	Site Series Number	Map Code	Site Series Name
IDFdm2	01		Fd – Pinegrass – Twinflower
IDFdm2	02		Fd – Moss
IDFdm2	05		Fd – Pinegrass
IDFdm2	06		SxFd – Bunchberry – Feathermoss
IDFdm2	07		LwFd – Birch – Snowberry
IDFdm2	08		SxAct – Dogwood – Thimbleberry
IDFdm2	03/04	XD	Fd – Rocky Mountain Juniper – Sidewalk moss/ FdPy – Bluebunch wheatgrass
IDFdm2	82es/82.1/ 82.2/83	XG	$Stiff needlegrass/ Rocky Mountain Juniper – Bluebunch wheatgrass/ Antelope brush – Bluebunch wheatgrass
IDFdm2		FE	Herb/graminoid dominated wetland
IDFdm2		OS	Shrub dominated wetland
IDFdm2	Gs01	WE	Distichlis
IDFdm2		RO	Rock outcrop
IDFdm2		RT	Talus
IDFdm2	Rt02	T2	Feathermoss – Clad lichens

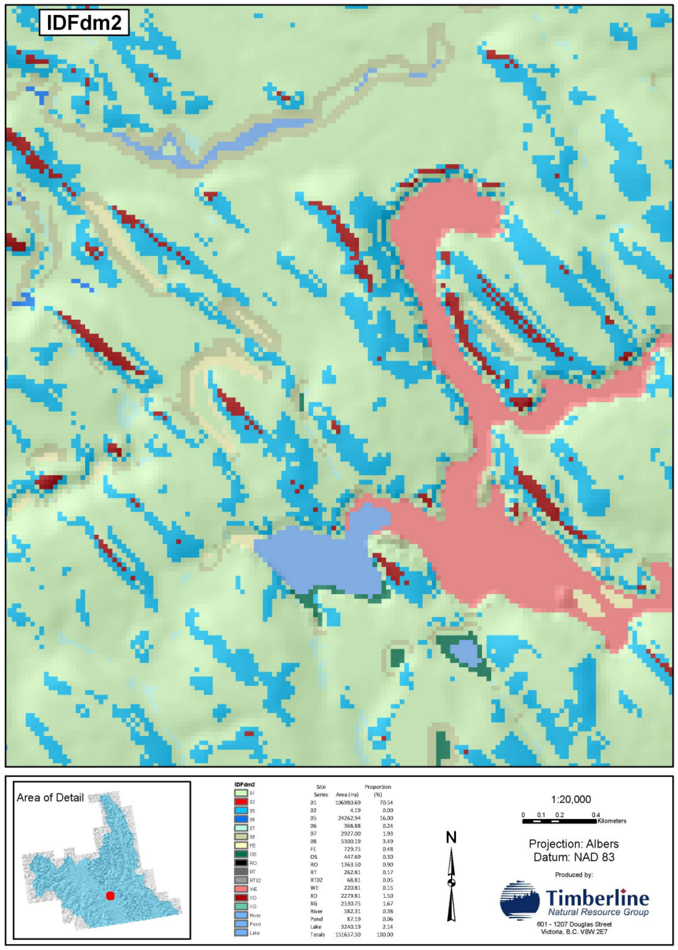

Figure 14. An example of the spatial output of the final PEM for the IDFdm2.

Table 29. Comparing field site series percentages and model run history for that IDFdm2, including percent overlap of site series between field transects and model output.

Site Series	FIELD PERCENTAGES	MODEL PERCENTAGES						
	Field	**Run1**	**Run2**	**GenMat**	**Run3 (Lakes)**	**Run4**	**Run5**	**Final**
02	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00
XG (82ES/82.1/82.2/83)	-	6.22	5.65	5.82	5.81	5.81	6.16	1.67
XD (03/04)	4.0	4.59	4.59	22.68	21.25	3.40	1.21	1.50
05	46.0	0.00	6.51	14.54	14.26	32.02	39.21	16.00
01	45.0	76.01	70.12	29.26	28.90	42.00	42.94	70.54
06	-	(06/08) 0.13	(06/08) 0.13	13.80	13.37	0.07	0.11	0.24
07	1.0	1.47	1.47	1.22	1.19	1.19	1.65	1.93
08	5.0	2.61	2.61	3.12	3.11	3.11	3.48	3.49
XM (09/10)	-	8.52	8.52	7.81	7.79	7.91	0.71	0.00
Transect / Model Overlap (%)					23.84	30.44	33.14	48.26

9.11 PPdh2

The PPdh2 variant was reclassified by Lloyd (2007), the model scored an internal accuracy of 91% based on four transects. The model seems to over predict the XM unit (08,09,10,11) as none were encountered in the field and under predict the 05 unit. The model also over predicts the 04 and under predicts the 01 when compared to the field transects.

Table30. Mapped Site Series of the PPdh2

Subzone	Site Series Number	Map Code	Site Series Name
PPdh2	01		FdPy – Pinegrass
PPdh2	03		PyFd – Kinnikinnick – Bluebunch wheatgrass
PPdh2	04		PyFd – Bluebunch wheatgrass
PPdh2	05/05ms	05	Py/Fd – Rough fescue – Bluebunch wheatgrass/ $PyFd – Stiff needlegrass
PPdh2	06		Fd – Moss
PPdh2	07		SxwFd – Aralia
PPdh2	82es/82/ 83es/83ls/ 83/84es/84	XG	$Antelope brush – Needle-and-thread grass/ Antelope brush – Bluebunch wheatgrass/ $Needle-and-thread grass/ $Antelope brush – Bluebunch wheatgrass/ Idaho fescue – Bluebunch wheatgrass/ $Kentucky bluegrass/ Rough fescue
PPdh2	08/09/10/11	XM	At – Snowberry – Kentucky bluegrass/ At – Dogwood – Water birch/ SxwAtc – Dogwood – Rose/ Sxw – Horsetail
PPdh2		FE	Herb/graminoid dominated wetland
PPdh2		WE	Mineral non-treed wetland
PPdh2		RO	Rock outcrop
PPdh2		RT	Talus

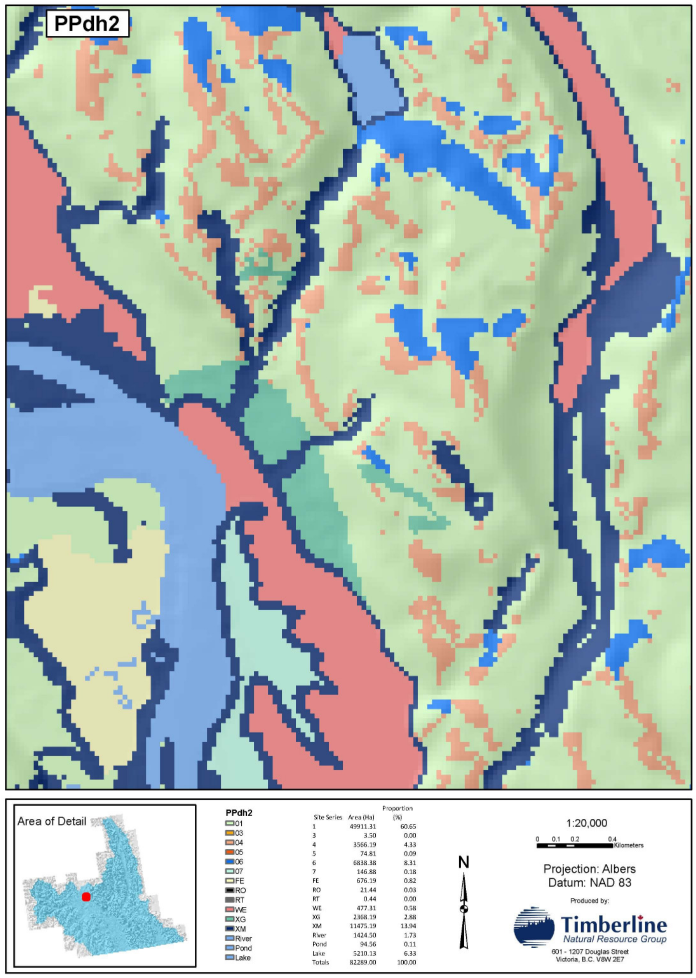

Figure 15. An example of the spatial output of the final PEM for the PPdh2.

Table 31. Comparing field site series percentages and model run history for the PPdh2, including percent overlap of site series between field transects and model output.

Site Series	FIELD PERCENTAGES	MODEL PERCENTAGES			
	Field	Run1	Run2	GenMat	Final (Lakes)
XG (82ES/82/83ES/ 83LS/83/84ES/84)	-	0.00	0.00	2.88	2.88
03	-	0.00	0.13	0.00	0.00
04	14.0	0.00	(04/05) 3.02	4.33	4.33
05 (05/05-MS)	-	0.00		0.09	0.09
01	79.0	77.13	73.99	68.52	60.65
06	-	8.45	8.45	8.43	8.31
07	8.0	0.00	0.00	0.19	0.18
XM (08/09/10/11)	-	14.41	14.41	14.12	13.94
Transect / Model Overlap (%)					91.20

10.0 DISCUSSION AND CONLUSION

The revised BGC classification of the Cranbrook TSA has been challenging to successfully model. Although the average overall internal accuracy is reported to be 67%, it is not acceptable for some of the major BEC subzone/variants, especially those in valley floors and on gentle terrain. The new classification is strongly based on floristics and inconsistent with regard to the nature of the sites that each site series can occur on. This differs from previous classifications and is difficult to model. Several site series differ by a few plant species that may be reflecting features other than site, such as disturbance history, grazing by wildlife or cattle, canopy closure, or microsite features in complex landscapes. The relationship between variables like tree site index and site series should be investigated in more detail before finalization of these revisions to the BGC in the Cranbrook TSA.

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APPENDIX I
AML FOR INPUT DATA LAYERS

TRIM II Water Features

Double line water features

Double Line Water Feature AML1:

```
precision double double
&do i &list dcb_twtrfill2 dkl_twtrfill2
  &if [exists %i% -cover] &then kill %i% all
&end

display 9999 0
&do i &list dkl dcb
&ty %i%
  copy %i%_twtr %i%_twtrfill2
  ae
  graphics off
  ec %i%_twtrfill2
  ef arc
  sel fcode cn 'GA'
  unsel fcode cn '90000'
  delete
  save
  weedtol 0
  grain 0
  arcsnap off
  nodesnap off
  get %i%_index
  save
  q
  clean %i%_twtrfill2 # 3 .1
  ae
  ec %i%_twtrfill2
  ef arc
  arcsnap on 25
  nodesnap closest 25
  sel all
  ext 50
  save
  q
  clean %i%_twtrfill2 # .1 .1
```

```
  createlabels %i%_twtrfill2
  idedit %i%_twtrfill2 poly
  additem %i%_twtrfill2.pat %i%_twtrfill2.pat surface 1 1 c
&end
```

Double Line Water Features AML2:

```
tables
&if ^ [exists dcb_twtrfill2.r -info] &then &do
  copy dcb_twtrfill2.aat dcb_twtrfill2.r
  sel dcb_twtrfill2.r
  sort rpoly#
  commit
&end

&if ^ [exists dcb_twtrfill2.l -info] &then &do
  copy dcb_twtrfill2.aat dcb_twtrfill2.l
  sel dcb_twtrfill2.l
  sort lpoly#
  commit
&end
  quit /* Tables
&label skip
ae
ec dcb_twtrfill2 poly
de all off
de poly fill
&if ^ [iteminfo dcb_twtrfill2.pat -info surface -exists] &then
   &do
     additem surface 1 1 c
     save
   &end

relate add
```

```
r
dcb_twtrfill2.r
info
dcb_twtrfill2#
rpoly#
ordered
ro
l
dcb_twtrfill2.l
info
dcb_twtrfill2#
lpoly#
ordered
ro
;

sel surface = ' '
res r//fcode cn 'GB'
&if [show number select] > 0 &then &do
moveitem 'K' to surface
calc $symbol = 4
&end
/*save
sel surface = ' '
res r//fcode cn 'GC'
&if [show number select] > 0 &then &do
moveitem 'S' to surface
calc $symbol = 3
&end
/*save
sel surface = ' '
res r//fcode cn 'GE25850'
```

```
&if [show number select] > 0 &then &do
moveitem 'B' to surface
calc $symbol = 8
&end
/*save
sel surface = ' '
res r//fcode cn 'GE'
&if [show number select] > 0 &then &do
moveitem 'L' to surface
calc $symbol = 2
&end
/*save
sel surface = ' '
res r//fcode cn 'GD'
&if [show number select] > 0 &then &do
moveitem 'G' to surface
calc $symbol = 1
&end
/*save
sel surface = ' '
res r//fcode cn 'GA'
&if [show number select] > 0 &then &do
moveitem 'R' to surface
calc $symbol = 4
&end
/*save
sel surface = ' '
res r//fcode cn 'GG'
&if [show number select] > 0 &then &do
moveitem 'O' to surface
calc $symbol = 5
&end
```

```
/*save
sel surface = ' '
sds 7
ds

&tty
relate drop
r
l
```

Digital Elevation Model

The following AML was used to translate the lattice to a point coverage.

```
&severity &error &ignore
&s ws [locase [entryname [show workspace]]]

/**CLEAN-UP
&if [exists baselat -grid] &then
    kill baselat all
&if [exists basetin -tin] &then
   kill basetin all
&if [exists pt_utm -cover] &then
   kill pt_utm all

/**CREATE TIN
&if ^ [exists basetin -tin] &then
&do
  createtin basetin 5 55
    generate tdem.gen point mass
    &if [exists tbrkl.gen -file] &then
       generate tbrkl.gen line hardline # 10
  end
&end

/**CREATE LATTICE
&if ^ [exists baselat -grid] &then &do
```

```
  &if [exists basetin -tin] &then &do
    tinlattice basetin baselat
    ;
    ;
    ;
    75
  &end
&end

&type Finished %ws%.
/*&if [exists basetin -tin] &then kill basetin all
&if [exists pt_alb -cover] &then kill pt_alb all
&if [exists pt_utm -cover] &then kill pt_utm all
gridpoint baselat pt_alb elevation
project cover pt_alb pt_utm ../alb-utm11.prj
kill pt_alb all
```

The following AML was used to extract sinks:

```
precision double double
&s filehandle [open dcb_msheets.txt openstatus -read]
&s sheet [read %filehandle% readstatus]

&do &until %readstatus% = 102
    &work %sheet%
    &if [exists sink -cover] &then kill sink all
    &if [exists twtr.pat -info] &then
     &do
       reselect twtr sink point
       reselect fcode = 'HB27550000'
       ~
       n
       n
     pullitems sink.pat sink.pat area perimeter sink# sink-id fcode elevation
     &end
    &work ../
  &s sheet [read %filehandle% readstatus]
&end
```

```
&ty [close -all]

&s filehandle [open dcb_msheets.txt openstatus -read]
&s sheet [read %filehandle% readstatus]
&if [exists dcb_sinks -cover] &then kill dcb_sinks all
append dcb_sinks point
&do &until %readstatus% = 102
  &if [exists %sheet%/sink -cover] &then
    %sheet%/sink
  &s sheet [read %filehandle% readstatus]
&end
end
&ty [close -all]
```

The following AML was used to issue the TOPOGRID command:

```
&if [exists tgrid -grid] &then kill tgrid6 all
&if [exists test_sink -grid] &then kill test_sink all
&if [exists test_drain -grid] &then kill test_drain all
&if [exists test_file -file] &then &ty [delete test_file -file]
precision double double
topogrid tgrid 25
boundary kl_5000
datatype spot
enforce on
lake dkl_lakes
iterations 35
point dkl_point elevation
sink dkl_sinks elevation
tolerances 2.5
outputs test_sink test_drain test_file
end
```

APPENDIX II:
INPUT DATA QUALITY ASSURANCE

Input data quality assessments were derived from two main methods. First, when possible, input data layers were compared against field plot data that had been collected over a number of years. When this data was incomplete or missing critical spatial information or potential inconsistent data was present data quality assessment was acquired from the *PEM Requirements Analysis for the Cranbrook Timber Supply Area* (2005).

11.1 Input layer processing and quality assurance

The quality of the input layers were assessed by three statistical tests. These tests were deemed appropriate and approved for the assessment of spatial data by the Ministry of Sustainable Resource Management (Meidinger, 2003). The methods are:

- The Chi-Square Test of Proportions
- The Confusion Matrix Description of Overall Accuracy
- The Statement of Percent Correct to the Nearest +/-95% Confidence Interval

The Chi-square test of proportions analyzes the distribution of the field data attributes against those of the GIS generated input layers. For example, if field data was collected from 100 randomly placed field locations, and slope was one of the criteria collected, the distribution of slope classes from the GIS generated slope layer should approximate the distribution of slope classes found in the field data. This test gives an indication of how well the PEM is modeling the distribution of classes of data (e.g. slope, aspect, soil moisture) across the landscape. This test does not indicate the spatial accuracy of those classes though. The field data may indicate that 20% of the landscape is slope class 1 (<=5% slope) and the GIS may predict that 19% of the landscape is slope class 1. This test will not indicate whether or not the GIS is predicting the occurrence of slope class one in the right locations.

To test the locational accuracy of the PEM a confusion matrix is developed to test each class of the field data against each class of the PEM output. For instance, how many of the field plots that were classified as slope class 1 actually fall into pixels that the PEM has modeled as slope class 1. The results of the matrix include a stated Error of Omission, Error of Commission, and an initial statement of Overall Accuracy. To use the slope attribute as an example, the Error of Commission represents the percentage of occurrences were the plot data (a known thing) has been classified by the PEM as being in a slope class where it does not belong. In this case we have *committed* the act of getting it wrong. The Error of Omission represents the percentage of occurrences where the plot data has not been classified by the PEM as being in the right slope class. In this case we have *omitted* the act of getting it right (Meidinger, 2003). The initial Statement of Overall Accuracy is the number of plots where the PEM and the field data agree divided by the number of plots where the PEM output and the field data disagree. The Initial statement of overall accuracy does not indicate how much overall confidence we have in the results of the Confusion Matrix Description of Overall Accuracy its result is limited to just the test.

The Statement of Overall Accuracy defines the results of the Confusion Matrix in terms of a 95% confidence interval. For example, the confusion matrix may state an Initial Overall Accuracy of 62% but if only 8 plots were used for the test then the lower 95% confidence interval would be

25% and the upper 95% confidence interval would be 87%. In testing the same spatial data with the same result of 62% Initial Overall Accuracy but with a sample set of 100 plots the Statement of Overall Accuracy would have a lower 95% confidence interval of 56% and an upper 95% confidence interval of 69%. With more plots (a greater sample population) we can state our results with a higher degree of accuracy.

It is important to remember that the field plots used in this analysis were not collected randomly or consistently. The data for these plots was collected for a variety of purposes, over a broad timeframe and most commonly on a non-random and inconsistent basis. The purpose of these tests of proportions was to provide a baseline idea of how well the input data layers reflect the on-ground site attributes prior to the season of field data collection and not a conclusive statement of the validity if the input layers. Once data is collected in the 2007 field season the input data layers will be re-assessed for their accuracy.

11.2 TRIM

Quality assessment of the TRIM data took place as part of the *PEM Requirements Analysis for the Cranbrook Timber Supply Area* (2005). The following is a summary of those results.

The accuracy (positional and thematic) of TRIM has been well documented in the context of PEM in numerous previous projects and has always been highly recommended for use in ecosystem mapping. A qualitative review of TRIM wetland and water features polygons were completed for the Cranbrook TSA land base. The polygons are viewed against ortho images for the following randomly selected map sheets: 082G036, 082G037, 082G045, 082G046, 082G071, 082G072. The following represents the findings:

There were no issues of positional accuracy in the TRIM revealed during the quality assessment process; however there are a few minor findings that may warrant attention for the use of TRIM features in PEM:

1) TRIM wetland size and shape sometimes need modification to account for the changes since the TRIM inventory; a general trend is that TRIM wetland underestimates the size of wetland in real world. This trend was also found in other projects of a similar nature. For example, Timberline has just completed an exceptional ecology/material mapping project on approximately 5,000,000 ha over the land base of the former Cariboo Region (i.e., to support a future Cariboo PEM) and found a similar trend of TRIM wetland features.
2) A good portion of TRIM water features such as shallow open water or small ponds became wetland ecosystems (i.e., dried out to certain extent). On the other hand, there is also a number of new water features (presumably caused on beaver dams) that TRIM did not accounted for.

Since the map accuracy assessment of PEM is based on the ground verification, rather than features indicated on TRIM, inaccurate wetland boundary placement may potentially cause negative impact on the resultant map accuracy.

11.2.1 TauDEM Wetness Index

The TauDEM wetness index was developed to provide a measure of soil moisture across landscapes (Tarboton 2005). Accuracy of the TauDEM wetness index input layer was determined through visual analysis rather than using point to point analysis with plot data. Plot data collected in the Cranbrook TSA was not collected randomly and presents a bias distribution of soil moisture across the landbase. Because soil moisture can vary metre by metre due to microscale site attributes a point to point analysis was not appropriate. For the purpose of input quality assessments wetness index classifications are viewed against ortho images for the following randomly selected map sheets: 082G036, 082G037, 082G045, 082G046, 082G071, 082G072. The following represents the findings:

- The TauDEM wetness index provided a very in-depth model of moisture flow across the landscape both in mountainous terrain and on more subdued landscapes. Drainages and moisture accumulation areas were well modelled and corresponded very well with TRIM data.
- In alpine and parkland environments soil moisture tended to be overestimated in catchments areas. This is often due to the coarse textured terrain in the areas, such as talus slopes. Adjustments to these classifications in the alpine and parkland may want to be considered or captured in generalized materials mapping.
- The TauDEM wetness index may fail to identify areas of unexpected seepage (ie- where bedrock comes uncharacteristically close to the surface of a slope). By combining the TauDEM wetness index with areas of seepage identified in the generalized materials mapping this issue should be resolved.

Overall the TauDEM wetness index was deemed to be very useful as a PEM input layer.

11.2.2 Slope Position

Accuracy of the slope position input layer was determined through visual analysis rather than using point to point analysis with plot data. Plot data collected in the Cranbrook TSA tended to classify slope position more so on a microsite scale and very inconsistently across the land base. This resulted in difficulty accurately describing this input layer using the field data. Significant time was spent adjusting classification of the slope position input layer to make sure it best represented slope position on the landscape. The slope position classifications are viewed against ortho images for the following randomly selected map sheets: 082G036, 082G037, 082G045, 082G046, 082G071, 082G072. The following represents the findings:

- Midslope-straight classifications were assigned to broad valley bottoms. This is a characteristic that is well documented with the Toposcale AML that was used to create this layer. To resolve this problem, the slope position layer must be combined with gentle slope classes (slope gradient classes 1 and 2) to better identify broad valley bottoms compared to more mountainous terrain.
- The output from the Toposcale AML has been smoothed, when combined with the already smoothed DEM some microsite features can be lost. As a result it is necessary to couple the slope position layer with another model that has greater definition that can indicate small pockets of changing soil moisture. In this circumstance the TauDEM wetness index appears to have provided a valuable input.
- The slope position layer is intended to provide macro scale input information rather than more specific site level information. In general the slope position layer provides very valuable input for the PEM at a macro scale level. It is important to acknowledge that the

PEM requires more detail than this layer provides and this layer must be coupled with more site specific layers to reach a quality PEM output. Examples of additional layers to couple the slope position layer are: wetness index, sensitive ecosystem inventory data, slope, aspect, and forest cover variables.

Overall the slope position layer was deemed to be very useful as a PEM input layer.

11.2.3 Aspect

The new aspect layer was tested against 778 field plots which were stratified into the same four classes as the PEM input layer. The proportional distribution of the aspect classes were then compared to those of the plot data using Chi-squared analysis. Spatial variability exists in the input and field data, therefore a 40m buffer was placed on the pixel. If the PEM input layer included the corresponding slope class as the field data within the 40 m buffer the corresponding value was accepted. Both the chi-squared analysis and the confusion matrix represent a direct field point to PEM input layer pixel analysis, due to the structure of these analyses it would be difficult to look at the data with a 40m buffer.

Table 1. **Statement of Overall Accuracy**

Total Plots	778
Number Correct	541
Percent Correct	69.9%
Lower 95% Confidence Value	66.7%
Median 95% Confidence Value	69.6%
Upper 95% Confidence Value	72.8%

Table 2. Results of the Chi-Square Test of Proportions for the Aspect Class

PEM Aspect class	Observed - Field	Expected – Input layers	Observed-Expected	(O-E)**2/E
1	161	147	14.0000	1.33333
2	167	237	-70.0000	20.67511
3	310	276	34.0000	4.18841
4	140	118	22.0000	4.10169
	778	778	0.0000	30.29854
Chi-Square = 30.29854, df = 3, p < .000001				

Table 3. Aspect Input Layer Confusion Matrix

GIS Input Aspect	Field Class 1	Field Class 2	Field Class 3	Field Class 4	Total	Error of Omission
Class 1	79	23	25	20	147	46.3%
Class 2	46	101	65	25	237	57.4%
Class 3	27	22	195	32	276	29.3%
Class 4	9	21	25	63	118	46.6%
Total	161	167	310	140	778	
Error of Commission	50.9%	39.5%	37.1%	55.0%		

Average Error of Commission: 45.6%

Average Error of Omission: 44.9%

Overall error (340/778): 43.7%

The overall accuracy (69.9%) of the aspect layer indicates it is valid for use in the PEM. The confusion matrix revealed some discrepancies in aspect. Several reasons maybe explain these errors. It is necessary to smooth the DEM to a minor degree to remove small pits and sinks, in addition a mean filter which averages pixel values is applied to the DEM. These processes add a level of generalization to the model. When mapped at a 1:20,000 scale this level of generalization is appropriate, however when compared to point specific samples on the ground variations due to microsite conditions can be expected.

11.2.4 Slope gradient

The new slope layer was tested against 778 field plots which were stratified into the same five classes as the PEM input layer. The proportional distribution of the slope classes were then compared to those of the plot data using Chi-squared analysis. Spatial variability exists in the field data, therefore a 40 m buffer was placed on the pixel. If the PEM input layer included the corresponding slope class as the field data within the 40 m buffer the corresponding value was accepted. Both the chi-squared analysis and the confusion matrix represent a direct field point to PEM input layer pixel analysis, due to the structure of these analyses it would be difficult to look at the data with a 40 m buffer. The tables below display the results of the chi-squared analysis.

Table 4. Statement of overall accuracy for slope gradient

Total Plots	778
Number Correct	412
Percent Correct	52.9%
Lower 95% Confidence Value	49.4%
Median 95% Confidence Value	52.9%
Upper 95% Confidence Value	56.4%

Table 5. Results of the Chi-square test of proportions for slope class

Slope class	Observed - Field	Expected – GIS Input layers	Observed-Expected	(O-E)**2/E
1	205	118	87.0000	64.1441
2	161	210	-49.0000	11.4333
3	264	325	-61.0000	11.4492
4	93	96	-3.0000	0.0938
5	55	29	26.0000	23.3103
	778	778	0.0000	110.4307
Chi-Square = 110.4307 df = 4 p < 0.000000				

In order to clarify places where the PEM input layer was differing in value from the field data a confusion matrix was developed. For the purpose of the confusion matrix a direct point to point analysis was used rather than the 40m buffer (Table13).

Table 6. Slope Input Layer Confusion Matrix

GIS Input Slope	Field Class 1	Field Class 2	Field Class 3	Field Class 4	Field Class 5	Total	Error of Omission
Class 1	81	20	12	4	1	118	31.4%
Class 2	82	70	46	9	3	210	66.7%
Class 3	35	66	161	47	16	325	50.1%
Class 4	4	3	37	27	25	96	71.9%
Class 5	3	2	8	6	10	29	65.6%
Total	205	161	264	93	55	778	
Error of Commission	60.4%	56.5%	39.0%	71.0%	81.8%		

Average Error of Commission 61.7%

Average Error of Omission 57.1%

When developing the DEM and the subsequent slope gradient PEM input layer the landscape slope was smoothed to a certain degree to remove small pits and sinks in the surface. When doing this it affects the accuracy of the slope gradient model, however it is necessary to create the input layers. This smoothing may account for a certain amount of shift in the classes. In addition, the majority of errors in the slope class occurred with adjacent slope gradient classes. This may be an indication of a slight spatial shift in the data. The overall accuracy of the data was 52.9% and deemed acceptable for use in the PEM.

11.3 VRI/FC1

The PEM standards supports the use of VRI forest cover maps where available, but recommends that the layers are based more so on the presence/absence of the tree species in the top three species rather than relying on the proportion of the VRI polygons that are dominated by specific tree species (RIC 1999). In order to provide a thorough review of the VRI/FC1 quality we referred to the *PEM Requirements Analysis for the Cranbrook Timber Supply Area* (2005) the summary of which is provided below.

VRI/FC1 may be potentially considered as one of major PEM input layers. For this reason, the quality assessment is conducted against ortho images using the same set of selected mapsheets as was used for the analysis of the TRIM data. The following is a summary of the assessment results:

Positional accuracy of the VRI is typically evaluated through the comparison of the position of VRI hydrological features to the corresponding TRIM features. Since VRI/FC1 is TRIM based, there are no issues revealed in terms of positional accuracy for the mapsheets assessed.

A comprehensive quality assessment was also conducted on thematic content of the VRI/FC1. Compared to the VRI/FC1 evaluated in the neighbouring Kootenay Lake TSA, the thematic content of the VRI/FC1 in the Cranbrook TSA is in reasonably good conditions for the purpose of PEM use.

Non-forested and non-productive polygons: It is generally believed that this layer of information is useful for PEM. Many of the previous PEMs in the region and elsewhere successfully used this layer of information. Based on this review, information contained in the Cranbrook TSA is considered reasonably accurate for the purpose of PEM. The following is a summary of review findings:

1) The delineation and classification of non-forested and non-productive areas are considered reasonably accurate both thematically and spatially.
2) Some major tree species type group such as “Py” and “Act” leading stands etc. are also reasonably accurate and will be useful for PEM.
3) Other tree species type group (e.g., Sxw leading, Cw leading, etc.) warrant further investigation, preferably using field data specifically designed for the purpose. This review only assessed Pl and Act type groups due to their unique photo signatures.
4) The definition of alpine forest (AF) and Alpine (A) is understandably inconsistent, i.e., may be caused by inaccurate boundary placement of old BGC mapping in the past.
5) Most of the VRI “Rock” polygons are in fact rock dominating polygons.
6) Most of the “NPBR” polygons reviewed are true “NPBR” polygons. However, since the VRI is rolled over from FC1 and there is no soil moisture attribute. It may be difficult for a PEM to distinguish between moist or wet “NPBR” and dry “NPBR”. A similar situation also occured with “NP” polygons reviewed.
7) Caution must be exercised when the VRI attribute “NPBU” is used in PEM. Significant numbers of the reviewed polygons are considered “NPBR” (i.e., on very shallow and coarse soil), rather than “NPBU”.
8) Polygon delineation is also at a much finer level compared to that in the neighbouring Kootenay Lake TSA.

The VRI/FC1 of Cranbrook TSA is recommended for use in future PEM. Cautions are advised on the uses of certain attributes as described above.

11.4 Terrain and Soil Mapping

Terrain data collected in the field plots was inconsistent in collection methods and quality. For this reason analysis of this layer relied on results presented in the *PEM Requirements Analysis for the Cranbrook Timber Supply Area* (2005).

This layer of information is recommended for reference use only due to the concerns of the mapping scale (1:50,000) and unknown thematic accuracy. Positional accuracy is not a primary concerns due to its intended use (i.e., not to be used directly in GIS overlay process).

Most sources of the mapping were, in fact, TRIM based and there are no concerns of the positional accuracy. For thematic accuracy, certain selected features polygons (e.g., esker complex, glacial fluvial terrace, active fluvial plains, rock and talus slopes, lacustrine etc.) were assessed. In general, the information contained within the selected terrain feature polygons are considered accurate but overly generalised. This is mainly caused by the mapping scale (i.e., 1:50,000).

Using the Terrain and Soil Mapping as a reference layer for generalized/exceptional materials mapping, as opposed to a direct GRID input layer provides useful guidance for identification of important site features for the PEM. This mapping can provide indication of coarse textured glaciofluvial parent materials, or alternatively fine textured lacustrine materials that would otherwise be difficult to model in the PEM.

APPENDIX III
VENUS PLOTS AND EXCEL FORMATTED TRANSECT DATA

Note: VENUS and Transect Data on CD held in sleeve at the back of the report.

APPENDIX IV
GENERALIZED MATERIALS AND SEI MAPPING LEGENDS

Table 1. SEI units, codes and descriptions.

SEI Code (Class)	SEI Class	SEI Class Description	SEI Code (Class:subclass)	SEI Subclass
AS	Antelope Brush Steppe	Shrub-steppe ecosystems dominated by antelope-brush.	AS:as	Antelope Brush Steppe
			AS:ds	Disturbed Antelope Brush Steppe
BW	Broadleaf Woodlands	Ecosystems dominated by trembling aspen occurring in depressions and moist areas in grasslands; old Broadleaf Woodlands are part of the Old Forest category.	BW:ac	Aspen copse
FS	Seasonally Flooded Fields	Agricultural areas that are often flooded during spring run-off.	FS	Seasonally Flooded Fields
GR	Grasslands	Ecosystems dominated by bunchgrasses.	GR:gr	Grasslands
			GR:st	Steep Grasslands
			GR:ss	Steep, Shallow-soiled Grasslands
			GR:ds	Disturbed Grasslands
MF	Mature Forest	Forests dominated by mature coniferous trees; excludes mature coniferous and broadleaf woodlands	MF:co	Mature Forest
NA	Not Sensitive		NA	Not Sensitive
OF	Old Forest	Forest ecosystems dominated by large, old trees; includes old Coniferous Woodlands and Broadleaf Woodlands.	OF:co	Old Forest
RI	Riparian	Treed or shrubby ecosystems associated with pond and lake shorelines (fringe), swamps, floodplains, or gullies with intermittent or permanent creeks.	RI:ff	Fluvial Fringe
			RI:sh	Shrub
			RI:fp	Floodplain
			RI:gu	Gully
			RI:ri	River
SS	Sagebrush Steppe	Shrub-steppe ecosystems dominated by big sagebrush.	SS:ss	Sagebrush Steppe
			SS:st	Steep Sagebrush Steppe
			SS:sh	Steep, Shallow-soiled Sagebrush Steppe
			SS:ds	Disturbed Sagebrush Steppe
SV	Sparsely Vegetated	Ecosystems with little vegetation occurring on bedrock or colluvial features.	SV:cl	Cliff
			SV:ro	Rock Outcrop
			SV:sh	Shrubby Rock Outcrop
			SV:ta	Talus Slope
WD	Coniferous Woodlands	Open stands of Douglas-fir or ponderosa pine, often on shallow soils, with typically grassy understories; old Coniferous Woodlands are part of the Old Forest category.	WD:co	Coniferous Woodlands
WN	Wetlands	Ecosystems where the water table is at or near the surface.	WN:ms	Marsh
			WN:sp	Swamp
			WN:sw	Shallow Open Water
			WN:wm	Wet Meadow
			WN:wn	Wetland (General)

Field Name	**Description**	**Allowable Codes**	**Code Description**
Poly_id	Polygon id number		A provincially expectable polygon id
Geocode	Empty ignore		
Material Depth	Depth to bedrock	20	Very thin veneer <50 cm
Material Texture	**General material/texture of the dominant parent material**		**Identifies Areas of non Medium Textures**
		99	Exposed bedrock
		88	Sloping Talus
		77	Gentle Blocky Colluvium
		20	Fine lacustrine/glacio lacustrine
		50	**Medium (default)**[3]
		70	Coarse fluvial/glaciofluvial/esker
Wetlands			**Identifies areas of wetland ecosystems**
		10	**TRIM Lakes and open water**
		11	Organic wetlands shrub <10% treed
		12	Organic wetlands herb <10% treed
		13	Organic wetland shrub treed >10% trees
		14	Organic wetland herb >10% trees
		15	Mineral non treed wetland <10% trees
Non-forested ecosystems			**Non wetland non forested ecosystems**

[3] Anything in blue does not have to be photo typed, but is either default or taken from TRIM data feature codes

		40	Permanent Herbaceous meadow
		41	Permanent heather meadow
		42	pasture
		43	Permanent brush
		44	Avalanche path herb
		45	Avalanche path shrub
		46	Avalanche path low conifer
		47	Snow and ice
		48	Permanent grasslands
		49	urban
Seepage and Floodplain			**Identifies Wetter than Expected areas**
		31	Very wet seepage non wetland hygric to subhydric
		32	Wet seepage non wetland subhygric
		33	Low bench floodplain
		34	Mid bench flood plain
		35	High bench floodplain
		36	**TRIM gravel bar**

APPENDIX V:
EXCEL FORMATTED KNOWLEDGE BASES

Note: Knowledge bases on CD held in sleeve at the back of the report.

APPENDIX VI:
MAPPED SITE SERIES LEGEND

Subzone	Site Series Number	Map Code	Site Series Name
ESSFdk1	01.1/01.2	01	Bl – Azalea – Feathermoss/ Bl – Grouseberry – Arnica
ESSFdk1	02		Bl – Selaginella
ESSFdk1	03		BlPl – Grouseberry – Beargrass
ESSFdk1	04		PlBl – Juniper – Soopolallie
ESSFdk1	05		PlBl – Azalea – Beargrass
ESSFdk1	06		SeBl – Goosberry
ESSFdk1	82/83	XG	Bluebunch wheatgrass – Silky lupine/ Idaho fescue – Sulphur buckwheat
ESSFdk1	07/08	XM	SeBl – Horsetail/ Pl – Bluejoint – Horsetail
ESSFdk1	Av04	AV	Alder – Hellebore
ESSFdk1	Av06	GT	Thimbleberry – Cow parsnip
ESSFdk1		FE	Herb/ graminoid dominated wetland
ESSFdk1	Me03	ME	Leatherleaf saxifrage – Horsetail
ESSFdk1		OS	Shrub dominated wetland
ESSFdk1		RO	Rock outcrop
ESSFdk1		RT	Talus
ESSFdk1		MD	Dry Meadow
ESSFdk2			
ESSFdk2	01.1/01.2	01	Bl – Azalea – Feathermoss/ Bl – Grouseberry – Arnica
ESSFdk2	03		Bl – Dicranum
ESSFdk2	08		SeBl – Horsetail
ESSFdk2	04/05	XJ	Pl(SxwBl) – Juniper – Grouseberry/ FdPl – Soopolallie - Juniper
ESSFdk2	06/07	XM	SeBl – Azalea – Oak fern – Foamflower/ Bl – Valerian - Foamflower
ESSFdk2		AV	Shrub dominated avalanche track
ESSFdk2		GT	Herb dominated avalanche track
ESSFdk2		OS	Shrub dominated wetland

ESSFdk2		FE	Herb/graminoid wetland
ESSFdk2		MM	Moist meadow
ESSFdk2	RO/02	RO	Rock outcrop/ PlBl – Juniper - Kinnikinnick
ESSFdk2		RT	Talus
ESSFdm			
ESSFdm	01		Bl – False azalea – Beargrass
ESSFdm	02		BlPl – Spirea – White hawkweed
ESSFdm	03		BlPl – Black huckleberry – Grouseberry
ESSFdm	04		BlSe – False azalea – Foamflower
ESSFdm	05		BlSe – Gooseberry – Oak fern
ESSFdm	06		SeBl – False Azalea – Horsetail
ESSFdm	72/RO	72	Fescue – Awned haircap moss/ Rock outcrop
ESSFdm	73		Black huckleberry – Pinegrass
ESSFdm		AV	Shrub dominated avalanche track
ESSFdm		FE	Herbaceous wetland
ESSFdm		GT	Herb dominated avalanche track
ESSFdm		ME	Non-wetland permanent herb meadow - moist
ESSFdm		OS	Shrub dominated wetland
ESSFdm		MD	Dry meadow
ESSFdm		RT	Talus
ESSFwm			
ESSFwm	01/04	01	Bl – Rhodo – Menzfer – Brachyt/ BlSe – Menzfer - Oakfern
ESSFwm	02		Bl – Juniper – Lichen
ESSFwm	03		Bl – Vaccmem – Orthsec
ESSFwm	05		SeBl – Trollius – Senecio
ESSFwm		AV	Shrub dominated avalanche track
ESSFwm		FE	Herb/graminoid dominated wetland
ESSFwm		GT	Herb dominated avalanche track
ESSFwm		OS	Shrub dominated wetland

ESSFwm		RO	Rock outcrop
ESSFwm		RT	Talus
ESSFwm		MM	Moist meadow
MSdk1			
MSdk1	01		SxwPl – Arnica – Feathermoss
MSdk1	02		Fd(Pl) – Bluebunch wheatgrass – Pinegrass
MSdk1	03		FdLwPl – Juniper – Pinegrass
MSdk1	04		Pl – Soopolallie – Pinegrass
MSdk1	05		Sxw – Gooseberry – Foamflower
MSdk1	82/83/84	XG	Saskatoon – Bluebunch wheatgrass/ Idaho fescue – Bluebunch wheatgrass/ Idaho fescue – Oatgrass
MSdk1	06/07	XM	Sxw – Horsetail/ Sxw – Trapper's tea – Peat moss
MSdk1		AV	Avalanche track
MSdk1		GW	Herb dominated wetland
MSdk1		WE	Shrub dominated wetland
MSdk1		RO	Rock outcrop
MSdk1		RT	Talus
MSdk2			
MSdk2	01		Sxw – Arnica – Feathermoss
MSdk2	02		Fd – Juniper – Kinnikinnick
MSdk2	03		Fd – Rocky Mountain Juniper – Bluebunch wheatgrass
MSdk2	04		Fd(Pl) – Juniper – Pinegrass – Kinnikinnick
MSdk2	05		FdPl – Soopolallie – Pinegrass – Twinflower
MSdk2	06		SxwPl – Labrador tea – Bunchberry – Feathermoss
MSdk2	07		Pl – Soopolallie – Velvet-leaved blueberry
MSdk2	08		PlSxw – Soopolallie – Feathermoss
MSdk2	09		Sxw – Dogwood – Feathermoss
MSdk2	10/11/12	XM	Sxw – Horsetail/ PlSxw – Labrador tea/ Sxw – Sedge
MSdk2		AV	Shrub dominated avalanche track
MSdk2		GT	Herb dominated avalanche track

MSdk2		FE	Herb/graminoid dominated wetland
MSdk2		OS	Shrub dominated wetland
MSdk2		RO	Rock outcrop
MSdk2		RT	Talus
ICHmk4			
ICHmk4	01/01-YC	01	CwSxw – Falsebox – Knight's plume/ Cw – Nudem
ICHmk4	02		Fd – Juniper – Pinegrass
ICHmk4	03		FdPl – Soopolallie – Pinegrass
ICHmk4	04/04-MS	04	SxwCwAct – Dogwood/ ActSxw – Snowberry
ICHmk4	05/06	XM	CwSxw – Oak fern – Ladyfern/ CwSxw – Devil's club – Lady fern
ICHmk4	07/08/09	XW	Sxw – Horsetail/ BlSxw – Labrador tea – Peatmoss
ICHmk4		AS	Shrub dominated avalanche track
ICHmk4		GT	Herb dominated avalanche track
ICHmk4		FE	Herb/graminoid dominated wetland
ICHmk4		OS	Shrub dominated wetland
ICHmk4		RO	Rock outcrop
ICHmk4		RT	Talus
ICHmk4	Rt02	T2	Feathermoss – Clad lichens
ICHdm			
ICHdm	01		HwCw – Falsebox – Twinflower
ICHdm	02		Kinnikinnick – Bluebunch wheatgrass
ICHdm	03		PlLw – Birch-leaved spirea – Pinegrass
ICHdm	04		HwCw – Black huckleberry – Oak fern
ICHdm	05		CwHw – Devil's club – Lady fern
ICHdm	06		Sx – Thimbleberry – Meadowrue
ICHdm		AS	Shrub dominated avalanche track
ICHdm		GL	Herb dominated avalanche track
ICHdm		FE	Herb/graminoid dominated wetland
ICHdm		OS	Shrub dominated wetland

ICHdm		RT	Talus
ICHdm		RO	Rock outcrop
ICHdw1			
ICHdw1	01a	1A	CwFd – Falsebox – sx sm phase
ICHdw1	01b	1B	CwFd – Falsebox – m shg phase
ICHdw1	02		FdPy – Oregon grape – Parsley fern
ICHdw1	03		CwHw – White pine – Devil's club
ICHdw1	04		CwHw – Devil's club – Lady fern
ICHdw1		OS	Shrub dominated wetland
ICHdw1		FE	Herb/graminoid dominated wetland
ICHdw1		RO	Rock outcrop
ICHdw1		RT	Talus
IDFdm2			
IDFdm2	01		Fd – Pinegrass – Twinflower
IDFdm2	02		Fd – Moss
IDFdm2	05		Fd – Pinegrass
IDFdm2	06		SxFd – Bunchberry – Feathermoss
IDFdm2	07		LwFd – Birch – Snowberry
IDFdm2	08		SxAct – Dogwood – Thimbleberry
IDFdm2	03/04	XD	Fd – Rocky Mountain Juniper – Sidewalk moss/ FdPy – Bluebunch wheatgrass
IDFdm2	82ES/82.1/ 82.2/83	XG	$Stiff needlegrass/ Rocky Mountain Juniper – Bluebunch wheatgrass/ Antelope brush – Bluebunch wheatgrass
IDFdm2		FE	Herb/graminoid dominated wetland
IDFdm2		OS	Shrub dominated wetland
IDFdm2	Gs01	WE	Distichlis
IDFdm2		RO	Rock outcrop
IDFdm2		RT	Talus
IDFdm2	Rt02	T2	Feathermoss – Clad lichens

PPdh2			
PPdh2	01		FdPy – Pinegrass
PPdh2	03		PyFd – Kinnikinnick – Bluebunch wheatgrass
PPdh2	04		PyFd – Bluebunch wheatgrass
PPdh2	05/05ms	05	Py/Fd – Rough fescue – Bluebunch wheatgrass/ $PyFd – Stiff needlegrass
PPdh2	06		Fd – Moss
PPdh2	07		SxwFd – Aralia
PPdh2	82ES/82/ 83ES/83LS/ 83/84ES/84	XG	$Antelope brush – Needle-and-thread grass/ Antelope brush – Bluebunch wheatgrass/ $Needle-and-thread grass/ $Antelope brush – Bluebunch wheatgrass/ Idaho fescue – Bluebunch wheatgrass/ $Kentucky bluegrass/ Rough fescue
PPdh2	08/09/10/11	XM	At – Snowberry – Kentucky bluegrass/ At – Dogwood – Water birch/ SxwAtc – Dogwood – Rose/ Sxw – Horsetail
PPdh2		FE	Herb/graminoid dominated wetland
PPdh2		WE	Mineral non-treed wetland
PPdh2		RO	Rock outcrop
PPdh2		RT	Talus