

Kamloops TSA
Future Forest Strategy

ClimateBC Modeling and Future Ecosystem Climate Mapping

Version 2.0

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Prepared For:

Symmetree Consulting Group Ltd. (c/o Ken Zielke),
on contract to the Kamloops TSA Future Forests Strategy Committee.

Prepared by:

Shamaya Consulting
Vernon, BC
Contact: Colleen Jones, RPBio



Forsite
Salmon Arm, BC
Contact: Cam Brown, RPF



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1. Introduction

1.1. Project Background

The Ministry of Forests and Range's (MoFR) Chief Forester launched the Future Forest Strategy initiative in early 2007 to help ensure BC's forest management framework is proactively considering the potential impacts of climate change on the range of values our forests provide. In support of this, the MoFR Research Branch has also stated that 'Resource managers need to start evaluating the vulnerabilities of forest and range resources to climate change. This will facilitate development of adaptation strategies to maintain resilience of ecological systems and our uses of them.' (Spittlehouse, Nov 25, 2007)

In response to the Chief Forester's Future Forest Strategy initiative, a committee of concerned licensees in the Kamloops Timber Supply Area (TSA) submitted a proposal to the MoFR asking to be a pilot area, and the proposal was accepted. The proposal consisted primarily of a multi-year work plan developed by the Symmetree Consulting Group and had the following goals:

1. Focus climatic change projections to the scale of the Kamloops TSA and its ecosystems.
2. Identify vulnerabilities that could impact forest values in the TSA.
3. Assess potential impact of vulnerabilities and identify those where adaptive strategies may prove useful and realistic at mitigating impacts.
4. Assess/develop adaptive strategies to mitigate identified key vulnerabilities.

In order to achieve these goals, the Kamloops Future Forests Strategy (KFFS) project has identified numerous sub-projects to be completed. Under the direction of the Symmetree Group, Forsite and Shamaya Consulting were given the tasks of focusing climate change projections to the scale of the Kamloops TSA and its ecosystems. This report summarizes the approaches taken and the results obtained.

1.2. Project Purpose

The general intent of this project is to forecast potential changes in climatic variables throughout the Kamloops TSA, and present such anticipated trends in a form that will be most useful for specialists and practitioners to understand. This will assist with initiating discussions with them regarding ecological and management vulnerabilities over time. To meet this outcome the goal is to identify the range of likely changes in specific climatic parameters, and then characterize those trends using the biogeoclimatic classification system in BC. In this way it is felt that those involved in vulnerability discussions will more easily grasp the potential impacts of climate.

To facilitate this general intent, the following objectives were set for this project:

1. Assign climate change projections from UBC's ClimateBC program to the Kamloops TSA at a 1 ha resolution.
2. Characterize the change in climate projected for each of the TSA's currently mapped BGC Subzones.

- Map projected future climate change in the years 2050 and 2080 by grouping the TSA into like BGC Subzone Climate envelopes using temperature and precipitation variables in ClimateBC.

1.3. Area of Interest

The Kamloops TSA is situated in south-central British Columbia and represents approximately 2,233,580 ha (Wells Gray park excluded). The northern half overlaps a portion of the Headwaters Forest District while the southern half consists of the entire Kamloops Forest District (Figure 1). TFL's 18 and 35 occur within the same geographic area but are not legally part of the TSA. However, for the purposes of this project, they have been included.

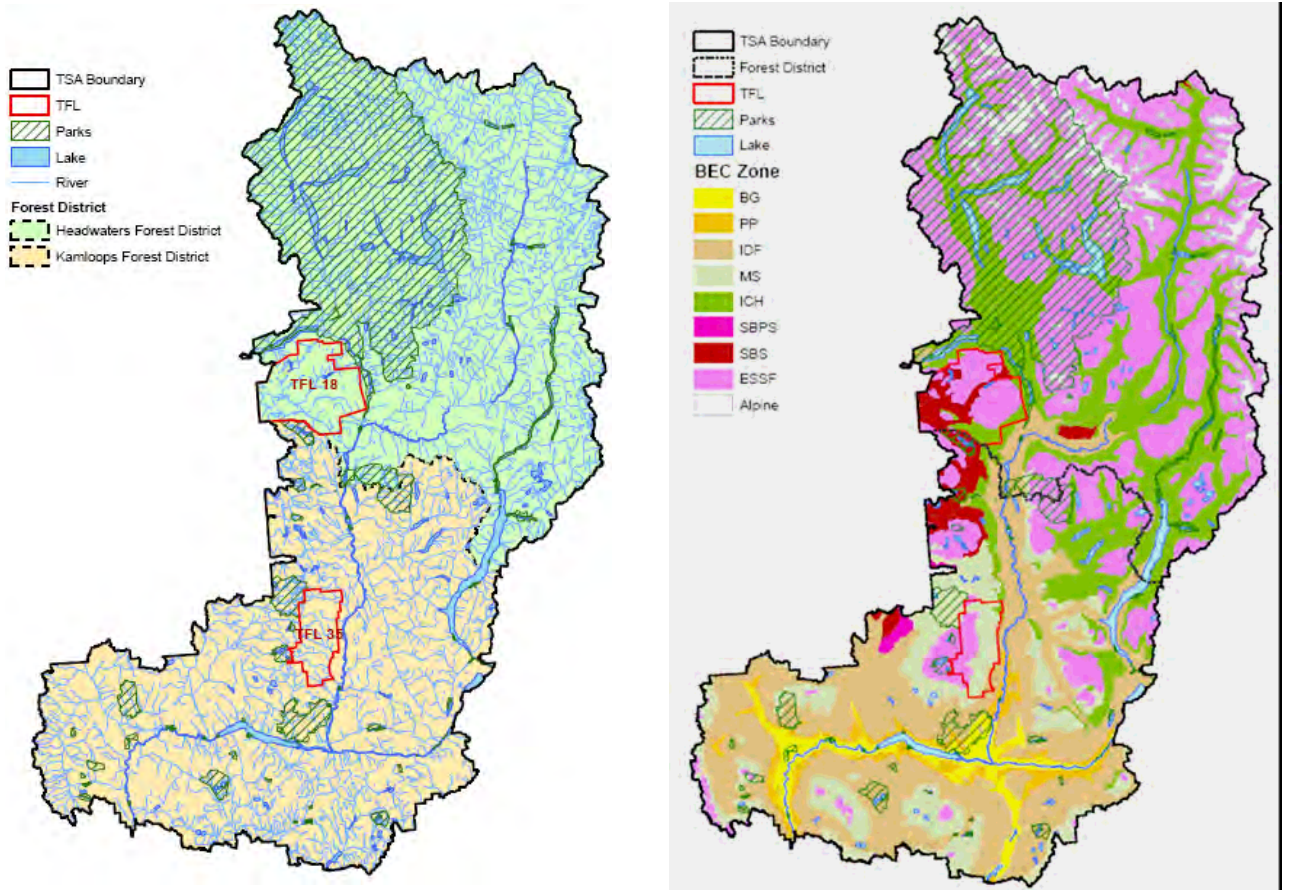


Figure 1. Kamloops TSA and MoF Forest Districts (Kamloops-south, Headwaters-north)

1.4. Current Biogeoclimatic Ecosystem Subzones

The Kamloops TSA contains 50 BGC variants that occur within the BG, PP, IDF, ICH, MS, SBS, and ESSF zones. Figure 2 provides a breakdown of the variants by TSA area.

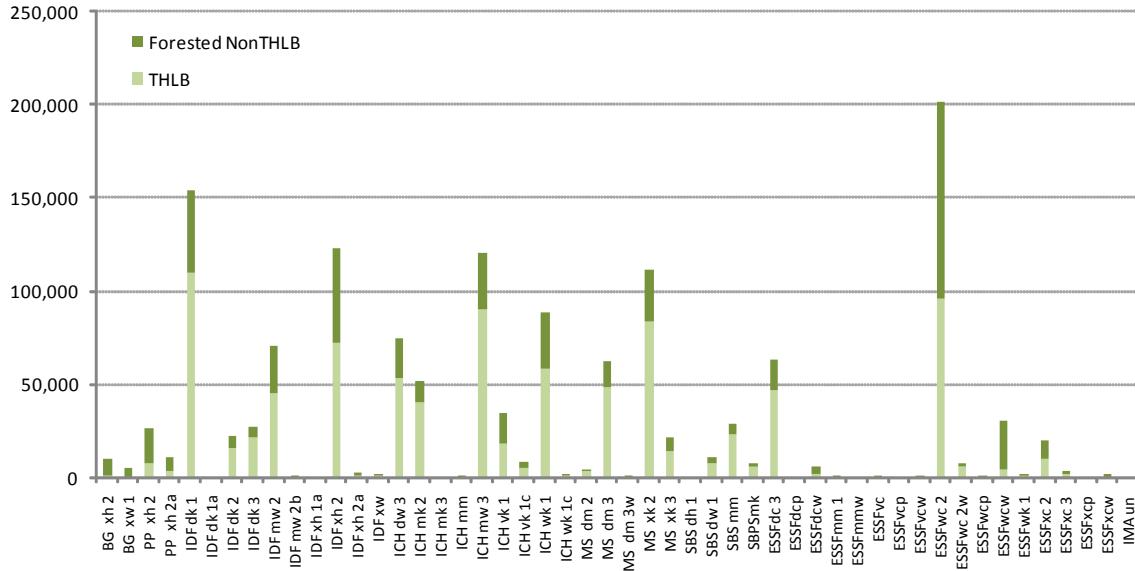


Figure 2. BGC variant areas in the Kamloops TSA by land base classification

2. Climate BC Modeling

This section of the report summarizes the assumptions used to generate predictions of climate change specific to the Kamloops TSA.

2.1. ClimateBC Model

ClimateBC is a software program developed by the MoFR Research Branch (Dave Spittlehouse) and UBC’s Centre for Forest Gene Conservation (Sally Aitken). It offers high-resolution, spatial climate data for current and future climate change scenarios. Methodologies are described in Wang et al. (2006) and Hamann and Wang (2005). A good overview can be found in Streamline (Spring 2006 Issue)¹.



Figure 3. Area covered by Climate BC model

ClimateBC provides data for BC and the Alaska Panhandle, to 113°W in Alberta, and to 2° of latitude into Yukon Territories and the United States adjacent to BC (Figure 3).

¹ Streamline Watershed Management Bulletin Vol. 9/No. 2 Spring 2006. http://www.for.gov.bc.ca/hre/pubs/docs/Spittlehouse_2006%20Streamline.pdf

Given the latitude, longitude, and elevation of any point in this area, ClimateBC will output a number of annual, seasonal, and derived climatic variables. For example, it can provide monthly maximum and minimum air temperatures or precipitation amounts, and can also provide derived variables such as degree-days, and frost-free periods.

A primary reason for developing ClimateBC was to help analyze the effect of climate change on resource management and develop adaptive actions (Spittlehouse 2005). The program can provide output from several global climate models using different carbon emission scenarios at three future time periods (2020, 2050, 2080), as well as historical normals.

2.2. Climate Change Scenarios

After a review of literature and direct consultation with Tongli Wang (UBC), Andreas Hamann (UofA), Dave Spittlehouse (MoF), and Del Meidinger (MoF), it was clear that no one climate change scenario should be considered 'most likely' and that the full range of possible outcomes should be explored (Meidinger, 2007, Spittlehouse 2006). Best and worst case greenhouse gas emission scenarios were needed to characterize the range of potential climate change outcomes – ideally coming from different global climate models. Based primarily on the advice of Andreas Hamann (developer of the scenarios in ClimateBC), the following scenarios were chosen:

1. HadCM3-A1F1 ('Worst' Case Scenario)

This scenario uses the Hadley Centre for Climate Prediction and Research global climate model and assumes minimal reductions in future greenhouse gas emission rates. The Hadley model typically predicts the hottest, driest summers of any model in ClimateBC and the A1F1 scenario provides a pessimistic view of future carbon emissions (minimal change from current emission rates).

2. PCM-B1 ('Best' Case Scenario)

This scenario uses the National Center for Atmospheric Research, Program for Climate Modeling global climate model and assumes significant reductions in future greenhouse gas emissions are achieved. The PCM model typically predicts more moderate summer climates and the B1 scenario provides an optimistic view of future carbon emissions.

These scenarios are felt to provide reasonable bookends, based on current knowledge, on the extent of climate change that could occur in the future.

2.3. Modeling Approach for Applying the Climate Change Scenarios

1. A 100m grid of points was generated to cover the entire TSA (~ 2 million points). The one hectare resolution was used because it was recognized that coarser grids may not account well for steep elevational gradients and finer grids became too onerous (time consuming) to work with.

2. Each point was assigned latitude, longitude, and elevation. Elevation data was obtained from a TRIM digital elevation model (90% of points accurate to within 10m of true elevation).
3. An input text file was created and fed into ClimateBC and annual, seasonal, and monthly outputs were obtained for the following scenarios and time periods:
 - 1961-1990 Climate Normals
 - HadCM3-A1F1: 2020, 2050, 2080
 - PCM-B1: 2020, 2050, 2080
4. Output text files were imported into Access databases for reporting.
5. Each of the points was also assigned to a BGC variant using GIS tools and the current provincial BGC dataset (version 6).
6. For each climate variable (i.e. mean annual temperature), averages and ranges (max/min) were derived at the BGC variant level.
7. Spreadsheets were produced to allow changes in climate variables to be graphed and summarized. The layout of the spreadsheets was taken from MoFR Research Branch's example (<http://www.for.gov.bc.ca/ftp/HRE/external/!publish/Climate/>). Adaptations were made to allow numerical comparisons between multiple variables from different scenarios.

2.4. Statistical Results of the Climate Change Modelling

Comparisons between historical normal conditions and projected 2050 (Table 1) and 2080 (Table 2) worst case (Hadley-A1F1) and best case (PCM-B1) scenarios for the entire TSA are provided below.

These tables show that the mean annual temperature of the Kamloops TSA is projected to increase between 1.1 to 3.3 degrees by 2050, and 1.4 to 5.4 degrees by 2080. The significant range seen between the best and worst case scenarios is due to the different global climate model assumptions (Hadley vs PCM) particularly around ocean currents and cloud formation, and the different assumptions around future carbon emissions (little change vs significant reductions).

Table 1. TSA wide averages for selected climate variables – historical normals vs best (PCM) and worst (Hadley) case predictions for **2050**

	Normal (1961- 1990)	HADCM3- A1FI 2050s	Difference From Normal	PCM- B1 2050s	Difference From Normal
Mean Annual Temperature	2.4	5.6	3.3	3.4	1.1
Mean Coldest Month Temperature	-8.9	-6.9	2.0	-6.7	2.1
Mean Warmest Month Temperature	13.4	19.0	5.6	15.0	1.6
Frost Free Period	68	110	62%	87	28%
Number Of Frost Free Days	145	190	31%	161	11%
Mean Annual Precipitation	854	891	4%	892	4%
Mean Annual Summer Precipitation	343	311	-9%	342	-1%
Precipitation As Snow	396	349	-12%	393	-1%

Table 2. TSA wide averages for selected climate variables – historical normals vs best (PCM) and worst (Hadley) case predictions for 2080

	Normal (1961- 1990)	HADCM3- A1FI 2080s	Difference From Normal	PCM- B1 2080s	Difference From Normal
Mean Annual Temperature	2.4	7.8	5.4	3.8	1.4
Mean Coldest Month Temperature	-8.9	-5.6	3.3	-6.0	2.8
Mean Warmest Month Temperature	13.4	22.9	9.5	15.6	2.2
Frost Free Period	68	135	98%	93	36%
Number Of Frost Free Days	145	226	56%	167	15%
Mean Annual Precipitation	854	917	7%	903	6%
Mean Annual Summer Precipitation	343	289	-16%	341	-1%
Precipitation As Snow	396	304	-23%	389	-2%

Other general trends that are evident are:

- The Hadley scenario (worst case, or most change) predicts warming to occur over the entire year but extreme warming is projected during summer months (9.5 deg in warmest month). Only a 3.3 deg increase is seen in the coldest month. A slight increase is seen in overall annual precipitation (7% by 2080), but summer precipitation and precipitation as snow decrease – meaning increased rain in spring, fall, and winter.
- The PCM scenario (best case or least change) predicts warming to occur relatively evenly in all seasons and the degree of warming is significantly less than in the worst case scenario. Annual precipitation increases similarly to the worst case scenario but the shifting of rain away from summer and into other seasons is less dramatic.

Results for the 12 largest BGC variants in the TSA (gross area) are provided below. Information on the units not shown here can be found in the project spreadsheets (Forsite 2008).

Table 3. Climate Normal (1961-1990) averages for the 12 largest BGC variants in the TSA

Variable	ESSF dc 3	ESSF wc 2	ICH dw 3	ICH mk 2	ICH mw 3	ICH wk 1	IDF dk 1	IDF dk 2	IDF mw 2	IDF xh 2	MS dm 3	MS xk 2
Mean Annual Temperature	1.5	0.7	4.1	3.2	3.2	2.3	3.5	4.1	5.0	4.9	2.8	2.6
Extreme Minimum Temperature	-40.2	-41.7	-38.6	-39.0	-39.5	-40.8	-37.9	-37.5	-37.1	-37.0	-38.8	-38.5
Mean Coldest Month Temperature	-9.3	-10.2	-8.1	-8.3	-8.6	-9.5	-7.5	-7.4	-7.2	-7.0	-8.3	-8.1
Mean Warmest Month Temperature	12.1	11.6	15.3	14.3	14.4	13.6	14.4	15.3	16.4	16.2	13.7	13.3
Frost Free Period	49.2	45.9	93.9	77.6	82.1	72.1	84.5	92.2	104.7	101.6	72.6	74.4
Number Of Frost Free Days	130.0	124.0	167.4	152.5	156.0	145.8	157.9	166.3	177.9	174.4	148.2	148.2
Degree-Days Above 18 Degrees C	0.6	-0.6	28.6	12.5	16.0	7.4	13.2	26.7	53.6	48.9	7.3	4.6
Degree-Days Below 0 Degrees C	1,090	1,232	805	897	913	1,044	823	768	699	701	924	928
Mean Annual Precipitation	727	1,265	738	618	917	1,137	409	478	544	383	567	484
Mean Annual Summer Precipitation	329	482	309	276	366	440	193	226	241	181	264	229
Precipitation As Snow	316	636	264	235	369	498	150	160	175	123	217	192
Annual Heat : Moisture Index	16.3	9.2	19.9	22.1	15.6	11.6	33.4	29.8	28.0	39.4	23.0	26.6

Table 4. Hadley A1F1 averages for the 12 largest BGC variants in the TSA (year 2080)

Variable	ESSF dc 3	ESSF wc 2	ICH dw 3	ICH mk 2	ICH mw 3	ICH wk 1	IDF dk 1	IDF dk 2	IDF mw 2	IDF xh 2	MS dm 3	MS xk 2
Mean Annual Temperature	7.0	6.0	9.4	8.7	8.5	7.6	9.2	9.9	10.5	10.6	8.5	8.3
Extreme Minimum Temperature	-32.7	-35.2	-30.9	-31.0	-32.0	-34.0	-29.1	-28.6	-28.5	-28.1	-30.5	-29.9
Mean Coldest Month Temperature	-6.0	-7.0	-4.9	-5.0	-5.4	-6.3	-4.0	-3.9	-3.9	-3.6	-4.9	-4.6
Mean Warmest Month Temperature	22.1	20.6	24.4	24.1	23.5	22.4	24.7	25.6	26.0	26.2	23.9	23.8
Frost Free Period	118	112	158	139	142	130	146	158	175	169	134	134
Number Of Frost Free Days	214	198	251	238	238	223	247	257	266	264	235	236
Degree-Days Above 18 Degrees C	343	251	502	477	456	400	487	522	535	530	465	439
Degree-Days Below 0 Degrees C	518	644	383	416	441	524	344	330	312	300	414	392
Mean Annual Precipitation	760	1,371	787	648	986	1,230	425	494	572	398	588	501
Mean Annual Summer Precipitation	271	412	260	227	310	376	156	184	199	147	216	186
Precipitation As Snow	223	499	173	157	255	368	93	96	107	76	140	121
Annual Heat : Moisture Index	23.1	12.7	25.9	29.9	20.5	15.3	45.8	40.5	36.7	52.5	32.0	37.3

Table 5. PCM-B1 averages for the 12 largest BGC variants in the TSA (year 2080)

Variable	ESSF dc 3	ESSF wc 2	ICH dw 3	ICH mk 2	ICH mw 3	ICH wk 1	IDF dk 1	IDF dk 2	IDF mw 2	IDF xh 2	MS dm 3	MS xk 2
Mean Annual Temperature	2.9	2.1	5.5	4.6	4.6	3.7	4.9	5.5	6.4	6.2	4.2	4.0
Extreme Minimum Temperature	-35.4	-37.0	-32.9	-33.8	-34.1	-35.7	-33.1	-32.2	-31.2	-31.6	-33.9	-33.8
Mean Coldest Month Temperature	-6.5	-7.3	-5.2	-5.5	-5.8	-6.6	-4.8	-4.6	-4.4	-4.2	-5.5	-5.3
Mean Warmest Month Temperature	14.3	13.8	17.6	16.5	16.6	15.7	16.6	17.5	18.6	18.4	15.9	15.5
Frost Free Period	78	72	116	102	105	95	108	116	127	123	98	98
Number Of Frost Free Days	152	145	190	175	178	167	180	190	202	198	171	170
Degree-Days Above 18 Degrees C	13	8	102	55	63	35	57	96	164	150	37	28
Degree-Days Below 0 Degrees C	823	951	554	634	650	770	569	520	464	468	661	668
Mean Annual Precipitation	767	1,339	780	652	969	1,201	431	503	575	404	598	511
Mean Annual Summer Precipitation	325	479	305	272	362	437	191	223	238	180	261	227
Precipitation As Snow	310	635	240	221	346	477	139	144	154	110	205	182
Annual Heat : Moisture Index	17.3	9.8	20.7	23.1	16.4	12.2	34.9	31.1	29.0	40.8	24.2	27.9

Differences from climate normals (1961-1990) for the best and worst case climate change scenarios are shown in the tables below.

Table 6. Hadley A1F1 differences from 1961-1990 normals for the 12 largest BGC variants (year 2080)

Variable	ESSF dc 3	ESSF wc 2	ICH dw 3	ICH mk 2	ICH mw 3	ICH wk 1	IDF dk 1	IDF dk 2	IDF mw 2	IDF xh 2	MS dm 3	MS xk 2
Mean Annual Temperature	5.5	5.3	5.4	5.6	5.3	5.2	5.7	5.7	5.6	5.7	5.7	5.7
Extreme Minimum Temperature	8	6	8	8	7	7	9	9	9	9	8	9
Mean Coldest Month Temperature	3	3	3	3	3	3	3	3	3	3	3	3
Mean Warmest Month Temperature	10	9	9	10	9	9	10	10	10	10	10	10
Frost Free Period	140%	143%	68%	79%	73%	81%	73%	71%	67%	67%	85%	80%
Number Of Frost Free Days	64%	60%	50%	56%	52%	53%	57%	54%	50%	52%	59%	59%
Degree-Days Above 18 Degrees C	343	252	473	464	440	393	474	495	481	481	458	434
Degree-Days Below 0 Degrees C	(571)	(587)	(422)	(481)	(472)	(521)	(479)	(438)	(387)	(401)	(511)	(535)
Mean Annual Precipitation	5%	8%	7%	5%	8%	8%	4%	3%	5%	4%	4%	3%
Mean Annual Summer Precipitation	-18%	-15%	-16%	-17%	-15%	-14%	-19%	-18%	-17%	-19%	-18%	-19%
Precipitation As Snow	-30%	-22%	-34%	-33%	-31%	-26%	-38%	-40%	-39%	-39%	-35%	-37%
Annual Heat : Moisture Index	42%	38%	30%	36%	31%	32%	37%	36%	31%	33%	39%	41%

Table 7. PCM-B1 differences from 1961-1990 normals for the 12 largest BGC variants (**year 2080**)

Variable	ESSF dc 3	ESSF wc 2	ICH dw 3	ICH mk 2	ICH mw 3	ICH wk 1	IDF dk 1	IDF dk 2	IDF mw 2	IDF xh 2	MS dm 3	MS xk 2
Mean Annual Temperature	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Extreme Minimum Temperature	5	5	6	5	5	5	5	5	6	5	5	5
Mean Coldest Month Temperature	3	3	3	3	3	3	3	3	3	3	3	3
Mean Warmest Month Temperature	2	2	2	2	2	2	2	2	2	2	2	2
Frost Free Period	58%	56%	24%	32%	28%	32%	27%	25%	21%	21%	35%	32%
Number Of Frost Free Days	17%	17%	14%	15%	14%	15%	14%	14%	13%	13%	15%	15%
Degree-Days Above 18 Degrees C	12	8	73	43	47	28	44	69	110	101	30	23
Degree-Days Below 0 Degrees C	(267)	(280)	(251)	(262)	(263)	(274)	(254)	(248)	(235)	(233)	(264)	(259)
Mean Annual Precipitation	6%	6%	6%	6%	6%	6%	6%	5%	6%	6%	5%	5%
Mean Annual Summer Precipitation	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%	-1%
Precipitation As Snow	-2%	0%	-9%	-6%	-6%	-4%	-8%	-10%	-12%	-11%	-6%	-5%
Annual Heat : Moisture Index	6%	7%	4%	5%	5%	6%	4%	4%	4%	3%	5%	5%

3. Future Ecosystem Climate Mapping

In an effort to make the climate change statistics more meaningful to practitioners, it was determined that mapping shifts in ecosystem climates would be useful. It is recognized that ecosystems, in all their complexity, will not suddenly shift as climates change – thus this remapping of ecosystems is only meant to reflect climate equivalents.

3.1. Ecosystem Units

While the original intention was to map shifts in BGC *variant* climates associated with future climate predictions, a choice was made to map at the BGC Subzone level for the following reasons:

- The tree species provenances are very similar within a BGC Subzone regardless of the Variant. Recent reforestation trials in the Kamloops TSA are showing that species known only to one Variant can thrive in the adjacent Variant having similar climatic conditions. For example, Western Larch is native to the ICHmw2 around Arrow Lakes, but can be transplanted to the ICHmw3 around Clearwater area where it was an uncommon occurrence. The climatic conditions are similar enough for the species to do very well. It appears that Larch's absence from the northern BGC Variant has more to do with the lack of seed source, than with climatic constraints. Experiments in "Assisted Migration" of tree species are becoming more common and more relevant given the climate change scenarios.
- The shifts in the BGC Subzone Climates are quite significant over the next 50 to 70 years, particularly with the Hadley worst-case scenario. It is unlikely that the same set of ecosystem units will develop within these shifting BGC Variants. It is safe to say that within a given climate envelope, a predictable BGC Subzone will occur but the ecosystem units themselves will likely vary from their current descriptions. Instead, the ecosystem units may develop as combinations of their former BGC

Subzone and the new Subzone. It is possible that they will resemble BGC Subzones seen elsewhere in the Province or in the USA.

- The potentially large number of permutations associated with 52 BGC Subzone variant climates shifting within a relatively small landbase would have made interpretations for management implications very complex and would add little additional clarity. The species and vulnerabilities associated with Subzones (i.e. ESSF dc) are very consistent with what those associated with their variants (i.e. ESSF dc2 and dc3).
- The differences in the climatic variables between BGC Variants of the same BGC Subzone were too subtle to be picked up by the ClimateBC model. The ClimateBC data is too coarse to identify the site-level factors such as cold-air drainages, dry rain-shadows and windward/leeward influences. We reduced the 52 BGC Variants down to 32 BGC Subzones in order to create a higher level of confidence in the results.
- Considerable overlap already occurs in the climate variable ranges between the BGC Subzones, which would have been exacerbated by working at the BGC Variant level. Typically, the outer limits of the ranges for each climate variable offered a distinction for each BGC Subzone, while the majority of the inner ranges were often shared with several other Subzones. We focussed on finding the breaks between the BGC Subzones with accuracy, rather than on attempting to distinguish the BGC Variants.
- Note however, that the lumping of the climate data to the BGC Subzone excluded the Woodland and Parkland Variants of the ESSF's. For example, the ESSFwc includes the wc2 and wc3; while the ESSFwcp was separated out and includes the Woodland and Parkland areas of high elevation. The Woodland/Parkland climate variable ranges were more extreme at the higher elevations, leading to differences in tree species provenances and management interpretations.

An area summary of the currently mapped (2008) BGC Subzones, excluding woodland and parkland Subzones, is provided in Figure 4.

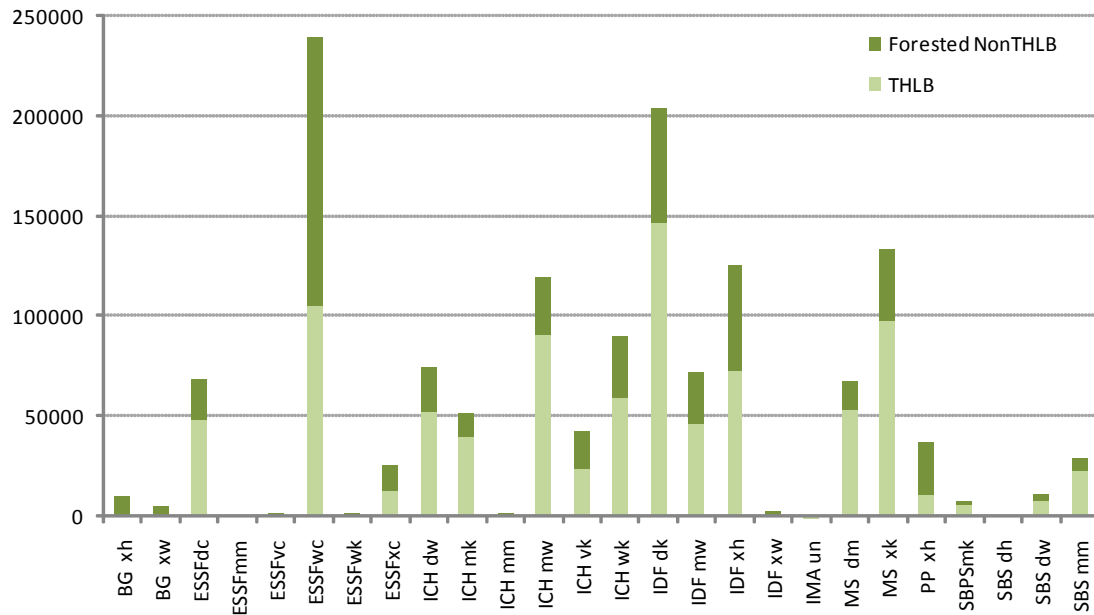


Figure 4. BGC Subzone areas in the Kamloops TSA by land base classification

3.2. Subzone Climate Mapping Approach

3.2.1. Overview

The approach used to map subzone climates evolved during this project. As a way to understand how the climates are changing and therefore a first step in the process of understanding vulnerabilities and designing adaptive strategies, the approach chosen combines local ecological interpretation with statistical analysis and computer modeling. An initial iteration of modeling and interpretations completed in March, 2008, prompted discussion and questions regarding the best use of BGC terminology to accurately express the range of climatic changes that were apparent in the modeling.

This second iteration of modeling in April, 2008 was conducted to address those questions.

3.2.2. Creating Initial Databases

The climate data was initially correlated to the existing BGC version 6.0 mapping recently updated by Dennis Lloyd, Ministry of Forests – Kamloops – Research Ecologist². The purpose of correlating the climate data to the current BGC mapping was to establish the range of each climate variables present in each BGC Subzone. Once calibrated, the climate data was used to show shifting BGC Subzone Climates (envelopes) in the Kamloops TSA.

Five databases comprised of the ~2.7 million grid points across the Kamloops TSA were created for this project – Current (2008), PCM_2050, PCM_2080, HAD_2050, and HAD_2080. Each of these databases contained the climate values for the annual and seasonal climate variables available from ClimateBC. The Current database was created by

² The BGC 7.0 mapping was released by MoFR in April, 2008 after this project was initiated.

overlaying the ClimateBC datapoints with the BGC 6.0 map, and further defined by identifying a 150-metre buffer around each BGC boundary to represent the transition areas versus the core areas within the BGC Subzones. Within the Current database, each climate variable was summarized within the core areas within the BGC Subzones (not Variants), then calculated as the average for the subzone, then the minimum and maximum values for each climate variable. We chose to use only those climate values within the core areas of the BGC Subzones because they were deemed to better represent the Subzone and avoided the 'noise' in the transition zones (150 m of the current BGC Subzone boundaries).

From this, a series of ACCESS queries were created to capture the natural breaks for each climate variable that could be used to make distinctions between the BGC Subzones – where one BGC Subzone begins its range, while another ends its range. The climate ranges used in this project have been calibrated specifically to the Kamloops TSA using the climate data for this area only. Climate ranges for Subzones elsewhere in the Province or from the US were not used. As such, the warmest Subzone available for this project was the BGxh.

Following this step, knowledge tables were created utilizing all the climatic variable ranges previously established. One point score was assigned to each BGC Subzone that possessed that climate range. The annual and seasonal climate variables were preferentially used in the knowledge tables since they reduce the variability experienced in the monthly climate ranges. Some of the annual climate variables were not used in the knowledge tables since they are derivations of other climate measurements, such as TD (total days), FFP (frost free period), the DD5_100, and the AHM (annual heat moisture index) – as well, these variables did not provide sufficient separation between the BGC Subzones.

The annual climate variables were used as the foundation of the knowledge tables in order to narrow down which Subzones were likely for that climate scenario. The seasonal climate variables were then used to separate out the specific BGC Subzone that most closely matched the climate values of that site. Rather than using the full range of the seasonal climate variables, such as TAV_sp (average spring temperature), we used only the portion of the climate range that was useful to distinguish between BGC Subzones.

3.2.3. Calibrating the Current BGC Subzone Climate Locations

After the knowledge tables were developed using the climate variables ranges as described above, they were calibrated using a random sample dataset to compare the predicted labels to the true labels of the Current BGC 6.0 map. A test dataset of 951 random points taken from the Current BGC 6.0 map comprised roughly of 15 points selected from each of the core and transition areas within each BGC Subzone. ScoreOne (an interface ACCESS program) was then used to list the true label, the predicted label and all climate values assigned to each point. The Ecologist then edited the knowledge tables to correct errors or to further separate tied Subzone labels.

Due to the significant overlap of climatic ranges between the BGC Subzones, it was typical for several BGC Subzones to have the same climatic values and to receive equal scores during the processing. As a final step in the knowledge tables, the Ecologist utilized the Current Subzone mapping as a filter to help predict the correct Subzone. If the correct BGC label was among the ties, an extra point separated it out as the predicted label. If the correct BGC label was not among the ties, it would not come out as the predicted label. Ties that remain after applying the last query were considered incorrect during the accuracy

assessment. Utilizing the BGC 6.0 map as a query within the knowledge tables allowed for the incorporation of ground-level ecological knowledge recorded by the Regional Ecologist for the Kamloops TSA, rather than relying solely on the ClimateBC data model. It also allowed for the incorporation of ecological knowledge by the project Ecologist wherein unlikely BGC Subzones could be removed from the ties, leaving the likely Subzones as the predicted labels.

The addition of the ecological interpretation is not unlike PEM or TEM ecosystem mapping wherein the Ecologist must interpret the landscape and vegetation information into ecosystem units relevant for the area. The BGC subzone maps are small-scale ecosystem maps that display the relationships of macro ecological patterns to one another. Any method used to create the climate change maps is “biased” whether the computer is used to make all of the decisions, or an Ecologist is used to insert ecological interpretation to support the decisions.

At the end of the calibration process, the accuracy of the knowledge tables in predicting the Current BGC 6.0 Subzone labels was 96.4%, using our methodology. The majority of the errors occurred within the transition areas at the boundaries of the BGC 6.0 Subzones. This high accuracy provided the confidence in the knowledge tables for predicting the Subzone Climates under the changing climates as modelled with the Hadley and PCM scenarios.

3.2.4. Predicting Future Subzone Climates Locations

The finalized knowledge tables were then processed against the Hadley and PCM climate change scenarios for the Kamloops TSA. Each 1 ha grid was assigned climate variables predicted by the PCM and Hadley models for 2050 and 2080. Then the same random dataset of 951 points was used to evaluate the predicted outcomes to make further adjustments if needed.

Based on the premise that there is a logical continuum of Subzones following moisture and temperature gradients, every BGC variant was assessed for its likely transition to another BGC Subzone(s) by reviewing the adjacencies that occur in the current mapping and the ecosystem unit descriptions listed on the MoF Site Series List (2006). For example, as the MS xk3 gets warmer and drier, it would be expected to transition into IDFdk, then IDFxh, then PPxh, and then BG xh; and unlikely to transition to the wetter and warmer ICH Subzones (see the Subzone Climate Change Trends below).

Since the shifts in the predicted Subzones were generally larger than expected, particularly with the Hadley models, the Ecologist guided the selection of the final BGC Subzone label by filtering out the unlikely Subzone labels for the location. In all cases of the knowledge tables, the climate data drove the selection of the predicted Subzone label, while the Ecologist guided only the separation of the tied Subzones in order to predict a unique label.

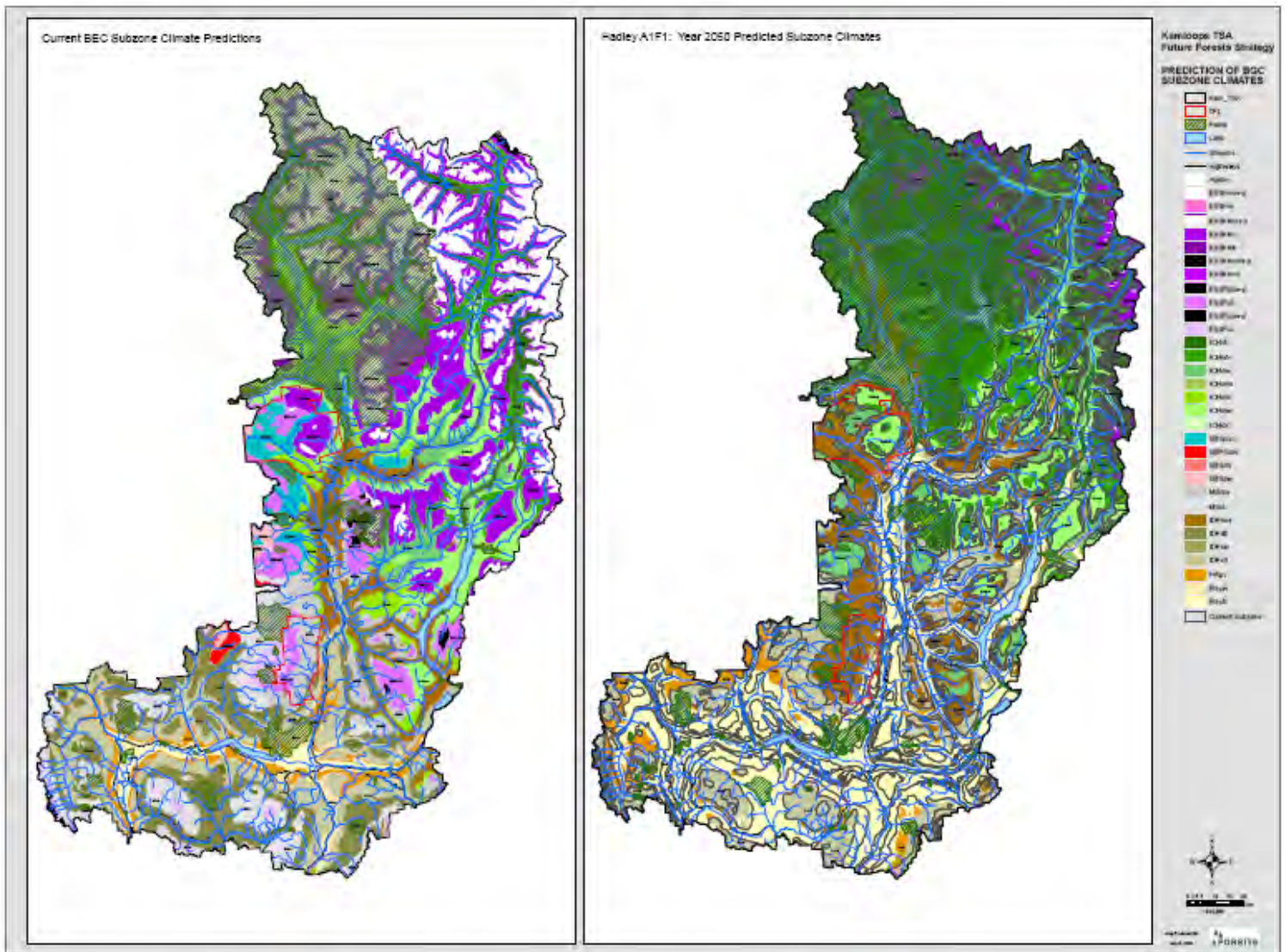
All five databases for the Kamloops TSA were processed using the knowledge tables – PCM 2050, HAD 2050, PCM 2080, and HAD 2080. Once processing was complete, the datasets were returned to Forsite for mapping and analysis purposes.

3.3. Subzone Climate Mapping Results

The results of the calibration process against the Current climate dataset were very high, reaching 96.4% accuracy when compared to the BGC 6.0 BGC mapping product (see Table 8). The scores for the future climate change scenarios cannot be assessed for accuracy as they are predictions of the future - although it can be assumed that the accuracy would not be as high as the calibration process because of the modelling and predictive processes.

Table 8. Subzone prediction accuracy relative to currently mapped Subzones

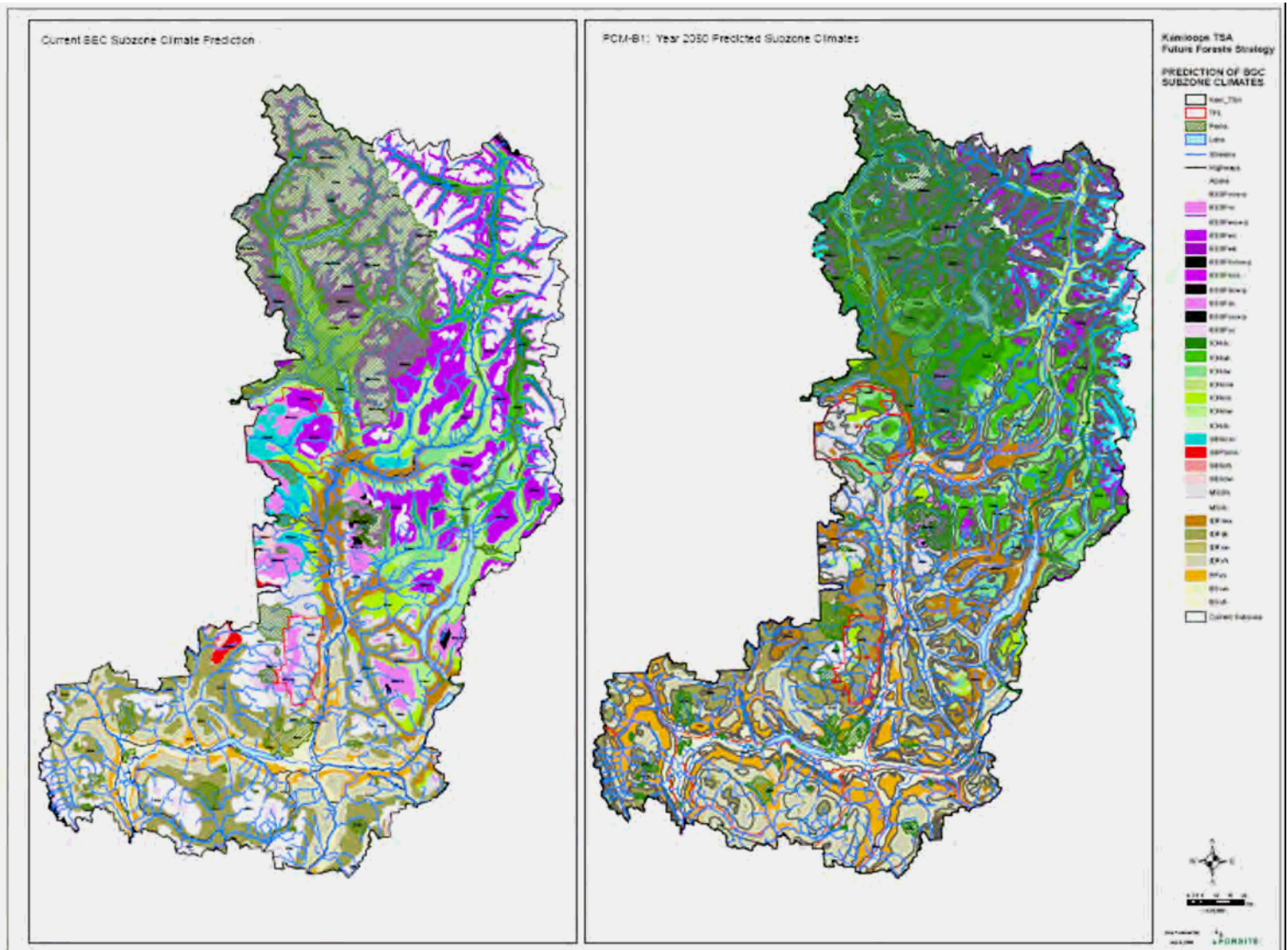
Current Mapped Subzone	Current TSA Area	# of Random Samples	Predicted % Correct
BGxh	63,196	30	100%
BGxw	24,798	30	100%
ESSFdc	90,521	30	97%
ESSFdcw-p	12,172	30	100%
ESSFmm	1,071	29	93%
ESSFmmw-p	1,752	30	97%
ESSFvc	2,158	30	93%
ESSFvcw-p	4,873	30	100%
ESSFwc	416,608	30	80%
ESSFwcw-p	291,867	30	93%
ESSFwk	19,274	30	100%
ESSFxc	28,677	30	100%
ESSFxcw-p	2,378	28	100%
ICHdk	424	29	100%
ICHdw	138,825	30	100%
ICHmk	71,639	30	100%
ICHmm	1,219	29	90%
ICHmw	207,392	30	100%
ICHvk	79,455	30	87%
ICHwk	167,751	30	90%
IDFdk	270,107	30	100%
IDFmw	134,912	30	100%
IDFhx	229,387	30	93%
IDFwx	2,438	30	97%
IMAun	106,115	30	100%
MSdm	96,004	30	100%
MSxk	149,309	30	97%
PPxh	76,017	30	100%
SBPSmk	7,746	30	97%
SBSdh	434	27	89%
SBSdw	13,841	30	93%
SBSmm	55,753	30	100%
TOTALS	2,768,115	951	96.4%

Figure 5. Current Subzone Climate Predictions vs Hadley 2050 Climate Prediction (Worst Case Scenario)

This worst case (most change) scenario shows that, by 2050, large areas of the southern portion of the TSA (all PP and majority of IDF) shift to resemble the BGxh Subzone Climate. The areas that were MSxk shift to have IDFxh climates with some PPxh in between.

In the northern portions of the TSA, the dryer ICH Subzones (i.e. ICH dw) have shifted to IDF climates and wetter ICH Subzones have become dryer. The lower elevations of the North Thompson Valley are now dominated by ICH mw climates (instead of ICHwk/vk), and the higher elevations now have ICH wk climates instead of ESSFwc. The only remaining ESSF at this time can be found in locations currently considered alpine.

Figure 6. Current Subzone Climate Prediction vs PCM 2050 Climate Prediction (Best Case Scenario)



This best case (least change) scenario shows a less dramatic change in the TSA's ecosystems but still quite a significant change. A large reduction in ESSF/Alpine climates is noticeable (having transitioned primarily into ICH climates).

The southern portion of the TSA is predicted to have more Bunch Grass and Ponderosa Pine climates in the valley bottoms, while the IDFdk is now mostly mapped as IDFxh (IDFdk) climates at higher elevations.

3.3.1. Subzone Climate Change Trends

Under the Current (2008) scenario, each BGC subzone shows a range of values for each climate variable, due to elevation changes and the progression of temperature and precipitation across the TSA. In one part of the Subzone, the climate may be warmer and drier than in another part of the Subzone. The range of climate values within the Subzone are said to characterize that Subzone, and are reflected in the knowledge tables. As the future climate change models (Hadley and PCM) are applied and calculated by ClimateBC across the TSA, the knowledge tables evaluate the climate characteristics of each point in the database in order to determine which BGC Subzone Climate matches these conditions. Thus, as the future climate variables changed relatively evenly across the TSA, the former Subzone areas often showed shifts towards two or more new Subzone Climates. For example, a point was currently mapped as MSxk but was on the warmer/drier end of the range, was likely to show a greater shift towards a new subzone climate, than a point that was on the cooler/moister side fo the MSxk range.

Lists of the Subzone Climates that were predicted within the former BGC boundaries are shown in Table 9 and Table 10 for the PCM and Hadley models respectively. The predominant trends are used to display the transitions – the ICHvk trend, the MSdm and MSxk trends. The most prominent Subzone Climate that occurs under the 2050 or 2080 model is shown in bold.

The same climate change trends are also shown in the diagram below (Figure 7) for the PCM and Hadley models. The three main climate change trends are illustrated – the ICHvk/wk, the MSdm and MSxk trends. In these diagrams, the former ESSF Subzone Climates are illustrated where they join in on the trend progression. It is estimated that they will continue to transition along this climate trend as the climate continues to change. Due to the variation of climate values within the former BGC Subzones, the warmer locations may skip over some of the Subzone Climate stages, while the cooler locations may be delayed in the cooler Subzone Climates a little longer. In both the tables and the diagrams, only the higher elevation Subzones are shown – ESSF's, SBS's, and MS's. It is assumed that the other Subzones at lower elevations (i.e. ICHmk) follow in sequence along the trends.

Table 9. Climate Change Trends for the PCM Models

PCM 2050 & 2080 Climate Models – Predicted Subzones within the current BGC area									
Trend	Current BGC	Climate Change Transitions							
ICHvk Trend	ESSFvc 2050 2080	ICHvk 2.7%	ICHwk 79.1% 29%	ICHmw 1.8% 16%	ICHdw 13.6% 51%	IDFmw	IDFxh	PPxh	BGxh
	ESSFvc 2050 2080	ICHvk 86.4% 89%	ICHwk 1% 6%	ICHmw	ICHdw	IDFmw	IDFxh	PPxh	BGxh
	ESSFmm 2050 2080		ICHwk 99.6%	ICHmw	ICHdw 100%	IDFmw	IDFxh	PPxh	BGxh
MSdm Trend	ESSFdc 2050 2080		MSdm 49.2%	ICHmk 35.7%	ICHdw 3.5% 84%	IDFmw 10.8% 13%	IDFxh	PPxh	BGxh
	SBSmm 2050 2080		MSdm 80.2%	ICHmk	ICHdw	IDFmw 19.7% 99%	IDFxh	PPxh	BGxh
	ESSFwk 2050 2080			ICHmk 51.7% 46%	ICHdw 47.8% 53%	IDFmw	IDFxh	PPxh	BGxh
MSxk Trend	ESSFxc 2050 2080		MSxk 57.0%	ICHdw 64%	IDFmw 6.5%	IDFdk 35.7% 20%	IDFxh 15%	PPxh	BGxh
	MSdm 2050 2080				IDFmw 38.1% 43%	IDFdk 55.2%	IDFxh 51%	PPxh	BGxh
	MSxk 2050 2080				IDFmw 15%	IDFdk 51.5% 6%	IDFxh 46.1% 79%	PPxh	BGxh
BGC Subzone Climates that will no longer exist:									
	IMAun 2050 2080	IMAunp 80.7% 48%	ESSFvc 18.9% 52%	ICHvk	ICHwk	ICHmw	ICHdw	IDFmw	IDFxh
	SBSdh 2050 2080		ICHwk 96.7% 76%	ICHmw	ICHdw 23%	IDFmw	IDFxh	PPxh	BGxh
	SBSdw 2050/2080					IDFmw 99.8%	IDFxh	PPxh	BGxh
	SBPSmk 2050/2080					IDFmw 99.8%	IDFxh	PPxh	BGxh
	ICHmm 2050/2080			ICHmw 95%	ICHdw	IDFmw	IDFxh	PPxh	BGxh
	IDFxw 2050 2080						PPxh 88.1% 82%	BGxw 11.5%	BGxh 18%

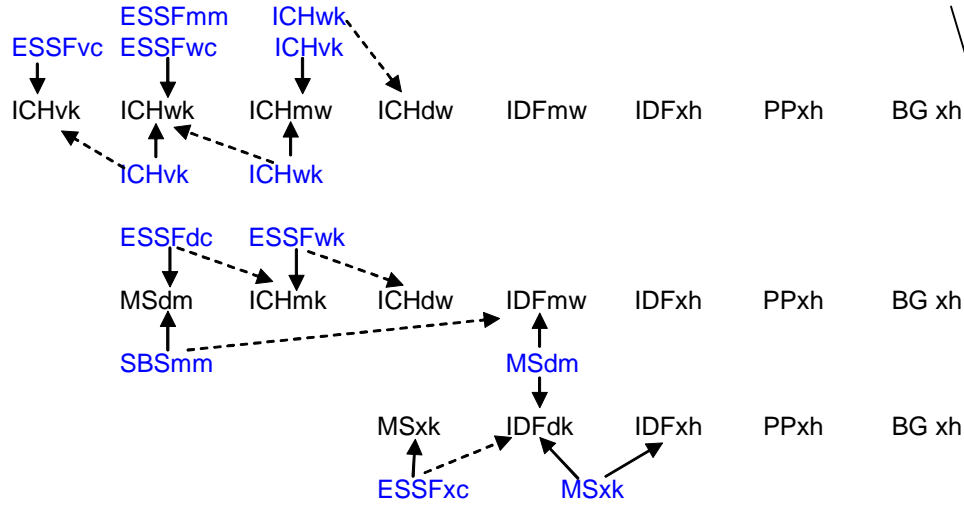
Table 10. Climate Change Trends for the Hadley Models

Hadley 2050 & 2080 Climate Models – Predicted subzones within the current BGC area									
Trend	Current BGC	Climate Change Transitions							
ICHvk Trend	ESSFwc 2050 2080	ICHvk	ICHwk 55.0%	ICHmw 37.0%	ICHdw 5.9% 74%	IDFmw 19%	IDFxh	PPxh	BGxh
	ESSFvc 2050 2080	ICHvk 67.3%	ICHwk 18.7%	ICHmw 13.8% 100%	ICHdw	IDFmw	IDFxh	PPxh	BGxh
	ESSFmm 2050 2080		ICHwk	ICHmw 99.6% 90%	ICHdw	IDFmw 10%	IDFxh	PPxh	BGxh
MSdm Trend	ESSFdc 2050 2080		MSdm	ICHmk	ICHdw 74.5%	IDFmw 25.2% 44%	IDFxh 53%	PPxh	BGxh
	SBSmm 2050 2080		MSdm	ICHmk	ICHdw	IDFmw 98.1% 16%	IDFxh 1.8% 79%	PPxh	BGxh 5%
	ESSFwk 2050 2080		ICHwk 15.1%	ICHmk 19.0%	ICHdw 65.8% 29%	IDFmw 71%	IDFxh	PPxh	BGxh
MSxk Trend	ESSFxc 2050 2080		MSxk	ICHdw	IDFmw 54.1%	IDFdk 23.2%	IDFxh 22.6% 74%	PPxh	BGxh 25%
	MSdm 2050 2080				IDFmw 79.3%	IDFdk	IDFxh 15.6% 18%	PPxh	BGxh 79%
	MSxk 2050 2080				IDFmw	IDFdk 2.6%	IDFxh 93.7% 17%	PPxh	BGxh 3.5% 81%
BGC Subzone Climates that will no longer exist:									
	IMAun 2050 2080	IMAunp 1.8%	ESSFwc 94.5% 2%	ICHvk 9%	ICHwk 2.8% 42%	ICHmw 43%	ICHdw	IDFmw	IDFxh
	SBSdh 2050 2080		ICHwk	ICHmw	ICHdw 100%	IDFmw 71%	IDFxh 8%	PPxh	BGxh 21%
	SBSdw 2050 2080					IDFmw 47.3%	IDFxh 52.2% 76%	PPxh	BGxh 24%
	SBPSmk 2050 2080					IDFmw 8.8%	IDFxh 92.1% 63%	PPxh	BGxh 37%
	ICHmm 2050 2080			ICHmw 96%	ICHdw 4%	IDFmw 68%	IDFxh	PPxh	BGxh 31%
	IDFwx 2050/2080						PPxh	BGxw	BGxh 100%
	BGxw 2050/2080								BGxh 100%

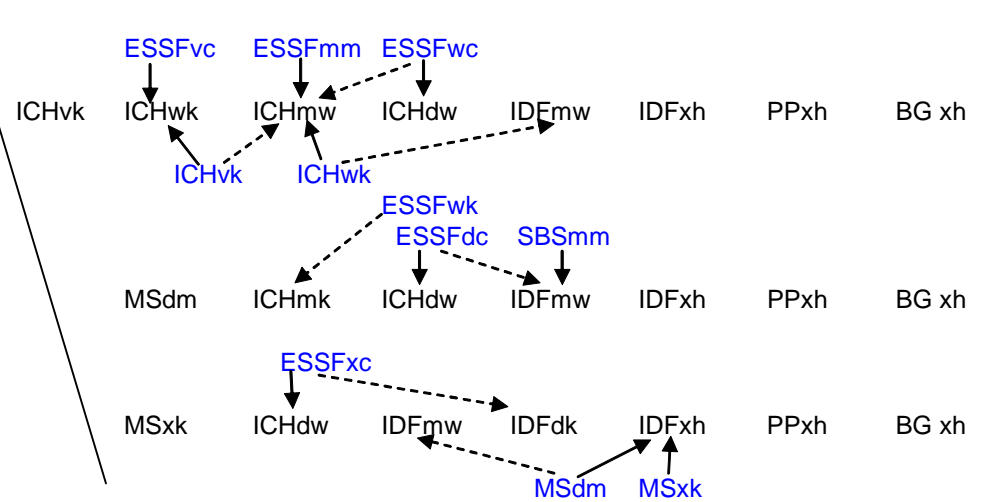
Figure 7. Trends of the Predominant Subzone Climate Shifts

(Current BGC Subzones shown in blue)

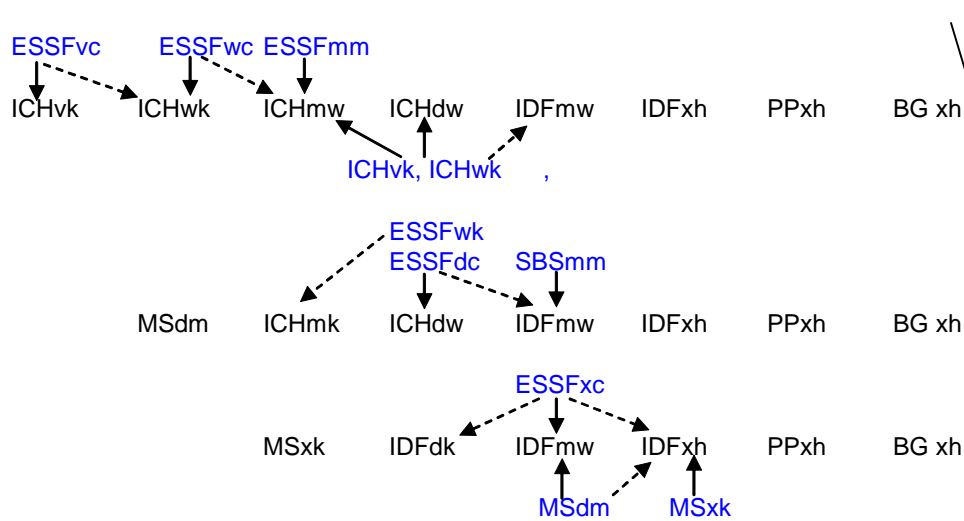
PCM 2050



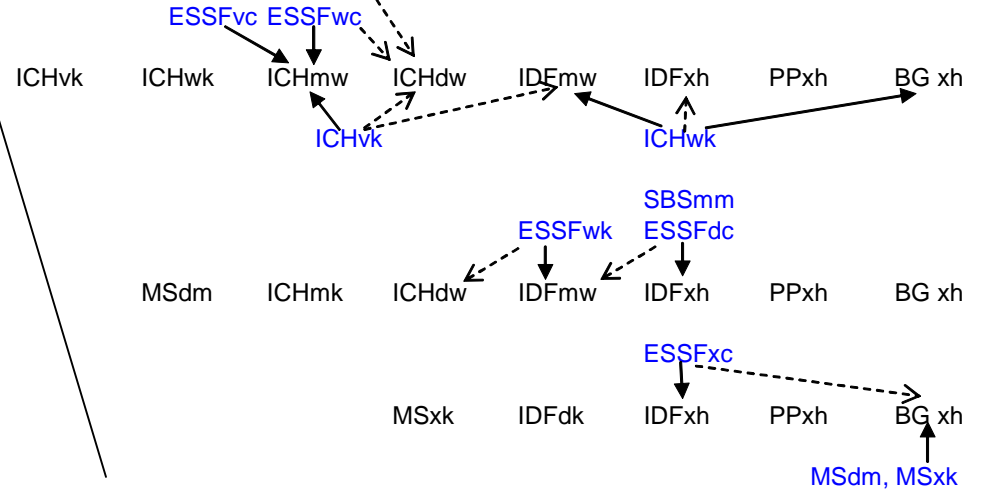
PCM 2080



HAD 2050



HAD 2080



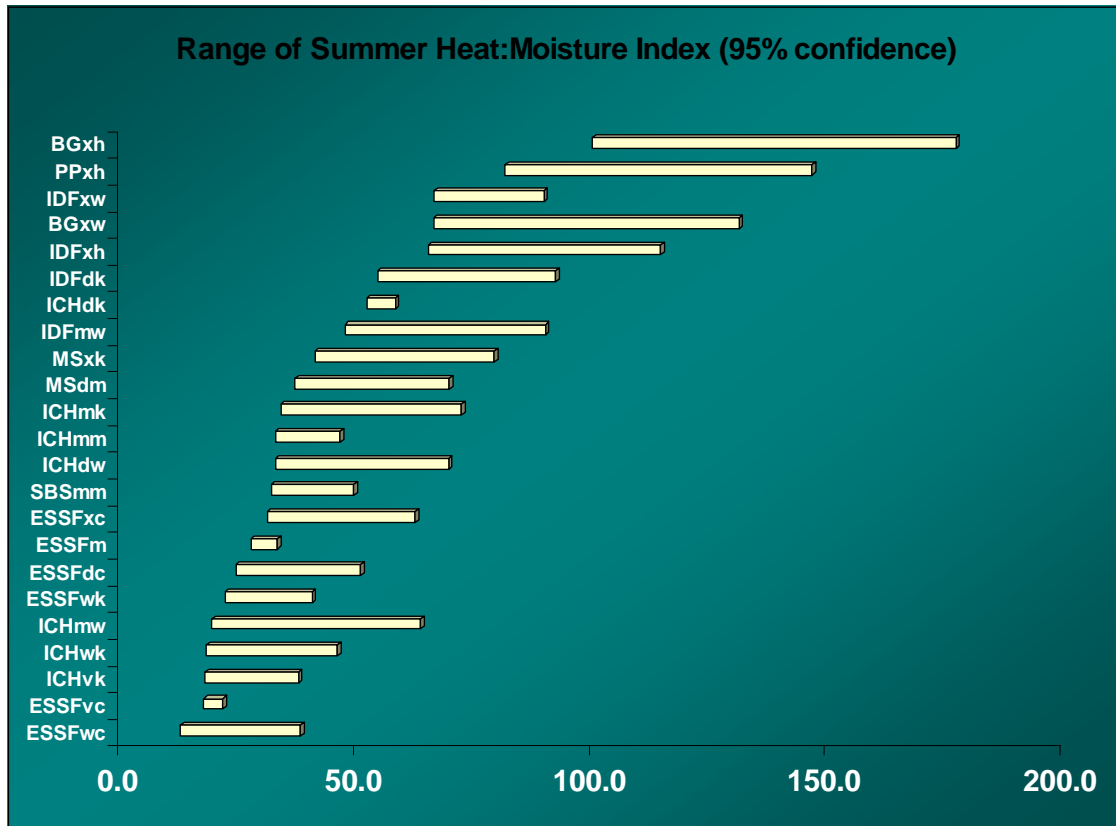
3.4. Precipitation Modifiers using the Summer Heat Moisture Index

Following the review of the predicted maps of the future Subzone Climates, it was noticed that the precipitation values sometimes exceeded the ranges for the current BGC 6.0 Subzones. In general, the precipitation as snow decreased and the summer rains decreased, yet the annual precipitation levels increased – meaning that the rains increased during the spring, fall and winter for many Subzone Climates. For those Subzone Climates at higher elevations or with high normal rainfall, these increases remained within the normal ranges for those Subzone Climates. For those Subzone Climates that are normally drier and warmer (relative within the Kamloops TSA), the increases in precipitation exceeded the normal range for these Subzone Climates. At first glance, it appeared that the precipitation increase may lead to Subzone Climates not experienced in B.C., but may instead be more like those seen in Idaho, USA.

A concern was raised that the maps may have been unintentionally biased by an emphasis on the temperature-related climate variables. Within the ClimateBC program there are 19 annual variables of which 5 are precipitation factors, and 15 seasonal variables of which 4 are related to precipitation. By virtue of the number of climate variables related to temperature (such as frost free days and degree days), the predicted Subzone Climates are tightly correlated to temperature and the derived criteria. Since no warmer Subzone than the BGxh was available, all high temperature-related values were assigned to this Subzone Climate. In many cases, the precipitation values exceeded the normal range for the BGxh climate envelope, but the high temperature-related values left only the BGxh subzone as the best fit. Upon reflection however, the higher rainfall coupled with the high temperatures may lead to increased forest growth on northern and moisture-receiving sites, as will be discussed in the vulnerability report.

This concern led to the decision to display the locations where the precipitation values exceed the normal ranges on the Subzone Climate maps. Rather than solely using the spring, summer or fall precipitation values, we chose to use the Summer Heat Moisture (SHM) values since these reflect the drought indexes during the growing season (May to September). The SHM is calculated as $MWMT/(MSP/1000)$ [or the mean temperature of the warmest month divided by the mean precipitation between May and September]; the higher the value, the stronger the drought index. The SHM variable takes into account the moisture evaporation rates and plant transpiration rates created by higher temperatures, which then mediate the contribution of spring and summer rains. The SHM variable balances the higher precipitation rates against the higher temperature rates and is therefore more useful in determining moisture conditions that are outside of the normal range for that climate envelope. The SHM ranges for each BGC subzone in the Kamloops TSA are shown in Figure 8.

Figure 8 - SHM values for each BGC Subzone



The normal SHM values were summarized within the Current BGC 6.0 for each of the BGC Subzones. The second standard deviations for the SHM values were calculated to determine the normal range of conditions for each BGC Subzone. When all SHM values for a Subzone are placed on a bell curve, the second standard deviation determines the upper and lower limits of the range that capture 95% of all the values (one standard deviation captures 68% of the values). The remaining 5% of the values are assumed to be outliers from the transition areas at the boundaries of the BGC Subzones. The SHM ranges showed natural breaks correlating to BGC Subzones which were used to assign a modifier symbol to the Climate Change Mapping (see Table 11). Novel BGC labels with asterisks are shown beside the modifiers to indicate the type of climate that may exist; there are no direct matches in the BEC classification system.

Table 11. Summer Heat Moisture (SHM) Ranges used to Modify the Subzone Climate Mapping

Climate subzone (predicted and current)	SHM variable – 2 nd Standard Deviation		Description of Range	
	SHM Range	Precipitation Modifiers	Precipitation Range of the Subzones in the KTSA	Temperature Range
BGxh	>= 100 >=65 and <100 >=47 and <65 < 47	(normal) + "m" (PPmx ³) "w" (PPwx*)	BGxw, PPxh, IDFxh range ICH range	Hot temp range
PPxh BGxw	>= 147 >=65 and <147 >=54 and <65 >=47 and <54 < 47	- (normal) + "m" (PPmh*) "w" (PPwh*)	BGxh range IDF x range IDF d, m range ICH range	Hot temp range
IDFxh IDFxw	>=110 >=65 and <110 >=54 and <65 >=47 and <54 < 47	- (normal) + "m" (IDFmh*) "w" (IDFwh*)	BGxh range IDF d range IDF m range ICH range	Hot temp range
IDFdk	>= 93 >=54 and <93 >=47 and <54 < 47	- (normal) + "w" (IDFwk*)	BGxh range IDF x, d range IDF m range ICH range	Kool temp range
IDFmw	>= 91 >=47 and <91 >=40 and <47 <40	- (normal) + "w" (IDFww*)	BGxh range IDF x, d, m range ICH trans – ½ way of 32-47 ICH range	Warm temp range
ICHdw ICHdk ICHmk ICHmm	>= 91 >=70 and <91 >=32 and <70 >=19 and <32 < 19	"x" (ICHxk*) - (normal) + "w" (ICHwm*)	BGxh range BG, PP, IDFx, d range ICH d, m range ICH range	Mild temp range
ICHmw	>= 91 >=64 and <91 >=19 and <64 >=17.5 and <19 < 17.5	"x" (ICHxk*) - (normal) + "w" (ICHww*)	BGxh range BG, PP, IDFx, d, m range ESSF range	Warm temp range
ICHwk ICHvk	>= 91 >=64 and <91 >=46.3 and <64 >=17.5 and <46.3 < 17.5	"x" (ICHxk*) - - (normal) +	BGxh range BG, PP, IDFx, d ranges IDF m range ESSF range	Kool temp range
MSxk	>= 90 >=80 and <90 >=41 and <80	"x" (IDFxk*) - (normal)	BGxh range BGxw, PPxh range	Kool temp range

³ Note that for this Subzone Climate, the modifier jumps to the PP zone since the increase in precipitation will sustain a forest cover. For other Subzone Climates, the predicted BGC zone remains the same while modifiers added to highlight differences from the normal precipitation ranges.

	>=32 and <41 <32	+ "w" (MSwk*)	ICH d, m range ICH m, w range	
MSdm	>= 90 >=70 and <90 >=37 and <70 >=32 and <37 <32	"x" (IDF _{xk} *) - (normal) + "w" (MSwk*)	BG _{xh} range BG _{xw} , PP _{xh} range ICH d, m range ICH m, w range	Kool temp range

These SHM ranges were applied through Access queries to the four climate change databases (PCM and Hadley models) and the precipitation modifiers were then displayed over top of the predicted Subzone Climate color scheme on the Climate Change mapping. The result was far fewer modifier symbols displayed on the maps than we anticipated. In fact, as shown in Table 12, most of the areas within the predicted Subzone Climate envelopes have normal SHM values (Hadley = 94%; PCM = 95%), making their predicted label appropriate. The majority of the modifiers tended to be the "-" (drier than normal) for the Hadley model and "+" (moister than normal) for the PCM model occurring along the transitions towards the next Subzone Climates.

Table 12. Hadley 2050 Summary of the SHM Precipitation Modifiers assigned to the Maps

Hadley 2050 SHM Modifier Summary				
Modifier	Total No. of Modifiers	Core Areas	Transition Areas	% of TSA
	2589971	2069448	520523	94%
-	94914	79871	15043	3.4%
+	58145	53155	4990	2.1%
IDF _{mh} *	81	81		0.00%
IDF _{wh} *	73	72	1	0.00%
PP _{mh} *	7120	6500	620	0.26%
PP _{mx} *	11200	11044	156	0.40%
PP _{wh} *	6413	5345	1068	0.23%
PP _{wx} *	1564	1503	61	0.06%
Total # of points in the Kamloops TSA			2769481	

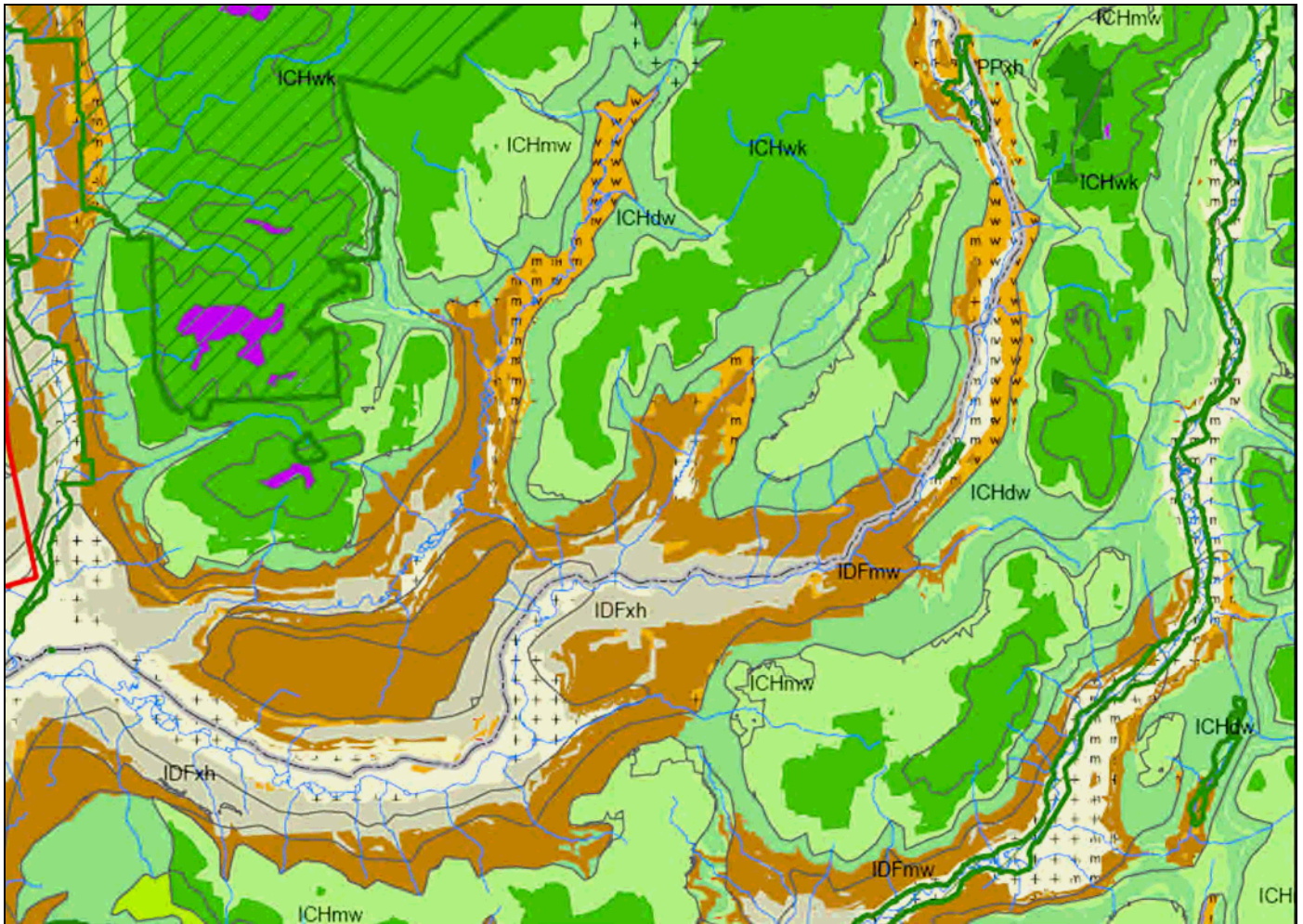
Table 13. PCM 2050 Summary of the SHM Precipitation Modifiers assigned to the Maps

PCM 2050 SHM Modifier Summary				
Modifier	Total No. of Modifiers	Core Areas	Transition Areas	% of TSA
	2633493	2112735	520758	95%
-	3080	2115	965	0.1%
+	130555	110196	20359	4.7%
IDFmh*	3	1	2	0.00%
IDFww*	1335	1090	245	0.05%
MSwk*	324	253	71	0.01%
PPmh*	27	3	24	0.00%
PPmx*	526	488	38	0.02%
PPwx*	138	138		0.00%
Total # of points in the Kamloops TSA			2769481	

The following images show the results of the Hadley – 2050 climate change model. The black polygon lines represent the Current BGC 6.0 linework, while the colors represent the predicted Subzone Climates – of note are the locations where two or more Subzone Climates transition within the former BGC Subzone area. The modifiers of “-”, “+”, “m” and “w” are shown over top of the Subzone Climate colors representing the SHM values that are outside of the normal climate envelope range. The first image (Figure 9) demonstrates the trend towards wet valleys while experiencing the high temperatures of the BG and PP Subzone Climates – a climate combination not currently seen in the Kamloops TSA and in fact may be more similar to climates in Idaho.

At our first glance of the databases, we expected this hot-but-wet scenario to be quite common in the future climate models. However, after running the SHM modifier queries, the maps showed a different trend. Figure 10 and Figure 11 show that most of the predicted Subzone Climates fit within the “normal” range for the precipitation, and some areas are in fact actually drier than normal.

Figure 9. Hadley 2050 Predicted Subzone Climates with Precipitation Modifiers – Moister-than-normal Valleys



Beige = BGxh	Tan = IDFxh	Medium Green = ICHdw	Dark Green = ICHwk	Purple = ESSFwc
Orange = PPxh	Brown = IDFmw	Light Green = ICHmw	Very Dark Green = ICHvk	

Figure 10. Hadley 2050 Predicted Subzone Climates with Precipitation Modifiers – Drier-than-normal Mountains

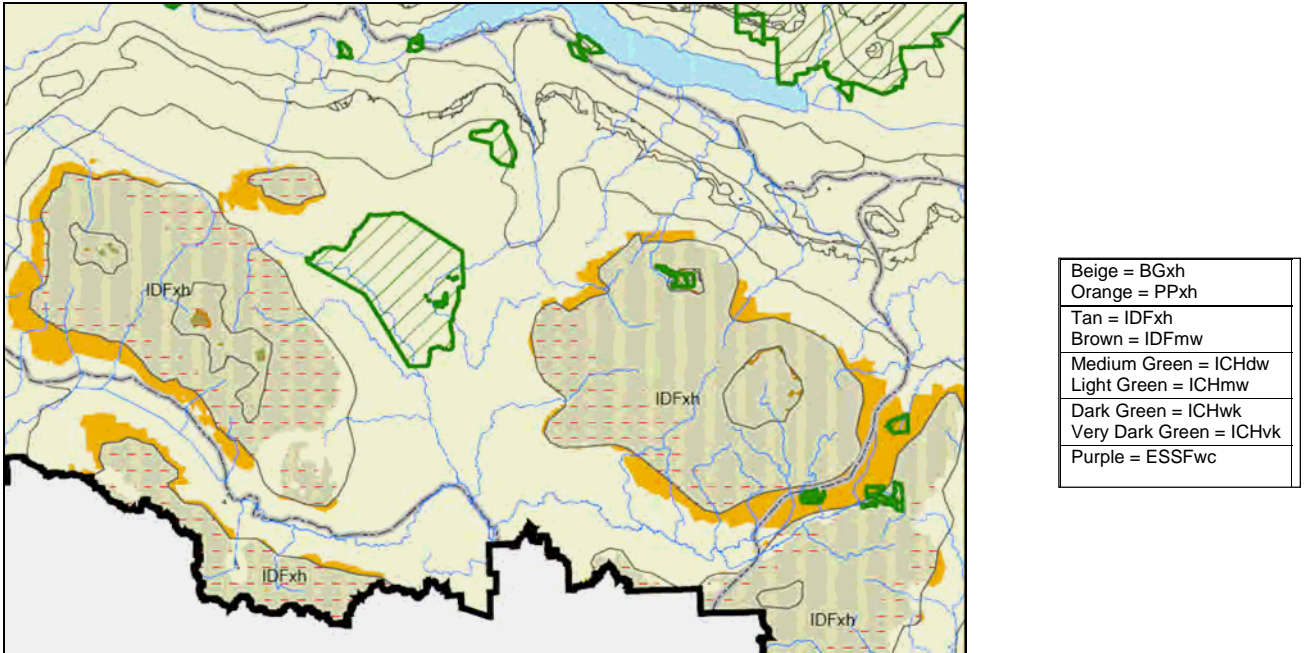
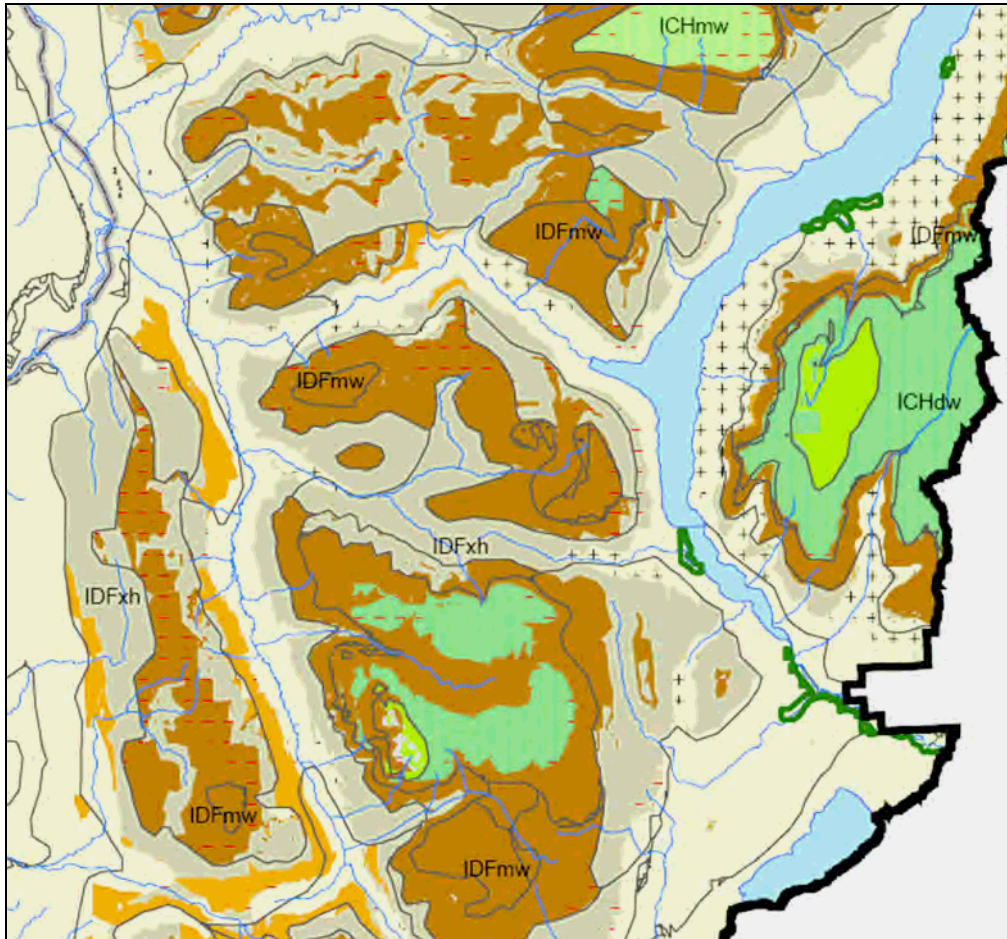


Figure 11. Hadley 2050 Predicted Subzone Climates with Precipitation Modifiers – Drier-than-normal Mountains and Moister-than-Normal Valleys



3.5. Subzone Climate Transitions

The following tables show the transitions to new subzone climates for the 12 major BGC subzones of the Kamloops TSA, for the PCM and Hadley 2050 climate models.

• ESSFdc	• MSdm	• ICHmw	• IDFdk
• ESSFwc	• MSxk	• ICHdw	• IDFxh
• SBSmm	• ICHwk	• IDFmw	• PPxh

Table 14. Subzone Climate Transitions from Current to PCM 2050 and Hadley 2050

Currently	Predicted Subzone Climates							
ESSFdc Relative position within the ESSFdc	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	MSdm	49%	Normal – 91% “+ “ – 8% “w” – 1%	Valley and upper boundary areas may have slightly moister conditions	ICHdw	74%	Normal – 95% “_ “ – 5%	Lower boundary areas may have slightly drier conditions
Mid Elevations	ICHmk	35%	Normal – 90% “+ “ – 10%	Upper boundary areas may have slightly moister conditions		IDFmw	26%	Normal – 99% “_ “ – 1%
Lower Elevations	IDFmw	12%	Normal – 89% “+ “ – 11%	Upper boundary areas may have slightly moister conditions				

Currently	Predicted Subzone Climates							
ESSFwc Relative position within the ESSFwc	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	ICHwk	79%	Normal – 100%		ICHwk	53%	Normal – 100%	
Mid Elevations					ICHmw	38%	Normal – 94% “_ “ – 6%	Lower boundary areas may have slightly drier conditions
Lower Elevations	ICHdw	15%	Normal – 79% “+ “ – 21%	Valley and upper boundary areas may have slightly moister conditions	ICHdw	6%	Normal – 99% “+ “ – 1%	Rarely, a few areas may have slightly moister conditions

Currently	Predicted Subzone Climates							
MSdm Relative position within the MSdm	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	IDFdk	58%	Normal – 89% “+ “ – 11%	Upper boundary areas may have slightly moister conditions	IDFmw	79%	Normal – 73% “_ “ – 27%	Hills and lower boundary areas may have slightly drier conditions
Mid Elevations	IDFmw	38%	Normal – 90% “+ “ – 7% “w” – 3%	Upper boundary areas may have slightly moister conditions	IDFxh	17%	Normal – 100%	
Lower Elevations	IDFxh	2%	Normal – 85% “+ “ – 15%	Valley and upper boundary areas may have slightly moister conditions	BGxh	4%	Normal – 96% “+ “ – 4%	Upper boundary areas may have slightly moister conditions

Currently	Predicted Subzone Climates							
MSxk Relative position within the MSxk	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	MSxk	2%	Normal – 100%		IDFdk	3%	Normal – 51% “_ “ – 49%	Hills and lower boundary areas may have slightly drier conditions
Mid Elevations	IDFdk	52%	Normal – 77% “+ “ – 23%	Valley and upper boundary areas may have slightly moister conditions	IDFxh	94%	Normal – 75% “_ “ – 25%	Hills and lower boundary areas may have slightly drier conditions
Lower Elevations	IDFxh	46%	Normal – 93% “+ “ – 7%	Upper boundary areas may have slightly moister conditions	BGxh	4%	Normal – 100%	

Currently	Predicted Subzone Climates							
SBSmm Relative position within the SBSmm	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	MSdm	80%	Normal – 98% “+ “ – 2%	Rarely, a few areas may have slightly moister conditions	IDFmw	98%	Normal – 100%	
Mid Elevations								
Lower Elevations	IDFmw	20%	Normal – 53% “+ “ – 46%	Most valleys and upper boundary areas may have slightly moister conditions	IDFxh	2%	Normal – 100%	

Currently	Predicted Subzone Climates							
ICHwk Relative position within the ICHwk	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	ICHwk	1%	Normal – 100%		ICHmw	26%	Normal – 91% “– “ – 9%	Lower boundary areas may have slightly drier conditions
Mid Elevations	ICHmw	99%	Normal – 100%		ICHdw	65%	Normal – 98% “+ “ – 1%	Rarely, a few areas may have slightly moister conditions
Lower Elevations					IDFmw	6%	Normal – 100%	
					BGxh	3%	“+ “ – 2% “m” – 81% “w” – 17%	All areas are slightly to much wetter

Currently	Predicted Subzone Climates							
ICHmw Relative position within the ICHmw	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	ICHdw	54%	Normal – 84% “+ “ – 16%	Valley and upper boundary areas may have slightly moister conditions	ICHdw	34%	Normal – 100%	
Mid Elevations	IDFmw	40%	Normal – 94% “+ “ – 6%	Upper boundary areas may have slightly moister conditions	IDFmw	32%	Normal – 100%	
Lower Elevations	IDFxh	4%	Normal – 92% “+ “ – 8%	Upper boundary areas may have slightly moister conditions	IDFxh	16%	Normal – 98% “– “ – 1% “+ “ – 1%	Rarely, a few areas may have slightly drier or moister conditions

Currently	Predicted Subzone Climates							
ICHdw Relative position within the ICHdw	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	ICHdw	12%	Normal – 91% “+ “ – 9%	Upper boundary areas may have slightly moister conditions	IDFmw	32%	Normal – 100%	
Mid Elevations	IDFmw	78%	Normal – 95% “+ “ – 5%	Upper boundary areas may have slightly moister conditions	IDFxh	41%	Normal – 99% “+ “ – 1% “w” – 0.1%	Rarely, a few areas may have slightly moister conditions
Lower Elevations	IDFxh	10%	Normal – 88% “+ “ – 12%	Valley and upper boundary areas may have slightly moister conditions	BGxh	17%	Normal – 5% “+ “ – 82% “m” – 11% “w” – 1%	Most areas have slightly to much wetter conditions

Currently	Predicted Subzone Climates							
IDFmw Relative position within the IDFmw	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	IDFmw	14%	Normal – 95% “+ “ – 5%	Upper boundary areas may have slightly moister conditions	IDFmw	3%	Normal – 98% “_ “ – 2%	Rarely, a few areas may have slightly drier conditions
					IDFxh	29%	Normal – 97% “_ “ – 3%	A few areas may have slightly drier conditions
Mid Elevations	IDFxh	81%	Normal – 95% “+ “ – 5%	Upper boundary areas may have slightly moister conditions	PPxh	6%	Normal – 98% “+ “ – 2%	Rarely, a few areas may have slightly moister conditions
Lower Elevations	PPxh	3%	Normal – 86% “+ “ – 13% “m” – 1%	Valley and upper boundary areas may have slightly moister conditions	BGxh	62%	Normal – 80% “+ “ – 20%	Valley and upper boundary areas may have slightly moister conditions
	BGxh	1%	Normal – 6% “+ “ – 94%	Almost all areas have slightly moister conditions				

Currently	Predicted Subzone Climates							
IDFdk Relative position within the IDFdk	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	IDFdk	8%	Normal – 98% “_ “ – 2%	A few areas may have slightly drier conditions	IDFxh	15%	Normal – 89% “_ “ – 11%	Lower boundary areas may have slightly drier conditions
Mid Elevations	IDFxh	83%	Normal – 97% “+ “ – 3%	A few areas may have slightly moister conditions	PPxh	30%	Normal – 100%	
Lower Elevations	PPxh	9%	Normal – 100%		BGxh	55%	Normal – 99% “+ “ – 1%	A few areas may have slightly moister conditions

Currently	Predicted Subzone Climates							
IDFxh Relative position within the IDFxh	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	IDFxh	6%	Normal – 100%		PPxh	4%	Normal – 78% “ – “ – 22%	Hills and lower boundary areas may have slightly drier conditions
Mid Elevations	PPxh	86%	Normal – 100%		BGxw	1%	Normal – 81% “ – “ – 19%	Hills and lower boundary areas may have slightly drier conditions
Lower Elevations	BGxh	8%	Normal – 75% “+ “ – 25%	Valley and upper boundary areas may have slightly moister conditions	BGxh	96%	Normal – 100%	

Currently	Predicted Subzone Climates							
PPxh Relative position within the PPxh	PCM 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope	HAD 2050	Proportion of former sub-zone	SHM modifier (% of predicted climate)	Added considerations for summer climate beyond the normal climate envelope
Upper Elevations	PPxh	3%	Normal – 100%					
Mid Elevations	BGxh	97%	Normal – 96% “+ “ – 4%	Upper boundary areas may have slightly moister conditions	BGxh	100%	Normal – 100%	
Lower Elevations								

4. Summary / Conclusions

Future climate predictions for the Kamloops TSA vary considerably between best and worst case scenarios obtained from UBC's ClimateBC program. It is clear that warming will occur (1.4 to 5.4 degrees by 2080) and precipitation levels will increase slightly overall (6 to 7% by 2080) but less will fall in the summer months (-1 to -16% by 2080) and less will fall as snow (-2 to -23% by 2080). The trend toward warmer, dryer summers is consistent between both scenarios, but the degree of warming and reduction in summer precipitation remains uncertain.

Trends across BGC subzones are similar and the absolute amount of change in temperature and precipitation varies little between variants. However, potential vulnerabilities and issues in specific landscapes, ecosystems, stand types and plant communities become much more apparent when these changes can be expressed using BGC terminology as subzone-climate envelopes. A combination of both local ecological interpretation along with computer modeling and statistical analysis was found to be best to create the most useful mapping for this purpose.

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Appendix A: Maps

1. Current BGC Subzone Climate vs Hadley A1F1 2050 Subzone Climate
2. Current BGC Subzone Climate vs PCM-B1 2050 Subzone Climate
3. Current BGC Subzone Climate vs Hadley A1F1 2080 Subzone Climate
4. Current BGC Subzone Climate vs PCM-B1 2080 Subzone Climate