

**Future Forest Ecosystems Scientific Council (FFESC)
Interdisciplinary Climate Change Adaptation Research
for Forest and Rangeland Ecosystems**

2009-10 Year End Progress Report

**Validating Impacts, Exploring Vulnerabilities, and
Developing Robust Adaptive Strategies under the
Kamloops Future Forest Strategy (File: 012_Nelson)**

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Table of Contents

Acknowledgements	3
Project Overview	3
Project Goals	4
Progress Summary.....	5
<i>Case Study Area and Delineation of Stand Units</i>	5
<i>Overview of the Forest Model Suite</i>	7
<i>Establishment of Modelling Goals, Questions and Indicators</i>	9
<i>Design of Management Scenarios to Explore Management Questions</i>	12
<i>Acquiring Climate Data</i>	13
<i>Designing Modeling Scenarios - Combining Climate Futures with Management Scenarios</i>	17
<i>Species Level Modelling with TACA</i>	19
<i>Stand Level Modelling with FORECAST Climate</i>	19
<i>Landscape Level Modelling with FPS</i>	20
<i>Community Outreach</i>	22
Next Steps.....	23
Appendices	25
A1. A Primer on Models and Modelling	25
A2. Baseline Climate Regimes for the Ecological Group.....	32
A3. Description of Stand Units.....	35
A4. Definitions and Terms	45
A5. Key Modelling Questions Proposed by Client Groups.....	55
A6. Modelling Indicators to Explore Modelling Questions	61
A7. Clearwater & Barriere Outreach Report	83
A8. Summary of Lessons and Challenges	87

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Project Overview

It is the intent of this project to inform practitioners and decision-makers facing increasingly complex questions with respect to forest management under climate change. It is part of a larger effort to understand what needs to be done in terms of forest operations and forest policy in the face of uncertainty. While it may not be immediately apparent, the information produced through this, and all FFESC projects, will inevitably increase our collective knowledge and ultimately understanding of not only the impacts of climate change but of our actions in this changing world. Enhanced understanding, however, can only be realized if the information produced is put to use in an adaptive management fashion such that learning leads to action and action leads to learning, perpetually. It is hoped that this project will facilitate such a process, even incrementally.

More proximately, this project seeks to understand the impacts of plausible climate change scenarios on the ecosystems, forest conditions and values under the current forest management regime in the Kamloops Timber Supply Area (TSA). As well, the influence of several potential adaptive strategies will be explored. This project is an extension of the Kamloops Future Forest Strategy (K1¹) and is known as K2.

K2 advances the expert opinion based K1 vulnerability analysis by *quantifying* the sensitivities and vulnerabilities through model-forecasting with a comprehensive linkage to the best available information and clearly defined assumptions where such information is lacking. K2 also expands the K1 assessment by linking to rural community climate change challenges, and evaluating potential solutions to high-priority strategic questions and challenges within the range of the anticipated effects of climate change.

Fundamental to K2 is a collaborative approach to model-based learning (with local clients, forest managers, experts, and community stakeholders) that accounts for uncertainties in the impact and outcome of climate change and builds on the relationships and shared understanding established in K1. This document records the progress of the K2 project since its commencement in October, 2009, highlighting important issues and how they were resolved.

¹ <http://www.for.gov.bc.ca/hcp/ffs/kamloopsFFS.htm>

Project Goals

Project goals were refined and clarified for clients as follows:

1. To improve on K1, to create a refined set of sensitivities, adaptive management options and related implications for local value goals linked to a vision of the future forest that can provide direction for future management planning in the TSA.

This goal will be pursued by exploring initial K1 sensitivities and management options:

- a. To examine their credibility, based on current science, emerging analytical tools, and local knowledge.*
 - b. To assess their utility for managers, by providing better context in time and space, and by considering impacts between overlapping and competing value goals.*
 - c. To ultimately, make them more robust so that we can better maintain options to service a range of values over time, considering the uncertainties linked to climate change.*
2. To provide resource managers, planners, policy-makers and others with a better understanding of the potential effectiveness of proposed management actions that will assist them in decision-making.

This understanding includes:

- a. Understanding the feasibility of different options- is it economic now? Will it be economic in the future?*
 - b. Understanding implementation issues - are there regulations, policies, or concerns that might affect our ability to start doing something new or different?*
 - c. Considering different outcomes-what is likely to happen if we don't do something now (follow a business as usual approach), versus trying to do something different?*
 - d. Evaluating robustness of proposed actions - by taking into account the uncertainties linked to climate change and understanding which ones might best maintain our options to service a range of values over time.*
3. To collaboratively explore climate change impacts and potential adaptive actions with the range of local clients – Agencies, licensees and management practitioners, First Nations, communities, and others.
 4. To explicitly identify assumptions and knowledge gaps that will require further research and/or monitoring over time.
 5. To translate the K2 process undertaken and the lessons learned for application in similar efforts elsewhere.

Progress Summary

Case Study Area and Delineation of Stand Units

The Kamloops TSA is situated in south-central British Columbia and represents approximately 2.7 million hectares. The case study area selected comprises 900,000 ha of the Kamloops TSA, mapped with six entire landscape units, and portions of four landscape units, representative of six key groups of 12 biogeoclimatic subzones in the Southern Interior Forest Region:

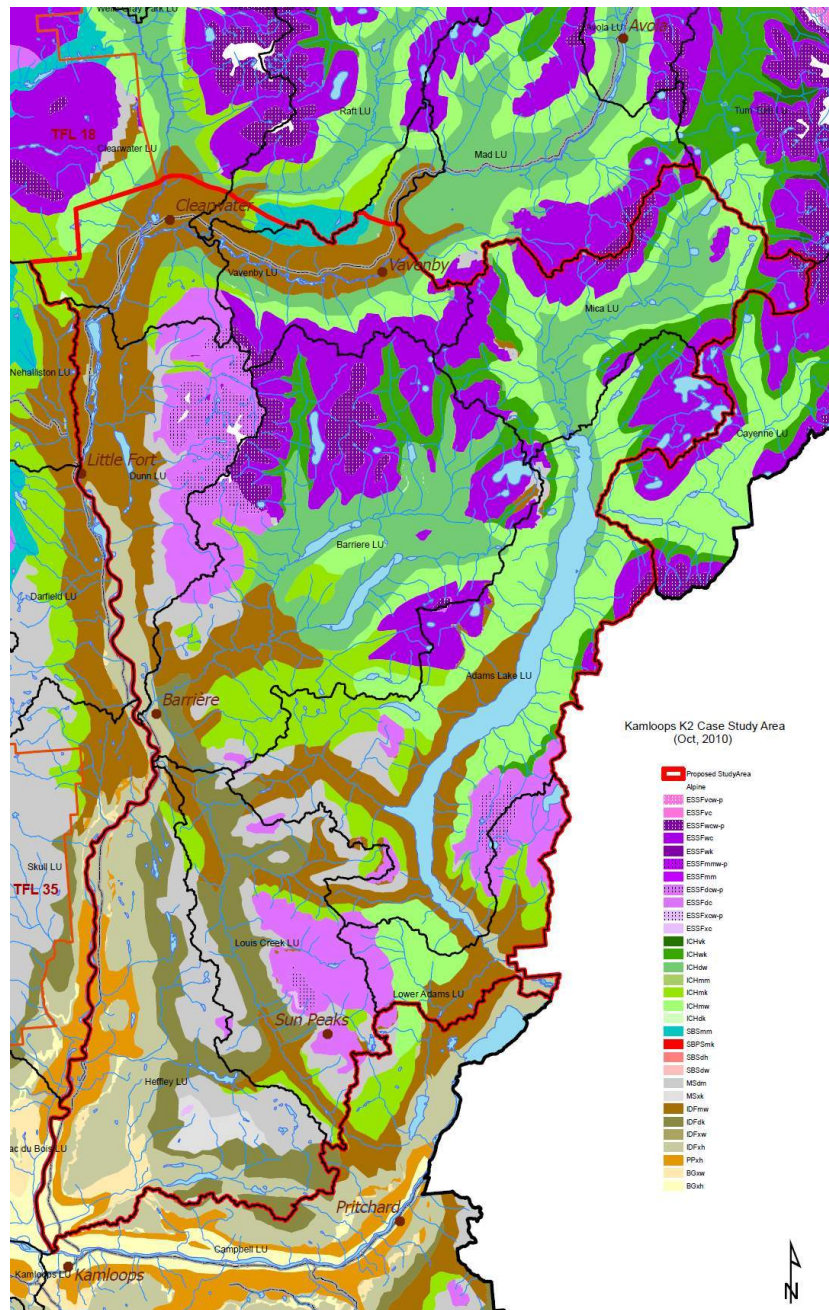


Figure 1. Case study area for the Kamloops TSA (red boundary), showing the biogeoclimatic subzones and landscape units.

Ecological Groups

1. Dry subzones dominated by Douglas fir and Ponderosa pine (IDF_{xh} and PP_{xh}) - 4% of forested area in the case study landscape.
2. Dry subzones dominated by Lodgepole pine (mostly IDF_{dk}, some MS_{xk}) - 6% of forested area.
3. Dry Transitional subzones (IDF_{mw}, ICH_{dw}) - 25 % of forested area.
4. Moist Transitional subzones (ICH_{mw}, ICH_{mk}, some ICH_{wc}) - 28% of forested area.
5. Dry Plateau (ESSF_{dc}, MS_{dm}, and SBS_{mm}) - 21% of forested area.
6. Wet Engelmann Spruce - Subalpine-fir (ESSF_{wc}) – 16% of forested area.

These ecological groups represent regions within the Kamloops TSA with similar climate regimes. It was necessary to provide a baseline climate regime for each of the ecological groups to facilitate the simulation of climate change described below. Historical climate data (~ 30 years of daily data) for each group were derived from local Environment Canada climate stations to facilitate the projection of climate change scenarios (see below). A summary of the historical climate data is provided in Appendix A2.

The case study landscape is divided into 21 stand types representing a number of key aggregations of tree species (approximating a range of site moisture regimes) to reflect and address key questions in each of the major ecological groups (Appendix A3). While representation of the entire Kamloops TSA was an important factor in selecting stand types, or units, to explore, this had to be balanced against increasing modelling complexity. The 21 stand units chosen will provide a good depiction as well as enough resolution to explore various management questions with the model suite.

The stand units were ground-truthed to ensure a good representation and linkage to potential modelling questions. These units range in size with nine hectares as the smallest size for spatial resolution at the landscape scale.

After exploring the idea of using two case study areas, one at each extreme of the Kamloops TSA, we decided on using one representative study area near the middle of the TSA. A number of criteria entered this decision, including:

- the comparative advantages and disadvantages of contiguous or discontinuous stand units,
- an appropriate size to accommodate disturbances and biodiversity at the landscape level,
- modelling capability and ease, and
- the ability to extrapolate results to other areas in the TSA and Southern Interior Forest Region.

Overview of the Forest Model Suite

K2 utilizes four linked forest models to quantify ecological sensitivities and implications from proposed management actions under climate change by exploring a) forest regeneration and growth dynamics and b) alternative management strategies as they unfold across the landscape over time, considering natural disturbance in the face of climate change. The modelling suite includes:²

1. TACA – The Tree & Climate Assessment Tool for modeling tree species response to climate change during regeneration.
2. FORWADY - The Forest Water Dynamics Model for simulating forest stand hydrology and its impacts on stand development and regeneration.
3. FORECAST-Climate Model – An updated version of FORECAST to model forest stand growth & ecosystem dynamics with a changing climate (by integrating FORWADY within it).
4. FPS (formerly known as Atlas) - a spatially explicit forest estate simulation model, which will allow for incorporation of natural and operational landscape level processes and considerations over time.³

TACA linked with FORWADY addresses the successful establishment and regeneration of various tree species within local ecosystems under a changing climate, while FORECAST addresses ecological dynamics, stand growth and mortality over time. FPS is concerned with landscape-level structures, ecological dynamics and management activities over time. FORWADY helps TACA determine if regeneration is successful, and subsequently imposes evaporative and transpirational water budgets upon stands within FORECAST. In TACA, environmental conditions are imposed upon a stand of tree species resulting in a cohort of seedlings that “survive” and become established, based on species specific thresholds incorporated into the model. The TACA model provides output regarding establishment probability for various tree species that is fed into the FORECAST climate model for suitable disturbed stand units.

FORECAST uses this information to “grow” new stands, as well as moving existing stands along developmental trajectories. Stand growth in the face of climatic stress is calibrated through dendrochronological analyses for a few key species, providing a greater level of confidence. This information is combined with stand/level information describing rates of decomposition, nutrient cycling, and other ecosystem properties to simulate forest growth under a wide range of management and climatic conditions.

Using FPS, we can then identify preferred management strategies for a number of indicators of forest management by accumulating TACA and FORECAST information and providing a spatial landscape context within the Case study area, building in landscape processes such as harvesting and natural disturbance (Figures 2 and 3).

² A complete primer on models and modelling can be found in Appendix 1.

³ We had initially intended to use the DYNA-PLAN model for projecting forest growth, management activities, and natural disturbances at the landscape level. See the “Landscape Level Modeling with FPS” section of this report for details.

Linkages between models and data

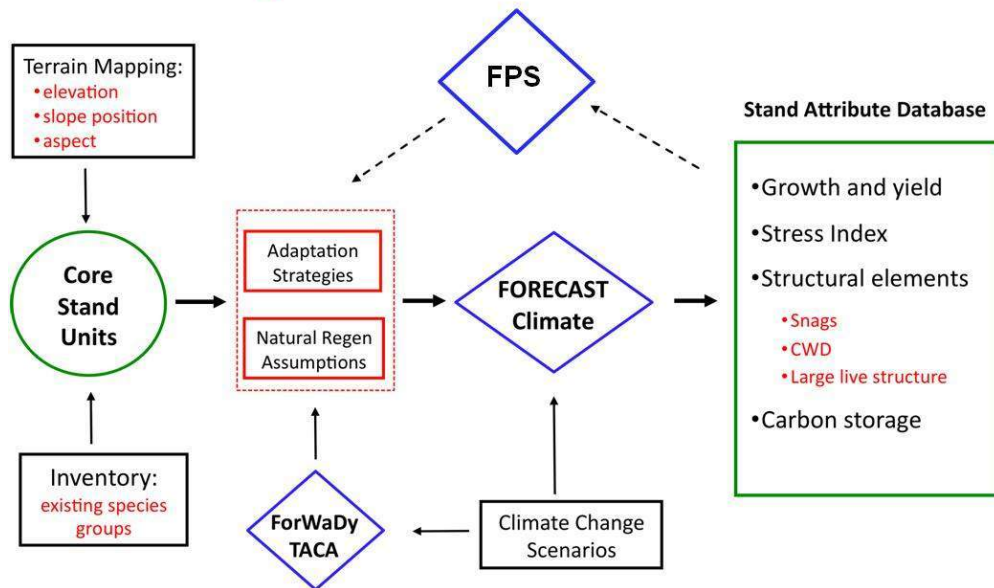


Figure 2. A representation of the linkages between the models (blue diamonds) and their inputs (black boxes), outputs (green), assumptions and scenarios (red boxes). The figure emphasizes inputs and outputs associated with the application FORECAST Climate. The landscape level modelling (FPS) will utilize the stand attribute database generated by FORECAST and will build in scenarios and assumptions for harvesting and natural disturbance.

DECISION SUPPORT SYSTEM: Modelling Framework

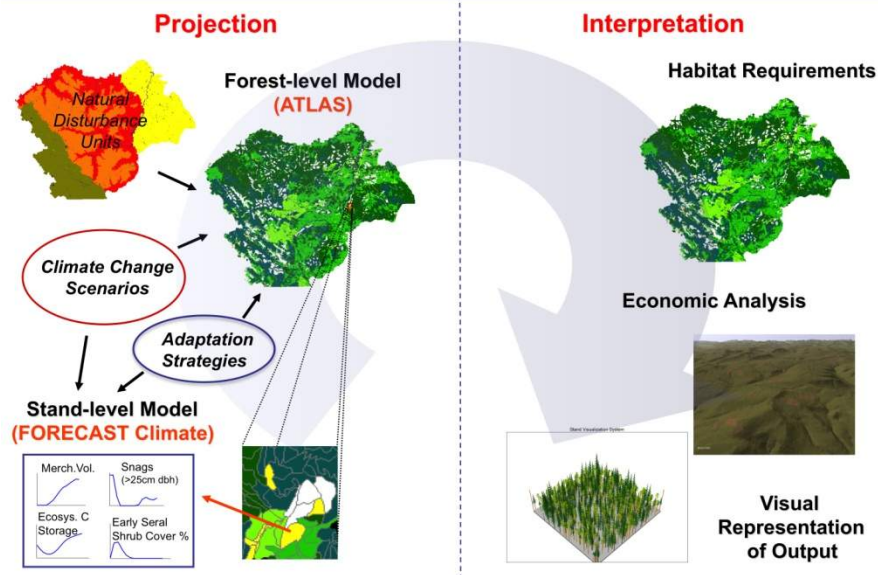


Figure 3. Another visual representation of modelling framework. This version graphically depicts examples of model inputs (e.g. climate scenarios and adaptation strategies) and projected outputs (e.g. merchantable volume and carbon storage) that will be the basis for interpretations.

Establishment of Modelling Goals, Questions and Indicators

Modelling Goals and Questions

Fundamental to the modeling process is the incorporation of local values, objectives, and indicators, achieved through the involvement of the project clients. To facilitate that process, the K2 team created a “definitions document” to ensure that the understanding of terms used throughout the project was consistent between all team members and clients (Appendix A4). As well, a website⁴ was created to facilitate sharing of key documents and background information.

K2 clients include forest managers from local resource agencies, forest companies, and First Nations, as well as local researchers and other knowledgeable stakeholders from the Kamloops TSA area. Through a series of facilitated workshops, the K2 team worked with these folks to identify important management goals and questions, allowing the team to establish a series of indicators and providing context for the modelling process.

The management goals (not be be confused with the project goals) may be discussed and/or refined at the end of the project, based on the lessons learned through the modelling and the interpretation and discussion of results (Table 1). For now, these goals fit under the definitions of goals previously established for this project. They also have linkages to the intent provided by current 2008 Canadian Standards Association Sustainable Forest Management (CSA SFM) guidance for certification within the TSA. The Timber objective also fits with the stated current provincial direction from the BC Ministry of Forests, Mines, and Lands.

Table 1. Local forest management goals to guide modelling and management scenario testing within the K2 project.

Overarching Goal:	<i>Encourage resilience within the ecosystems to maintain productive, “healthy” forests that will continue to be able to provide future benefits (for timber, biodiversity, etc.) in spite of the disturbances (and surprises) that may result from climate change.</i>
Timber:	<i>Maintain or increase the flow of timber volume and/or value over time.</i>
Habitat & Biodiversity:	<i>No loss of native species due to management over time.</i>
Fire:	<i>Minimize fire risk to people and property.</i>

⁴ <http://k2kamloopstsa.com>

Complementary to the management goals, management questions were formulated by clients to express key interests in the Kamloops TSA within each broad management goal (timber, habitat & biodiversity, and fire). Clients were organized in two groups to identify management questions (Table 2): Biodiversity, Habitat & Natural Disturbances; and Timber Management & Economics.

Table 2. Sample management questions posed by each of the two client groups.

Timber Management & Economics	<ol style="list-style-type: none"> 1. <i>Will some areas suffer such a reduced productivity for timber that they will drop out of the THLB?</i> 2. <i>How will the size and nature of the THLB change over time? Where will we harvest, when and how?</i>
Biodiversity, Habitat & Natural Disturbances	<ol style="list-style-type: none"> 1. <i>How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</i> 2. <i>How will adaptive strategies applied at the stand level to leave structure influence habitat and biodiversity over time?</i>

The complete list of questions formulated by the working groups (Appendix A5) was used to:

1. Help establish what was possible to address within the scope of the project.
2. Set the priorities to address within the timeframe of the project.
3. Build scenarios and indicators to explore the key priorities.
4. Select and modify inputs to best accommodate the questions and the models.
5. And build and/or modify various aspects of the models to better accommodate exploration of priority questions.

Modelling Indicators

A complete set of indicators has been built for each goal to ensure all key aspects of the goal itself would be measured (Appendix 6). In a strategic planning environment indicators are measurements or trends of interest that best reflect the progress toward strategic objectives. Because K2 is not a strategic planning exercise *per se*, but rather an investigation of questions posed by clients, the indicators are linked to both those questions, and the broader goals established for the K2 modelling (Table 3).

Indicators are useful both in modelling scenarios (as in K2) and in subsequent field-monitoring to evaluate potential and actual performance, and ultimately, success in achieving the strategic objectives. Indicators used in modelling may differ from those used in monitoring since modellers often must incorporate assumptions to evaluate potential performance in the modelling environment. Monitoring indicators more directly measure actual performance on the ground.

Indicators are often tied to thresholds that are known or estimated to be acceptable based on current knowledge. Often they are just trend indicators of interest based on their trend up or down relative to the current or some other baseline situation. In either case, they will be useful to determine: The impact of climate change with the current management approach (business as usual or BAU); and the difference that various adaptive management strategies could make (relative to the BAU); and the sensitivities and vulnerabilities that should be of most concern.

Table 3. Examples of modelling indicators developed from the client goals and questions.

Goal	Linked Question	Modelling Indicator
<i>Maintain or increase the flow of timber volume and/or value over time.</i>	<i>How will the size and nature of the THLB change over time? Where will we harvest, when and how?</i>	<i>Area in hectares – broken down by subzone groups to indicate those with the greatest challenges over time.</i>
<i>No loss of native species due to management over time.</i>	<i>How will adaptive strategies applied at the stand level to leave structure influence habitat and biodiversity over time?</i>	<i>Percent of larger/older trees dead or stressed across the case study area (>23 or 30 cm diameter depending on species).</i>

Project Lessons and Challenges

- 1. It is challenging to engage clients in a project like K2, when there is no operational strategic planning process into which K2 and its recommendations can be incorporated.**

The initial K1 project identified the lack of such a process as a major adaptive capacity issue for implementation of adaptive strategies for climate change. For some K2 clients, the exposure to modelling process and knowledge emerging from it is sufficient to effectively engage them. It is much more difficult to engage others - particularly Forest Company licensees who are under significant economic pressures, and agency specialists who are under time constraints do not see K2 as directly relating to their responsibilities.

- 2. Communicating models is challenging yet essential for developing a common understanding and managing expectations; it should not be rushed.**

Effective communication of the model framework gives clients a clear understanding of model assumptions and limitations allowing them to ask appropriate questions that can be incorporated into the modelling process. However, this can be challenging, especially if the audience has no previous experience with the models. Effective communication includes managing expectations of what the models can actually deliver within the scope of the project and conveying the computational complexity of exploring every interesting scenario that could possibly be explored.

3. The best modelling indicators require some context.

The most useful modelling indicators require some context based on a thorough exploration of potential future forest issues, and subsequent management goals and questions that are of most interest to the clients. The time spent within the project to address this challenge was worthwhile as it permitted the development of a suite of indicators that are both meaningful to the clients and relevant for the modelling process. Fundamental, however, is a shared understanding amongst clients and researchers of the models, their assumptions and limitations.

Design of Management Scenarios to Explore Management Questions

In communicating model assumptions and exploring management questions with clients and in team meetings, it became clear that there was an enormous number of potential scenarios that could be explored while modelling. A number of potential climate change futures, considered at different time periods, coupled with current approaches to management, and including various management adaptations involving four different linked ecological models - can lead to an unworkable potential number of modelling runs.

Working from management goals to management questions and a thorough discussion of indicators allowed the K2 team to focus in on the most useful and feasible set of scenarios to be explored with the suite of models. The following is a list of scenario themes that the K2 project intends to use with three different climate futures (no change, low change, and high change scenarios) over several key points in the future:

1. **Business as Usual (BAU) theme** - reflects harvesting and silviculture planning and decisions as currently carried out across the case study area.
2. **Reduced harvesting (for biodiversity) management theme** - lowered annual allowable cut as a strategy to increase resilience for biodiversity.
3. **Targeted harvest management theme** – targeted harvesting of tree species in more vulnerable stands as a strategy to increase resilience.
4. **Alternate Regeneration management theme** – reforestation with tree species less sensitive to climate change as a strategy to increase resilience.

The Business as Usual (BAU) scenarios are intended to explore current management approaches with climate change (BAUCC), and without a changing climate (BAU base case or BAUBC). The purpose of this exercise is to ascertain the potential impacts of climate change on current management approaches and regimes using selected indicators to reflect the impacts on various management goals (timber, habitat, fire). It will also facilitate an assessment of the robustness of the initial ecological and

management impacts assumptions developed during K1 to explore management actions under climate change.⁵

Once the BAUCC scenario is completed, it can be used as a comparison (using each of the two climate change data sets) against adaptation scenarios designed using the modelling questions and recommendations from K1. Comparisons of the adaptation modelling scenarios (themes 2-4) against BAUCC will indicate the extent of improvement provided by the adaptation measure – and comparison with the BAUCC will indicate how the scenario compares to our current vision of the future without climate change. This is critical to understanding the cumulative difference that adaptive actions may or may not make to increase resilience.

Acquiring Climate Data

Climate Change Futures (Scenarios) and Data

To incorporate projections of climate change, K2 uses projected relative mean monthly precipitation and temperature data from two general circulation models (GCMs). One GCM was used with moderate climate-forcing assumptions paired with a LOW carbon emissions scenario⁶, and another GCM was used with more extreme climate-forcing assumptions paired with a HIGH carbon emissions scenario⁷. This provided a “high-change” and “low-change” climate scenario, each examined for the years 2020, 2050, and 2080 across the case study landscape. Having high and low climate change scenarios is useful because it provides the “bookends” of a probable range of impacts from which forest and range management can be evaluated.

A short list of GCMs were recommended by both the Pacific Climate Impacts Consortium (PCIC) and the BC Ministry of Forests, Mines, and Lands for their robustness in the province (Bonsal et al. 2003). From the recommended list and available SRES⁸ global emissions scenarios, the following GCM/emission combinations have been selected to capture an appropriate range of uncertainty/predicted change and to provide the widest “bookends” for climate change in BC:

1. **High change future (scenario)** = A1B carbon emission scenario, using three GCMs:
 - a. UKMO_HADGEM1
 - b. MIROC32_HIRES
 - c. UKMO_HADCM3
2. **Low change future (scenario)** = B1 carbon emission scenario, using three GCMs:
 - a. MRI_CGCM232A
 - b. UKMO_HADCM3

⁵ <http://k2kamloopsta.com/background-2/>

⁶ LOW emission scenario – This Intergovernmental Panel on Climate Change (IPCC) global carbon emissions scenario assumes a more ecologically friendly world focused on sustainability with reductions in material intensity and the introduction of clean and resource efficient technologies.

⁷ HIGH emissions scenario – An IPCC global carbon emissions scenario assuming global conditions of rapid economic growth with a balanced emphasis on all energy sources, including fossil fuels.

⁸ Intergovernmental Panel on Climate Change Special Report on Emissions Scenarios (SRES).

c. CCCMA_CGCM3

Figure 3 below shows the percent change in precipitation that is expected to occur for one High and one Low change scenario (HadGEM1 A1B1 and HadCM3 B1). The graphs highlight that the 2050s is predicted to be drier based on the HADGEM1 model. It is a common misconception that climate change is going to progress linearly and get warmer and drier in each successive time step. In the HADCM3 scenario (blue bars), precipitation is predicted to remain relatively unchanged at the annual scale; however, another model, the MIROC32_HIRES, predicts annual precipitation to increase in all time periods. Nevertheless, all models, for both High and Low change scenarios, predict a general increase in precipitation (wetter) from October to May with declines in precipitation (drier) occurring from June to September (June to August in the low scenarios). One exception is the HADGEM model which predicts a decline in January, February and November precipitation in the 2020s and February precipitation in the 2050s. So, under High climate change, precipitation is predicted to decline from June to September and increase over the remaining year

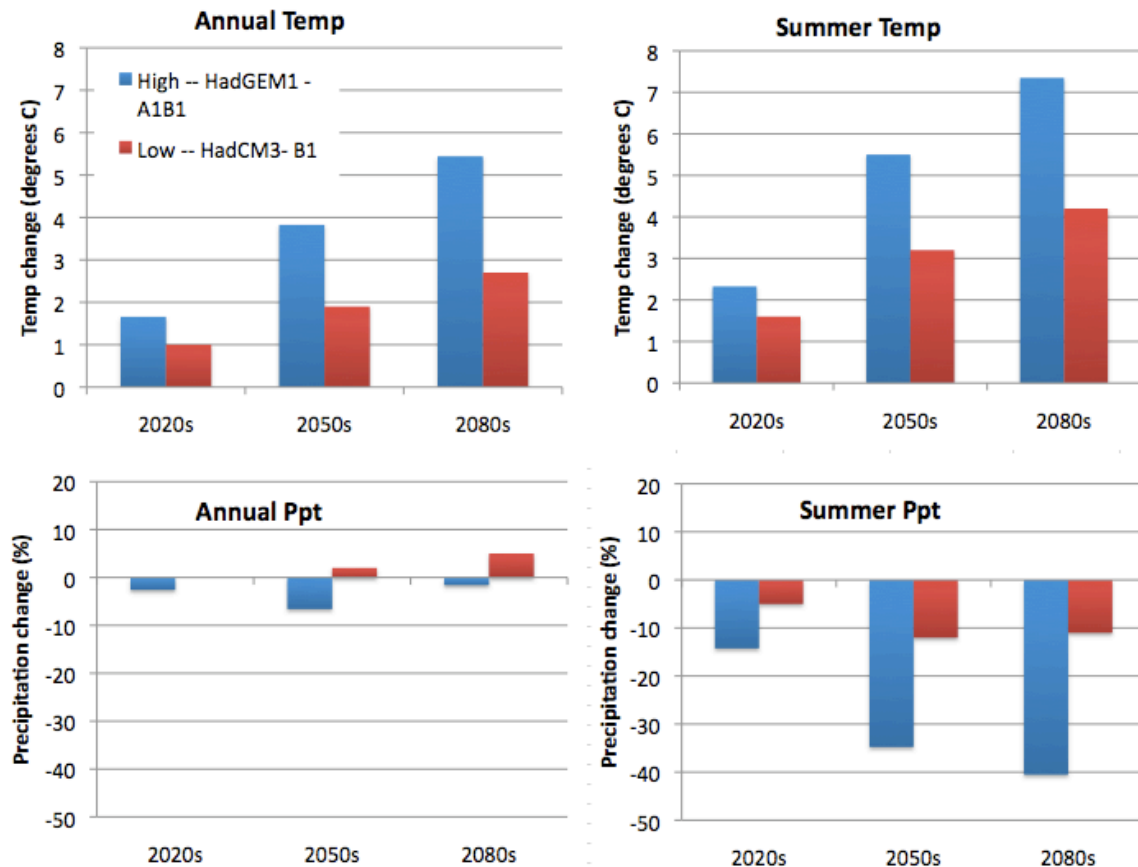


Figure 3. The relative differences between two selected high and low climate change scenarios for HadGEM1 A1B1 and HadCM3 B1.

Based on an ensemble of the scenarios (as used in the modelling), precipitation is expected to be higher in the 2080s vs. 2050s. The decline in summer precipitation is larger in the 2080s than the 2050s but the increase in autumn, spring and winter

precipitation is far greater. Thus in the 2080s, non-summer precipitation is offsetting the decline in summer precipitation at the annual scale but in the 2050s this is not occurring to the same extent leading to a larger annual decline in precipitation.

The climate scenarios utilized in K2 are slightly different from those used in the K1 project, mostly because they have been updated since, using the latest IPCC Fourth Assessment Report and reflect the current science being used to describe potential climate change. The projected relative mean monthly climate data, for both the high and low change scenarios, was applied to a relative time sequence in order to simulate a period of continual climate change, which can then be used in our modelling. This was done in the following manner:

- The time period from 2010 to 2035 uses the 2020 projected climate data.
- The 2036 - 2065 period uses the 2050 projected climate data.
- The 2066 - 2100 period uses the 2080 projected climate data.

Downscaling and Projecting Annual Variability using Daily Time-steps

Projected relative mean monthly precipitation and temperature data for the two climate scenarios were downscaled to the case study area using local climate stations, to reflect local variation in elevation, latitude and aspect across the K2 area.

In addition to downscaling GCM data, it is also important in the K2 modelling to capture local inter-annual climate variability in the projections. The TACA model requires the use of a rank and percentile method to select 10 years from the historical data that reflect the variability of the historical climate data. The ten years of daily data are then downscaled using a direct approach to reflect the expected climate change patterns as derived from the GCM models/scenarios. The ForWaDy/FORECAST Climate model requires the development of a long-term daily climate change datasets to simulate the growth and development of stands over a 100-year period. One hundred-year daily data sets were created for each combination of ecological group and climate change scenario using a direct downscaling approach such that the 100-year period was divided into 3 sections depending on the year. Each section was scaled according to the climate change projections for that particular time period (see above) to create a more realistic gradual pattern of change. An example of the 100-year output from this downscaling method is shown for the Dry Transitional ecological group in Figure 4.

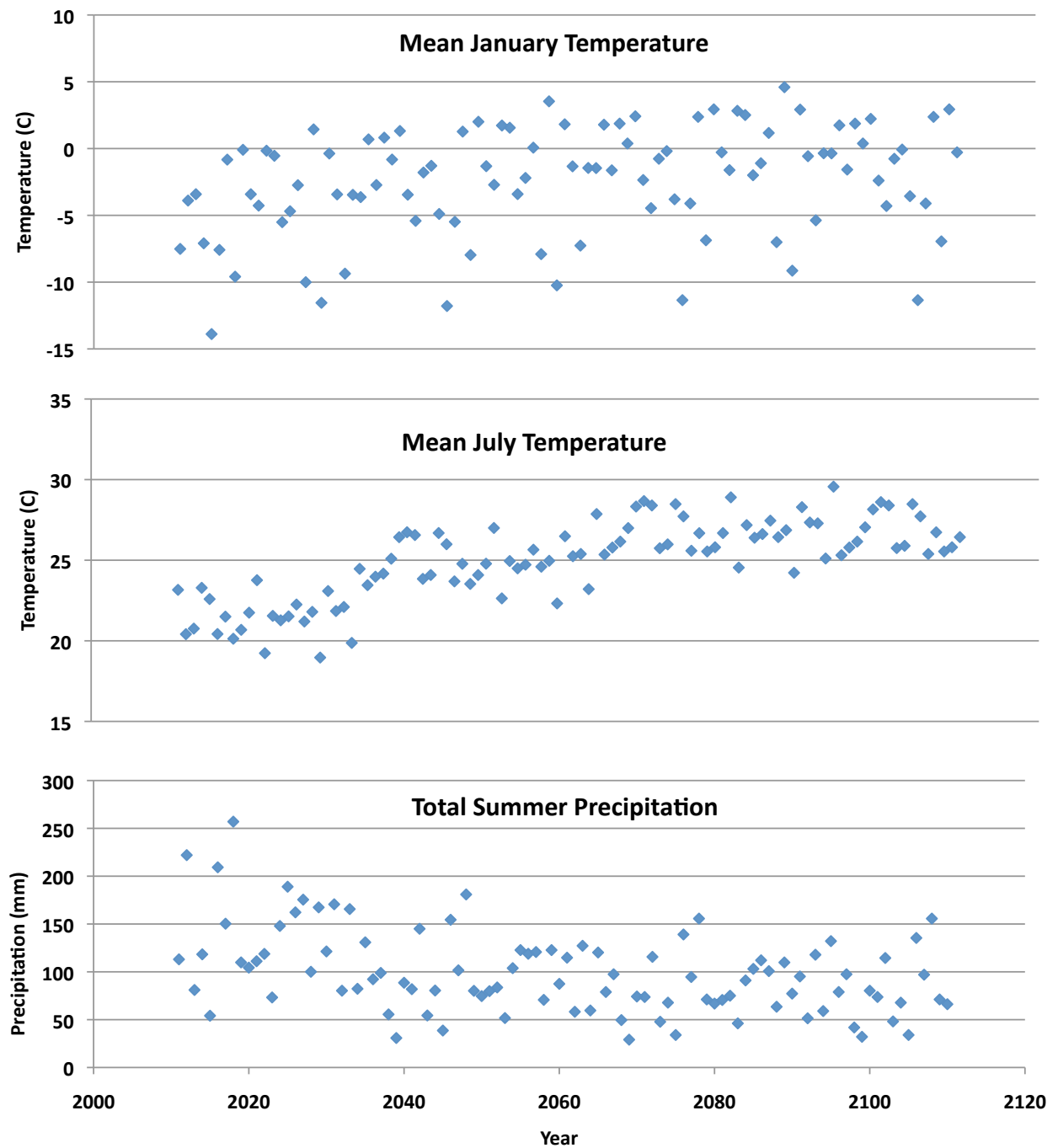


Figure 4. A summary of downscaled data for the Dry Transitional ecological group. Mean January and July temperatures and total summer precipitation (June-August) are shown for the 100-year simulation period.

Designing Modeling Scenarios - Combining Climate Futures with Management Scenarios

When the two climate futures options are combined with the management scenarios the number of potential modeling scenarios expands. To allow for flexibility particularly with the landscape modeling, the following nine modeling scenarios were designed and are being worked through sequentially:

Core scenarios

1. Business-as-usual (BAU) with no climate change (no CC)
2. BAU with HIGH CC
3. BAU with LOW CC

High climate change scenarios

4. 50% harvest level (for biodiversity) with HIGH CC.
5. Alternative regeneration species with HIGH CC.
6. Targeted harvesting with HIGH CC.

Low climate change scenarios

7. 50% harvest level with LOW CC and
8. Alternative regeneration species with LOW CC.
9. Targeted harvesting with LOW CC.

The core scenarios address the current approach to management with different climate regimes in the future. These will allow for the development of baselines from which to measure the effects of climate change on current management systems and to compare the effects of alternative management actions across the different climate scenarios. Business-as-usual (BAU) is defined using many of the same assumptions and inputs for the latest timber supply review (TSR) in the Kamloops TSA for appropriate stands. In some cases other data augmented for the BAU picture. For example, the government harvested block database, RESULTS, was consulted for information over the past decade to determine tree species planting preferences in the K2 stand units.

The high climate change scenarios present three different adaptation actions which were of most interest to the K2 clients, reflected by their modeling questions. The 50% harvest level is to roughly simulate higher retention levels for biodiversity. Alternative regeneration species is to simulate planting of more resilient species (as per TACA results) for that particular stand type, after it is harvested. The “targeted harvesting” scenario is when harvesting is more focused on stand types that are particularly susceptible to the impacts of climate change, possibly rendering them uneconomic to harvest for some time.

1. It is critical to anticipate the range of potential modelling runs in advance to set limits and priorities.

Simulating Climate Change Scenarios

1. **Temporal Resolution (5-7)**
 - Climate scenarios (high, low)
 - Years (2000, 2050, 2080)
2. **Spatial Resolution (21)**
 - Core stand units
3. **Management options (2-4)**
 - Managed stands
 - Harvest systems
 - Species selection
4. **Disturbance regimes (2-4)**
 - Natural Stands
 - Fire
 - Insect outbreaks
 - Endemic/stand replacing

Same for natural stands



18

Species Level Modelling with TACA

Modelling Outputs

An analysis of the effect of climate change on the expected regeneration patterns of 16 different species within the Kamloops study area has been completed using the TACA model in combination with the climate change data described above. The analysis was structured such the probability of successful establishment was calculated for each species, climate change scenario and ecological group combination. The analysis was further stratified to consider the relative impact of soil edaphic conditions on establishment success. A table was created for each species to summarize model output.

Modelling Challenges

The TACA model takes into consideration many of the phenological relationships known as requirements or limiting factors for the successful establishment of a given species under specific climate and soil conditions. The results from TACA will often require careful interpretation as there can be complex interactions among the phenological variables considered which may sometimes generate counter intuitive results.

Stand Level Modelling with FORECAST Climate

Forecast Calibration with Dendrochronology

A dendroclimatology field study was undertaken during the summer of 2010 to evaluate the effect of past climate regimes on tree growth within the Kamloops study area. The study was focussed on the growth of developing lodgepole pine and Douglas-fir stands within two general site types: 1) Dry IDF dk and 2) Moist ICH mw/mk. Cookies were taken from a total of 240 trees (120 PI and 120 Fd) during July 2010. The cookies have been processed and measured by the Kathy Lewis in the tree ring lab at UNBC. Data from the analysis (to be completed in January, 2011) will be used to refine the regional calibration of FORECAST Climate for Douglas-fir and lodgepole pine.

Integration with TACA and the Climate Data Set

Output from the regeneration analysis conducted with TACA will be used to determine the regeneration patterns to be simulated with FORECAST Climate for the different stand units and climate change scenarios. It will provide insight with respect to changing patterns of natural regeneration as well as species combinations that may perform well in different adaptation strategies.

The long-term (100-year) climate change datasets generated for each combination of ecological group and climate change scenario will be used as input for the application of FORECAST Climate to simulate the growth and development of the different core stand units described in Appendix A3.

Modelling Challenges

1. The use of a new model can lead to unexpected obstacles

While FORECAST and ForWaDy have been extensively applied FORECAST Climate is new and its application in the K2 project has been slowed by a few unexpected challenges related to calibrating the feedback from climate variables to stand growth rates. We have been able to address these obstacles and anticipate that the results from the dendroclimatology study will provide additional confidence in the model output.

2. The complexity of the climate change scenarios can lead to ballooning combinations of runs

The inherent complexity of the climate change scenarios when considered in the context of the 21 core stand units can create unreasonably high numbers of run combinations to be simulated and evaluated with FORECAST Climate (Figure 5). We have had to invest a considerable amount of time in narrowing down the options to those that will provide the greatest level of insight with respect to the long-term implications of climate change in the Kamloops study area.

Landscape Level Modelling with FPS

Landscape Model Choice

DYNAPLAN, the simulation/optimization model of choice for this project was originally selected for its ability to base local decision-making at the stand-level upon the larger landscape and dynamic context (ecological processes, economies of scale, road networks, etc.) from one time period to the next. However, due to unanticipated personnel changes, a gap was left in the K2 team's capacity to use this uniquely designed model. Rather than putting the project on hold, it was determined that the most cost/time effective option was to use Forest Planning Studio (FPS – formerly known as ATLAS) instead of DYNAPLAN.

FPS is a simulation model that has been integrated with other simulations models, including FORECAST. It has been widely used and tested throughout BC and is adequate for the purposes of the project, with limitations as in any model. Nevertheless, the K2 Team has recently brought on a research scientist with expertise in forest ecosystem modelling to use DYNAPLAN. As such, the optimization approach DYNAPLAN offers, and its ability to address spatial complexity is now viewed as added-value to the project while FPS will remain as the primary landscape-level model.

Integration with FORECAST, TACA, the Climate Data Set and Management Scenarios

The K2 team has not yet begun modelling with FPS. While TACA, FORWADY and FORECAST modelling are completed, the approach to landscape level modelling with FPS is being finalized. Unlike TACA, modelling progressive climate change with daily time steps is extremely challenging for landscape modelling and is beyond the scope of this project. However, it is possible to model progressive climate change in a simple way.

To accomplish progressive climate changes, the model will focus on the differences between: the current climatic situation; the climate projected in 2050; and the climate projected in 2080. The impacts of and the impacts associated with climate change will be represented through 3 broad mechanisms:

1. Altered yield curves for each stand unit.

Altered yield curves for each stand unit (designed in FORECAST) will address the following anticipated impacts from climate change: (a) changes in growth (productivity); (b) changes in mortality from insects and disease; (c) changes in mortality directly from increased climatic stress.

2. Altered natural disturbance regimes (fire return Intervals)

Landscape-level natural disturbances are expected to be significantly modified by climate change. While insect and disease infestations will be addressed at the stand unit level with FORECAST, the K2 team is currently working out an approach to simulate landscape level fire disturbances with fire risks responding to changing climatic factors. The approach used will be tailored to help explore the indicators of interest within the project scope.

3. Changes to the Size of the Timber Harvesting Landbase (THLB).

The K2 team is also currently exploring options to account for removals over time from the THLB based on either: (a) stand units that are no longer capable of regenerating tree species, or (b) stand units that will no longer be capable of producing an economic harvest.

Modelling Challenges

1. **The use of a new uncirculated model can present some challenges.**

This situation created a couple minor issues for the project. When K2 no longer had a modeller to work with DYNAPLAN, a replacement modeller was sought. It was clear that finding someone to work with DYNAPLAN would take some time, so the project switched to FPS, which could be run by Forsite Consultants who were already part of the K2 team. Nevertheless, the K2 team has not completely ruled out the use of DYNA-PLAN since a researcher was recently acquired by UBC to run the model. As an option, it may be used to compare results of some scenarios with FPS.

2. **Modelling adaptive scenarios for climate change at the landscape level is complex. Assumptions that are needed to expedite the process must be transparent.**

While it is always desirable to try to simulations in a realistic fashion that remains true to ecological processes and likely human choices, often some assumptions must be made to simplify the modelling and stay within timeframes

and budgets. It is critical that these assumptions are clear so that results can be interpreted within the appropriate context.

Community Outreach

The K2 research team spent time both in Clearwater and Barriere, British Columbia to share the initial findings of the K2 project, and to hear observations about climate change from residents. Public presentations and discussions were held over the course of several days with over 100 participants of all ages and affiliations, including:

- The BC Ministry of Forests and Range
- BC Timber Sales
- Clearwater Community Forest
- Woodlot licensees
- Junior Council of high school students
- Tourism Wells Gray
- Official Community Plan Steering Committee and District Council
- Clearwater Ski Hill Society and Wells Gray Outdoors Club
- Community members from Barriere, including the Mayor and a Councilor

Presentations compared key findings from the initial K1 project with local observations on the ground. Discussions highlighted that communities' knowledge of possible impacts from climate change is growing, and that a number of the project's findings (primarily from K1) for forests do in fact reflect what people in Clearwater are seeing.

We found that people are already thinking about climate change adaptation (Appendix A7). In Clearwater, for example, groups are considering how best to include issues of climate change in the tourism sector, such as the impacts of less snow at lower elevations. In addition, the Official Clearwater Community Plan will examine flood and wildfire risks. The K2 project team remains available to support community adaptation and we plan to return to the communities in 2011 to share findings from the K2 project and analyse them alongside the ongoing observations of community members.

Next Steps

K2 has recently shifted from the primary phase of information gathering and collaborative exploration to the computational and analytical phase. To date we have investigated the literature, engaged clients and communities, calibrated and integrated the models, refined project goals, identified key questions, and selected management indicators. Therefore, we now have a clear understanding of exactly what this project can deliver to inform forest management in the Kamloops TSA. We are currently in the process of modelling at the stand level with TACA results and the acquired climate data. Below is the updated work plan, from the project proposal, and our timeline as we move forward.

Updated Work Plan			
Milestone	Description of activities	Anticipated starting date	Anticipated completion date
Stream A. Exploration of Forest Management Issues and Questions (including modeling and other research activities denoted)			
Focus Workshop	Initial meeting with clients and researchers to define key research questions	Preparation starting in November 2009	January 2010 Completed
Primary Data Collection Complete	Modeling: Data collection	December 2009	February 2010 Completed
Focus workshop report	Report on key questions/Case study selection	January 2010	March 2010 Completed
Working groups	Establishment of working groups as appropriate for both streams to run through project	January 2010	October 2011 Completed
Models Calibrated for Case Study	Modeling: Model calibration	January 2010	October 2010 Completed
Dendroclimatology research	Fieldwork for Dendroclimatology study, lab work and data analysis	May/June 2010	December 2010 Completed
Integrated Models Operational	Modeling: Model integration	June 2010	October 2010 Completed
Dendroclimatology research report	Report on research results and validation of models	November 2010	March 2011
Model Results	Modeling: Model Runs	October 2010	August 2011

Other data analysis:	Modeling: Additional questions and issues identified from focus workshop	April 2009	April 2011
Communication Workshops	Workshops as needed for both streams to provide information from working groups and inform clients of scenario results from modeling	March 2010	June 2011
Review findings and workshop results	Summarize findings from Stream A and Stream B and preparation of Final Reports	November 2011	December 2011
<i>Stream B. Exploration of Community Impacts</i>			
Scoping	Initial discussions with the community of Clearwater to explore climate change	Preparation starting in November 2009	December 2009 - January 2010 Completed
Community Scoping report	Report on key perceptions, concerns and opportunities	January 2010	February 2010 Completed
Share Results and Discuss Implications for Community Planning	Present results of the forest management findings to the community and advise on the possible integration into planning.	September 2011	November 2011

Appendices

A1. A Primer on Models and Modelling

A primer on models and modeling

The K2 project uses output from four forest models to quantify ecological sensitivities and project the implications of proposed management activities under a series of climate change scenarios (see the Section: Overview of the Forest Model Suite). Each model is resident within an overall modeling framework (see Figures 2 and 3) such that the output from one model is used as input into another. The resulting ‘meta-model’ is a more powerful tool because it encompasses spatial and temporal scales, and management activities beyond that which is possible if each of the component models is applied separately.

To appreciate the importance of the meta-modeling approach in satisfying the objectives of the K2 project requires an understanding of the basic principles of model construction, and the limitations inherent to all models. In this regard, the first question to ask is ‘What exactly is a model’?

What is a model?

Because models are ubiquitous in modern society, there are many definitions that pertain to their specific application (engineering, physics, transportation, economics etc.). At its most elementary, however, **a model is a simplified representation of something**. The ‘something’ that the model represents is ‘reality’ (however, we choose to define it); it can be reality, as we know it today, how we thought things were in the past, or how they might be in the future. Note that a model only approximates reality, to varying degrees. That’s because reality is often too complex to try and represent in its entirety. Here is a more utilitarian definition:

A model is a representation of the essential aspects of an existing system that presents knowledge of that system in a usable form

This definition suggests that a model should be ‘good’ for something and indeed all models are, to varying degrees (and opinion). Forest ecosystem management models, for example, are designed to be useful within a specific context but as we’ll see below, each model has limitations in how it is best applied.

There are 3 basic types of models: Conceptual, graphical, and mathematical.

A **conceptual** model is a description of a system based on qualitative assumptions about its elements, their interrelationships, and system boundaries.

The 2008-2009 KFFS pilot project used a conceptual model to develop a series of ecological narratives of how conditions within a subzone may change over time and the ecological sensitivities that could emerge.

Graphical models are conceptual models presented using diagrams that indicate the flow of information (interrelationships) between elements of a system.

A **mathematical** (or quantitative) model uses mathematical language to describe a system, and is often translated into computer code. This project relies principally on mathematical models.

Why do we need a quantitative model?

Quantitative models are required in situations where traditional experimental approaches are inappropriate for reasons of spatial scale, duration, or the need to include complex processes.

For example, climate sets the overall framework for the biotic potential of an area through its influence on the structure, composition, and functioning of ecosystems, and therefore the goods and services upon which we rely. Anthropogenic emissions of CO₂ and other greenhouse gases are modifying the climatic regime such that the future climate may be very different from historical patterns.

Quantitative models can help ascertain how climate change may act to disrupt ecosystem function (and the implications for existing management practices) and assess alternative management practices to mitigate those impacts. This is an important objective in the K2 project.

Ecosystem management models

An ecosystem can be defined as:

A unit that includes all of the organisms (i.e., the community) in a given area interacting with the physical environment so that a flow of energy leads to a clearly defined trophic structure, biotic diversity, and material cycles (i.e., exchange of materials between living and non-living parts within the system)

Note that the concept explicitly recognizes complexity, interaction, functional processes, and change over time but that it does not specify any physical boundaries

An ecosystem management model then represents the essential aspects of an ecosystem (as defined above) in a form that facilitates management to achieve desirable outcomes.

To be useful, ecosystem management models should:

- (a) **Be consistent with accepted theory**, based on well-documented fundamental science, and integrated across disciplines and scales, as appropriate
- (b) **Make predictions** about properties that people care about and that are based on inputs that can be measured and managed
- (c) **Quantify uncertainty of the predictions** based on uncertainty in model inputs, parameters, and structure

- (d) Be subject to **continuous improvement** both in terms of their ability to capture reality and their utility as a guide to management

The models used in the K2 project satisfy these requirements.

All mathematical models have a **domain of application**

The application domain reflects the **ecological concepts** represented in the model, and the **spatial representation** and **temporal scale** at which the model can be meaningfully applied. The application domain also sets limits on the nature of the questions that a particular model can address (i.e., its goal). Here are examples of the application domain of three of the four models used the K2 project.

Examples of the application domain:

Tree and climate assessment (TACA) model

Goal: A model to analyze the influence of predicted changes in climate on the ability of a tree species to regenerate.

Ecological concepts

- growing degree day thresholds (GDD Min and GDD Max);
- species-specific threshold temperature;
- minimum temperature;
- chilling requirement;
- bud break;
- drought;
- frost.

Temporal scale

Daily to many decades

Spatial representation

Aspatial. Variable scale.

Forest Water Dynamics (ForWaDy) model

Goal: A model to analyze the impacts of vegetation on moisture dynamics and competition for moisture.

Ecological concepts

- evaporation;
- transpiration;
- interception;
- sublimation;
- percolation;
- drought;
- competition

Temporal scale

Daily to many decades

Spatial

Aspatial. Variable scale but restricted to a defined soil type, and community assemblage

FORECAST Climate model

Goal: A model to analyze the impacts of forest management practices and climate change on nutrient cycling, moisture, competition, and ecosystem development

Ecological concepts

- decomposition;
- moisture availability
- net primary production;
- net biomass accumulation;
- biomass allocation

Temporal scale

Yearly to
many decades

Spatial representation

Aspatial. Minimum of 1
ha.

The application domain of a given model can be expanded in two ways:

1. Build a more comprehensive model (the **mega**-model approach)

Expand the ecological concepts represented within the model and/or modify the spatial representation and temporal scale

Advantages

- (a) Confidence that the model provides a truer representation of the system (i.e., the model is more realistic)
- (b) Model components are well integrated such that variables can be updated in real-time (i.e., the model is more dynamic)

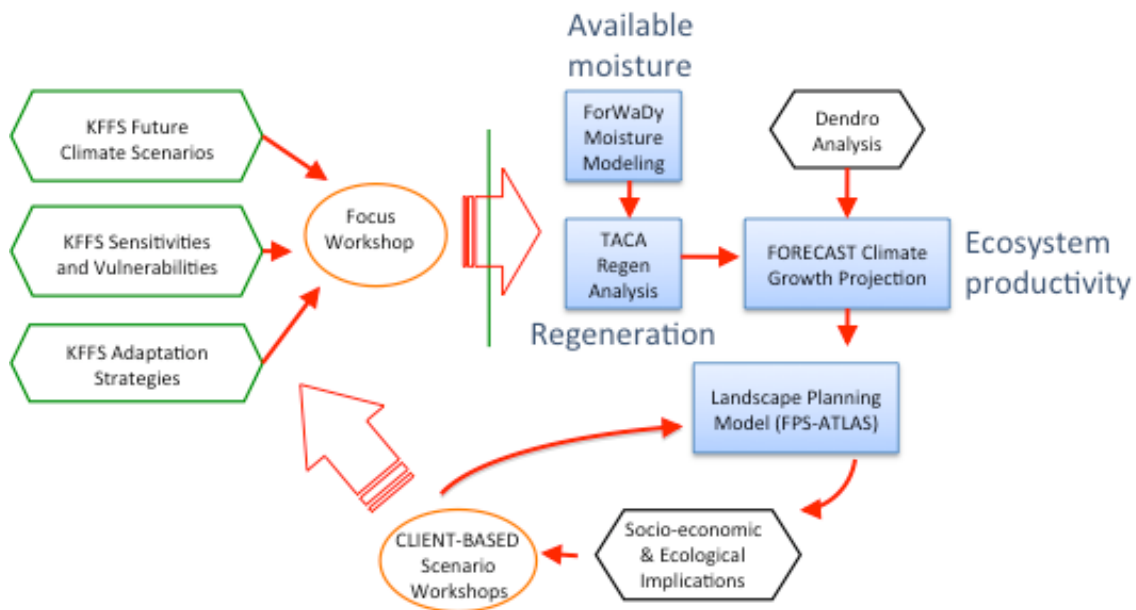
Disadvantages

- (a) Requires expertise across a broader range of disciplines
- (b) More variables mean more calibration data are required
- (c) Calibrating more variables increases the chances for error propagation. Hence, uncertainty around the accuracy of the model outcomes is increased.
- (d) Processing times can become impractical

An example of mega-model construction was the addition of climate representation and moisture dynamics (i.e., the ForWaDy model) to the FORECAST model, to produce FORECAST Climate

2. Link models with different application domains (a **meta**-model approach)

Expand the overall ecological concepts, as represented by the different models.
 Example: Linking TACA, ForWaDy, and FORECAST Climate, and embedding those models within the landscape-level model, FPS-ATLAS (the approach adopted in K2):



Advantages

- (a) Confidence that the meta-model provides a truer representation of the system (i.e., the model is more realistic).
- (b) Relatively easy to do.
- (c) Error propagation is less of an issue.

Disadvantages

- (a) Requires expertise across a broader range of disciplines.
- (b) More variables mean more calibration data are required.
- (c) Relationship between models is relatively static.
- (d) Model output/input linkages often cannot be linked in real time.

After careful consideration, the relative advantages to the meta-modeling approach were deemed to outweigh its disadvantages, particularly in light of the impracticality associated with the time and resources necessary to develop a mega-model. After all,

'The goal should be not to believe models but rather to use them to understand the system' - Dale and Van Winkle 1998

A2. Baseline Climate Regimes for the Ecological Group

Baseline Climate Regimes for Ecological Groups

Long-term, historical climate data was available for each of the six ecological zone within the K2 study area with the exception of the Wet Engelmann Spruce zone. A summary of the climatological characteristics of each zone is show in the figures below. The annual heat index (AHI) statistic was calculated for each zone based on the following equation:

$$AHI = (MAT+10)/(TAP/1000)$$

where:

MAT = Mean annual temperature (°C)

TAP = Total annual precipitation (mm)

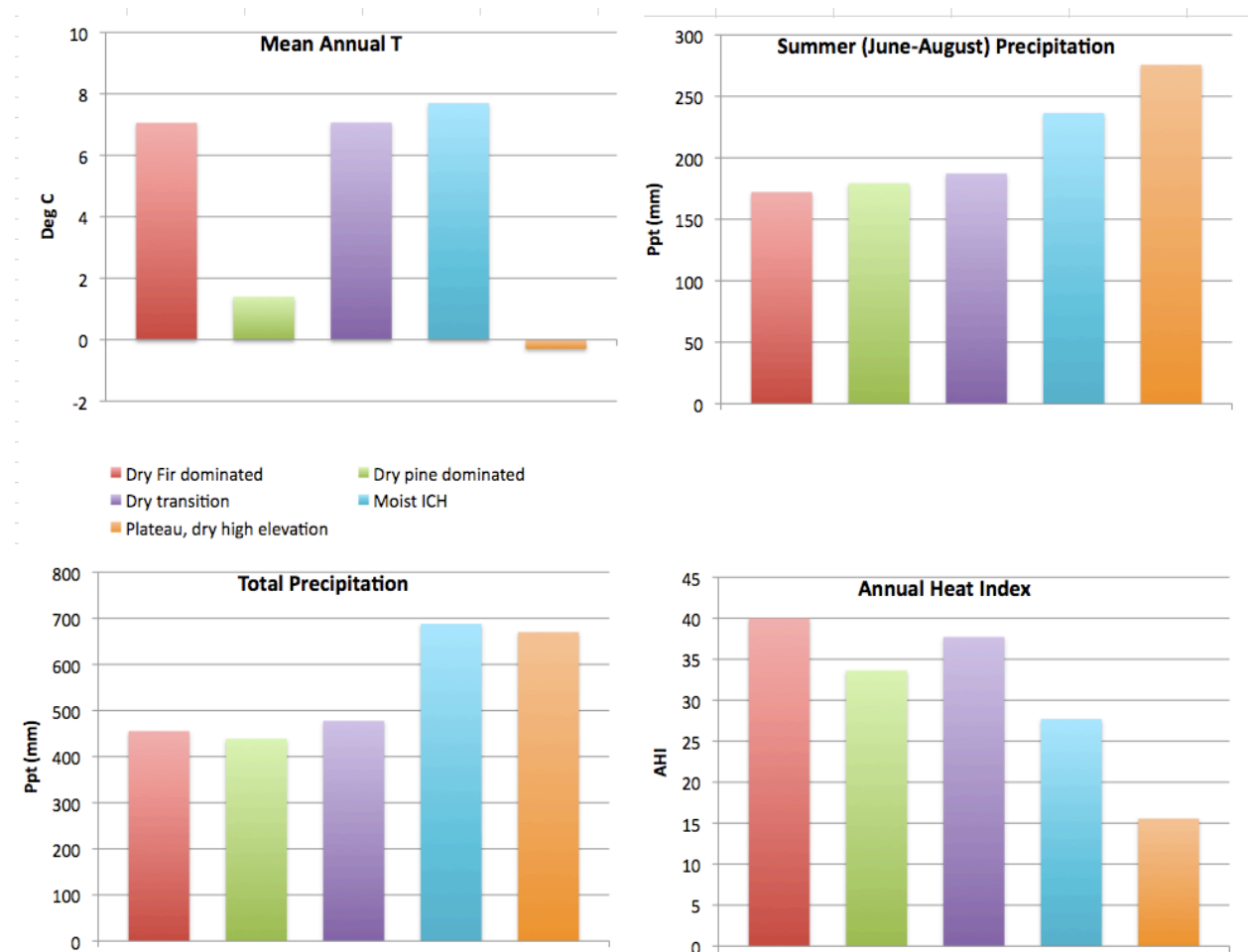


Figure A1. A summary of the climate regimes for the different ecological groups within the K2 case study area.

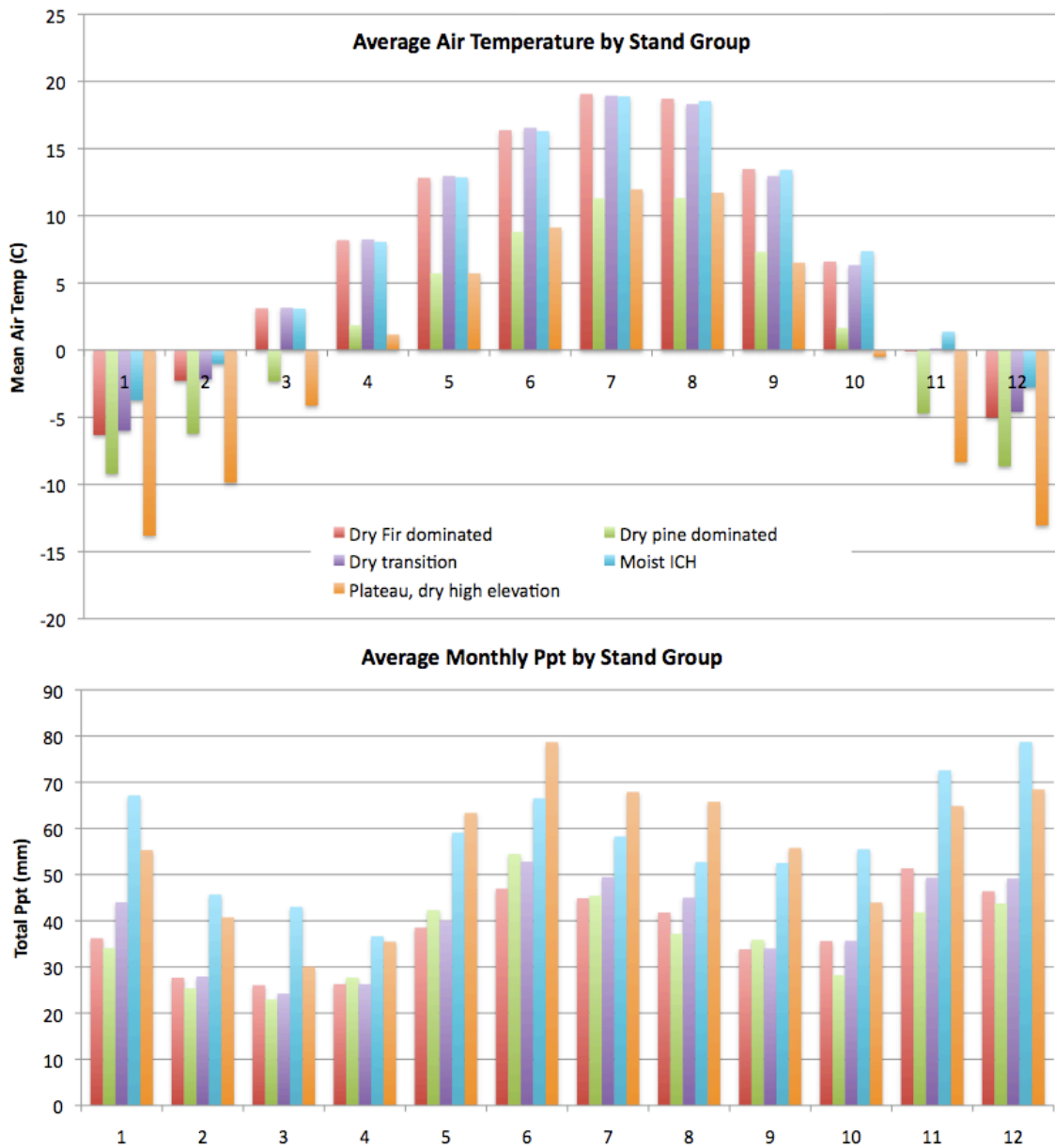


Figure A2. A summary of the monthly mean temperature and precipitation for the different ecological groups within the K2 case study area. The numbers on the x-axis represent numerical months.

A3. Description of Stand Units

K2 Stand Unit Descriptions Oct, 2010

SUMMARY OF STAND UNITS BY ECO GROUP

A. DRY Fd Dominated Group (IDF_{xh}, PP_{xh}):

- 1. Fd-Broadleaf (20% or more broadleaf)**
(Inventory Average by Area – At(Ac)-42%/ Fd-39% / Ep-14% (Sx-2%, Py-1%, Cw-1%)
- 2. Fd-Py & Py-Fd (at least 20% Py)**
(Inventory Average by Area – Fd-60% / Py-39% (At-1%)
- 3. Fd dominated (Fd>80%)**
(Inventory Average by Area –Fd-95% (Py-2%, At-2%, Sx-1%)
- 4. Conifer-other.**
(Inventory Average by Area – Fd-64%/ Py-12% / Pl-9% / At-7% (Sx-4%, Ep-2%, Cw-1%)

B. Dry Fd and Pli Group – IDF_{dk} / (MS_{xk}):

- 5. Fd-broadleaf (20% or more broadleaf)**
(Inventory Average by Area – At(Ac)-47%/ Fd-34% / Ep-11% (Pl-4%, Sx-4%)
- 6. Fd-Pli / Pli-Fd (at least 20% Pli)**
(Inventory Average by Area –Fd-53% / Pl-39% (S-3%, At-3%, Bl-1%, Ep-1%)
- 7. Fdi dominated (Fd> 80%)**
(Inventory Average by Area – Fd-94% (Pl-2%, Py-1%, Sx-1%, Ep-1%, At-1%)
- 8. Conifer-other.**
(Inventory Average by Area – Fd-41%/ Pl-27% / Sx-16%/ Bl-8%, At-5% (Py-2%, Ep-1%)

C. Dry Transition- (ICH_{dw}, IDF_{mw}):

Pli – 80% of inventory is dead (20 years+) from MPB.

- 9. Broadleaf dominated (> 50% broadleaf component)**
(Inventory Average by Area – Ep-42%/ At(Ac)-34% / Fd-15% (Pl-3%, Cw-3%, Sx-2%)
- 10. Mixedwood (with 50-80% conifer component)**
(Inventory Average by Area – Fd-42%, Ep-19%, At(Ac)-11%, Pl-10%, Cw-9% (Pw-3%, Sx-3%, Hw-1%?)
- 11. Fd dominated (Fd > 80%) -**
(Inventory Average by Area – Fd-94% (Pl-2%, Ep-2%, At-1%)
- 12. Fd-Pli / Pli-Fd**
(Inventory Average by Area – Fd-47%, Pl-46% (Ep-2%, Cw-1%, Pw-1%, Sx-1%, At-1%)

13. Conifer-other

(Inventory Average by Area – Fd-40%, Pl-18%/ Cw-14%/ Sx-13% (Pw-5%, Hw-4%, Ep-3%, Bl-3, At-1%)

D. Moist Transition – ICHmw, ICHmk (ICHwc)

Pli – 80% of inventory dead (20 years+) from MPB.

14. Mixedwood (with 50-80% conifer component)

(Inventory Average by Area – Fd-30%, At(Ac)-17%, Ep-15%, Pl-14%, Sx-10%, Cw-9% (Pw-2%, Hw-2%, Bl-2%)

15. Fd, Cw, Sx

(Inventory Average by Area – Fd-54%, Sx-18%, Cw-17%, (Pl-3%, Bl-3%, Hw-2%, Pw-1, Ep-1%, At-1%)

16. Fd-Pli / Pli-Fd

(Inventory Average by Area – Fd-50%, Pli-42%, (Sx-3%, Pw-1%, Bl-1%, Cw-1%, Ep-1%, At-1%)

17. Conifer-other

(Inventory Average by Area – Sx-24%, Fd-18%, Cw-15%, Bl-13%, Pl-11%, Hw-9% (At/Ac-3%, Pw-2%)

E. Dry Plateau (ESSFdc, MSdm, SBSmm)

18. Bl dominated (>=75% (IU types) – were originally Sx leading)

(Inventory Average by Area – Bl-86%/ Sx-14%)

19. SxBl or BlSx (with <10% of Pli or Fd)

(Inventory Average by Area – Sx-59%/ Bl-41%

20. Other

(Inventory Average by Area – Pl-41%/ Sx-23%/ Fd-22%/ Bl-10% (At-3%, Ep-1%)

F. Wet ESSF (ESSFwc)

21. Spruce and Balsam (or BlSx)

(Inventory Average by Area – Sx-53%/ Bl-40% (Pl-3%, Fd-2%, Cw-1%?)

INTERPRETATIVE NOTES FOR STAND UNITS:

A. DRY Fd Dominated Group (IDF_{xh}, PP_{xh}):

Py – About 80% of inventory is dead (20 years+) from bark beetles.

- **Fd-Broadleaf (20% or more broadleaf) – usually mesic**

(Inventory Average by Area – **At(Ac)-42% / Fd-39% / Ep-14%** (Sx-2%, Py-1%, Cw-1%))

- Broadleaves (mostly aspen, but some birch) mix through these stands generally at lower levels as distinct clumps (occasionally small clumps). Because true mixedwood is uncommon, just a presence of aspen is significant as a more diverse stand type.
- Generally the aspen is not merch and is really only for biodiversity and amenity values.
- **Some pure stands of aspen are evident** – usually on the less productive (non-economic) areas (scattered in a matrix of open grasslands).
- Limited harvesting here in the past 30+ years.

- **Fd-Py & Py-Fd (at least 20% Py) – Usually mesic**

(Inventory Average by Area – **Fd-60% / Py-39%** (At-1%))

- These stands were mixes of Douglas-fir and Ponderosa pine with the Py in them now mostly dead (70-80%). Some stands of mostly pure Py may be found in the PP_{xh} close to the Thompson River Valley, especially on hot dry slopes.
- Where these stands were open or gappy (mostly the PP_{xh}) and young regen of Py is occurring, a considerable Py component may still be in the stand in the regen.
- Where these are relatively dense stands, the loss of Py in many is not hugely significant except in localities with almost pure Py – low down near private lands.
- A number of these stands have been hit with tussock moth in patches in the past several years – mostly within a km of the Thompson Valley. With the Py hit by MP Beetle and the Fd hit with tussock moth, most trees are dead in these patches.
- Data shows – mostly Fd planted with about one third as Py.

- **Fd dominated (Fd>80%) – Usually mesic**

(Inventory Average by Area – **Fd-95%** (Py-2%, At-2%, Sx-1%))

- Relatively dense with a range of sizes – logged in the past and understory released so there are lots of ladder fuels etc.
- A caution about fuel treatments – there seems to be a reluctance to open the stands up too much – curious due to the fact that this is not a highly important area for timber management. Where we observed fuel treatments along the Sun Peaks Road (though in the IDF_{dk}) not enough trees were removed nor were they pruned high enough in our opinion to make a huge difference – would it make a big difference to open these stands significantly so it is Fd-parkland?

- Data shows – mostly Fd planted with about one third as Py.

- **Conifer-other. Usually subhygric**

(Inventory Average by Area – **Fd-64% / Py-12% / Pl-9% / At-7% (Sx4%, Ep2%, Cw1%)**)

- Generally still have considerable Fd, but also Sx, often with At and Ep mixed in – these are the moist mesic to subhygric sites, usually on cooler aspects, or in swales.
- Note – inventory has Pli in it even though it is not typically found in the PPxh or the IDFxh – likely a trans-boundary issue or some confusion with the two pines.
- Data shows – mostly Pl planted with about one quarter as Fd?

B. Dry Fd and Pli Group – IDFdK / (MSxk):

NOTE – this is mostly IDFdK in the Case Study Area (with much more Fd than you would expect for the MSxk).

Pli – about 80% of the inventory is dead (20 years+) from bark beetles.

Fd-broadleaf (20% or more broadleaf) mesic

(Inventory Average by Area – **At(Ac)-47% / Fd-34% / Ep-11% (Pl-4%, Sx-4%)**)

- Some of this – usually the At are much taller and more merch than in IDF – generally mesic to slightly wetter sites. These are mostly getting planted to Pli but the At is coming in naturally.
- Data shows - Mostly Pli planted (some Fd)

Fd-Pli or Pli-Fd (at least 20% Pli) mesic to submesic

(Inventory Average by Area – **Fd-53% / Pl-39% (S-3%, At-3%, Bl-1%, Ep-1%)**)

- This is a common stand type, generally with Fdi leading. A high percentage of the pine has died (80-90%?) and/or has been salvaged.
- Data shows - Almost all blocks here are planted to Pli even though Fd is very productive.
- Mostly Pli has been planted here, switching the stand toward pure pine.
- At the margin of Pli presence this stand type will resemble Fd dominated – we distinguished it so we could ID those types that will be more open with recent Pli mortality.

Fdi dominated (Fd > 80%) mesic

(Inventory Average by Area – **Fd-94% (Pl-2%, Py-1%, Sx-1%, Ep-1%, At-1%)**)

- Another relatively common type – pretty similar to the IDFxh except with better Fdi site indices.
- There is still the same problem with ladder fuels – treatments don't seem too effective (see comments above which actually pertain to IDFdK going up to Sun Peaks).
- Data shows - Mostly Pli planted (small amount of Fd and Sx)

- Again, mostly switching species to pine even on these sites – see pictures. These are very good Fdi sites – excellent site indices.

Conifer-other.

(Inventory Average by Area – **Fd-41%/ PI-27% / Sx-16%/ BI-8%, At-5%** (Py-2%, Ep-1%))

- This is everything else – generally those stands in the IDFdk with more spruce and less pine and Douglas-fir, but usually with considerable aspen (possibly cottonwood) mixed in.
- These appear to be very productive sites for a range of species.
- Even aspen are exceptionally large where they are found – some of the best in the TSA.
- Sx (BI) tends to dominate the understory.
- Stands may be a bit open with Pli salvage in the past couple years.
- Data shows - Mostly Pli planted (small amount of Fd and Sx)

C. Dry Transition- (ICHdw, IDFmw):

Pli – 80% of inventory is dead (20 years+) from MPB.

Broadleaf dominated (> 50% broadleaf component) mesic to possibly subhygric

(Inventory Average by Area – **Ep-42%/ At(Ac)-34% / Fd-15%** (Pl-3%, Cw-3%, Sx-2%))

- Mix of birch, aspen and in some cases cottonwood. Mostly dominated by birch (some Ac) lower down with more At higher up.
- Some older cutblocks have the heavier concentrations of these types. Also along old roads. In some old fires there is quite a high hardwood content – see pictures.
- Birch in the IDFmw and drier slopes of ICHdw are in rough shape – significant to severe top-dieback. Most 30+cm dbh birch have 25% or more of top dead.
- Aspen, more noticeable as small clumps on hot dry slopes, or as large trees with cottonwood on the subhygric sites.
- Data shows - More than half of planting is to Pli (the rest is Fd and other species)

Mixedwood (with 50-80% conifer component) mesic

(Inventory Average by Area – **Fd-42%, Ep-19%, At(Ac)-11%, Pl-10%, Cw-9%** (Pw-3%, Sx-3%, Hw-1%?))

- Similar in content to the hardwood dominated above – not so concentrated on old logging. Often is maintained by root disease.
- Generally it is Fd that is mixed in (with good growth etc) but likely hit by root rot.
- We found the activity of root disease to be highly variable but over most of the IDFmw and perhaps about half of the ICHdw it appeared in the mixedwood stands that root disease was occurring at about 10% mortality over the past 10 years – so about 1% per year.
- Fd is often mixed in these types broadly as bands or patches of pure Fd (1 to 5 ha) in a matrix of scattered birch, small Cw and scattered Fd (Sx, Pw and possibly Ac on

wetter sites with higher levels of Cw, some merch – GS Forest Products only needs a fat 5 inch top)

- If there is enough conifer – they are logging and stumping if terrain is feasible, and mostly planting a mix of Pli (80%) and Fd (20%).
- Data shows - More than half of planting is to Pli (the rest is Fd and other species)

Fd dominated (Fd > 80%) - mesic to submesic

(Inventory Average by Area – **Fd-94%** (Pl-2%, Ep-2%, At-1%))

- The pine component in this type – would be nice to find out what the mortality rate on the pine is – looks variable (50-80%) but this is just a guess looking across a valley.
- This is still a strong type across the landscape. Cutblocks appear to have more planted Fd (often with 20-30% Pli mixed in) based on what was seen on the ground. Growing well. Often areas are stumped.
- Data shows - Slightly more Fd planted than Pli.

Fd-Pli & Pli-Fd (submesic sites)

(Inventory Average by Area – **Fd-47%, Pl-46%** (Ep-2%, Cw-1%, Pw-1%, Sx-1%, At-1%))

- Naturally – On dry flats and ridges etc. Generally beetle has hit this at about 70% mortality. Often little in understory to take over.
- The data shows - Slightly more Fd planted than Pli.
- What we noticed in the ICHdw - New Pli planted stands in cutblocks are more scattered as pure Pli – occasional and probably more than 6-7 years old.
- What we noticed in the IDFmw – most plantations are dominated by pine (Pl80% and Fd maybe 20%) with pure Pli plantations in some older 15+ year old stands. Most of these stands were stumped before planting.
 - This is significant. It means we are actively converting what were Fd stands to a Pli dominated type without much thought of the consequences on the landscape.
- Larch noted as tried in both the ICHdw and the IDFmw and are doing very well after 5-10 years. Note – it is not naturally found here.

Conifer-other - subhygric sites

(Inventory Average by Area – **Fd-40%, Pl-18%/ Cw-14%/ Sx-13%** (Pw-5%, Hw-4%, Ep-3%, Bl-3, At-1%))

- Subhygric sites – Considerable Sx-Cw with Fd, Ep, At, Ac, Pw. This is one of the few areas in these subzones where you may find pretty good merch cedar.
- Data shows - Mostly Pli planted here (Lw and Sx as well).

D. Moist Transition – ICHmw, ICHmk (ICHwc)

Pli – 80% of inventory dead (20 years+) from MPB.

Mixedwood (with 50-80% conifer component) mesic

(Inventory Average by Area – Fd-30%, At(Ac)-17%, Ep-15%, Pl-14%, Sx-10%, Cw-9% (Pw-2%, Hw-2%, Bl-2%))

- Seems to have less root disease here (than in ICHdw) – true mixtures where most tree species are doing well (except Pli if it is large enough to be hit by MPB -15 cm diameter plus) – Fd, Pw, Sx, Cw, Hw, At, Ep (possibly Ac).
- Still considerable Pl planted here with significant Fd and Sx mixed in.

Fd, Cw, Sx (mesic sites)

(Inventory Average by Area – Fd-54%, Sx-18%, Cw-17%, (Pl-3%, Bl-3%, Hw-2%, Pw-1%, Ep-1%, At-1%))

- High diversity of species (many quite valuable) regenerating and growing well.
- Very productive for many of these species
- Data shows - Usually clearcut and planted equally (by proportion) to Pli and Sx.

Fd-Pli & Pli-Fd (submesic sites)

(Inventory Average by Area – Fd-50%, Pli-42%, (Sx-3%, Pw-1%, Bl-1%, Cw-1%, Ep-1%, At-1%))

- Data shows - Mostly planted to a mix of Pl (leading) with Fd.

Conifer-other - subhygric sites

(Inventory Average by Area – Sx-24%, Fd-18%, Cw-15%, Bl-13%, Pl-11%, Hw-9% (At/Ac-3%, Pw-2%))

- Likely Sx, Fd planted (maybe some Pli) – data not clear.

E. Dry Plateau (ESSFdc, MSdm, SBSmm)

Bl dominated (>=75% (IU types) – were originally Sx leading)

(Inventory Average by Area – Bl-86%/ Sx-14%)

- This is in the ESSFdc
- There is considerable old IU strip and partial-cuts from the 60's, with mostly balsam of many sizes left. The Bl is vigorous, healthy, growing well, fully stocked, but these stands are pretty much pure balsam – could be an issue with climate change.

SxBl or BlSx (with <10% of Pli or Fd)

(Inventory Average by Area – Sx-59%/ Bl-41%)

Sx – about 15-20% of the inventory in SxBl/BlSx stands (200+ years-old) is dead from spruce beetle over the past couple years. This mortality is not even across the Plateau in the case study area – it is concentrated in the ESSFdc in the Sun Peaks / Cahilty Basin area (about 80% mortality of Sx there).

- This type takes all the remaining stands after considering the one above and tries to capture the rest of the ESSFdc
- One third to one quarter of this unit in the case study area (in the Cahilty Creek basin) has been hit heavily by bark beetles. First the pine bark beetle took the pine out of the mixed conifer stands, now over the past 2-3 years spruce bark beetle has literally killed most of the mature spruce (70-80%).
- This beetle mortality first encouraged more harvesting in a landscape already hit hard by harvesting with not a lot of mature forest cover. Secondly, the mature stands that are left, mostly close to riparian, or less accessible/operable, have just scattered mature balsam in the overstory and a pretty solid layer of balsam in the understory.
- Anywhere logging has occurred in the past has mostly been planted to Se with some Bl infill. Planted Pli is more prevalent lower down in the ESSFdc, or on drier south slopes which we didn't really see.
- Data shows - Planted Sx 100%.

Other - mesic on average

(Inventory Average by Area – **Pl-41%/ Sx-23%/ Fd-22%/ Bl-10%** (At-3%, Ep-1%))

Pli – 80% of inventory in older stands are dead from MPB– see breakdown below for ages.

- These stands are MSdm mostly with some SBSmm on the west side.
- These are often mixed Sx, Pli, Fd Bl stands that are losing their Pli to MPB – 80% death.
- MPB mortality in pine – an ocular estimate...
 - Older stands (40 years plus) – 80%
 - Young stands (20-40 years) – 50%
 - Less than 20 years old – 0-10% mortality depending on size.
- Pure pine stands seems to often have Sx-Bl understory so all is not lost. Even smaller pine (20 cm diameter).
 - Some small pine stands have been treated where 50% mortality from MPB. The understory alder was cut to “release” the Sx and Bl in the understory. Not sure if it is really necessary?
- The smaller pine were hit down to 10-20 cm (maybe 15-20 years old)?
- Aspen patches throughout this zone makes it quite mixed.
- Some Fdi leading stands found lower down closer to IDFdk.
- Most planting up to about 5-6 years ago was pure pine. In the last six years about 20-25% of Sx (occasionally Fd) was mixed in, in most cases but this is not a rule – we did see a number pure Pli plantations that were 5 years old. The planting records for last 10 years matches this trend. There will generally be a conversion of stands from Sx dominated to pine, although there is a question of how understory Bl and Sx will mix in over time.
 - Data show that Pli is planted at 65% (with Sx and some Fd mixed in)

F. Wet ESSF (ESSFwc)

- **Spruce and Balsam (or BIsx)** mesic average

(Inventory Average by Area – **Sx-53%/ BI-40%** (Pl-3%, Fd-2%, Cw-1%?)

Pli – 80% of inventory in older (20+ yrs) stands are dead from MPB

BI – Maybe 10% of mature BI have experienced mortality in the past couple years from Balsam bark beetle.

- Decent looking stands with pretty good looking Sx that will likely just do better, especially in the cooler areas (North slopes). Scattered Balsam bark beetle mortality in BI.
- Young stands in cutblocks are dominated by good, vigorous, healthy spruce. Scattered natural balsam.
- Fire – generally thought of as not being a huge issue here, however we were reminded it is where you are positioned on the landscape that is important. A large fire started near the resort at North Barriere Lake in the hot dry year of 2003 and ripped through the ICHdw to the ESSFwc above. Generally we think of the ESSFwc as being buffered by the wet ICH, but that is not always the case.
- On the ESSFwc/ICHdw transition, there appears to be a fair degree of stress (drier) and we are seeing a number of dead BI and Sx mixed with Pl. Likely the droughty conditions at times have made these trees more susceptible to bark beetles. This might give us a bit of glimpse into what climate change will do.
- Balsam has currently been hit at varying levels (5-30%) by balsam bark beetle (we think). Overall hit might be 10-20 % of the balsam so not too bad.
- But we also think this will get worse over time which could take out 20-30% of these mature stand types at some point past 2050.
- There are some old IU stands in this type (down near Johnson Lake) – likely dominated by BI as in the dc near Sun Peaks.

A4. Definitions and Terms

UNDERSTANDING WHAT WE MEAN:

Clarifying Our Intent and Defining Our Terms for K2

This document is intended to provide clarity for communication within the K2 technical team, with K2 clients, and with others interested in the project.

Our Vision for the Project:

The K2 Mission:

K2 will explore forest management adaptations to climate change in the context of the Kamloops Timber Supply Area, building on previous work completed in the area (K1). K2 will combine computer models, current science, and local knowledge to collaboratively expand our understanding of sensitivities, and the interactions between potential adaptive strategies, ultimately to improve future forest management planning and community adaptation in the area.

K2 Project Goals:

1. To improve on K1, to create a refined set of sensitivities, adaptive management options and related implications for local value goals linked to a vision of the future forest that can provide direction for future management planning in the TSA.

This goal will be pursued by exploring initial K1 sensitivities and management options:

- a. *To examine their credibility, based on current science, emerging analytical tools, and local knowledge.*
- b. *To assess their utility for managers, by providing better context in time and space, and by considering impacts between overlapping and competing value goals.*
- c. *To ultimately, make them more robust so that we can better maintain options to service a range of values over time, considering the uncertainties linked to climate change.*

2. To provide resource managers, planners, policy-makers and others with a better understanding of the potential effectiveness of proposed management actions that will assist them in decision-making.

This understanding includes:

- a. *Understanding the feasibility of different options- is it economic now? Will it be economic in the future?*

- b. *Understanding implementation issues - are there regulations, policies, or concerns that might affect our ability to start doing something new or different?*
 - c. *Considering different outcomes-what is likely to happen if we don't do something now (follow a business as usual approach), versus trying to do something different?*
 - d. *Evaluating robustness of proposed actions - by taking into account the uncertainties linked to climate change and understanding which ones might best maintain our options to service a range of values over time.*
- 3. To collaboratively explore climate change impacts and potential adaptive actions with the range of local clients – Agencies, licensees and management practitioners, First Nations, communities, and others.
- 4. To explicitly identify assumptions and knowledge gaps that will require further research and/or monitoring over time.

Definition of Key Terms for K2:

The following terms may be used throughout the project from time to time. Many of these terms have been interpreted over the years in different ways. To avoid confusion the following is an attempt to clarify our interpretation of these terms for the purposes of this project.

OVERVIEW OF TERMS

CLIMATE CHANGE ASSESSMENT TERMS

Sensitivity – is the potential capacity for, or the degree of, a response when exposed to the projected outside influence of climate change.

Vulnerability – Vulnerability of a system to climate change is a function of the exposure, the sensitivity of the system and the adaptive capacity of the system.

Adaptive Capacity – is the potential ability of a system to adapt to the projected exposure of climate change. Adaptive capacity may refer to ecological systems, or management systems. When referring to forest management systems – it considers both the ability to adapt and the likelihood or willingness that a forest manager will adapt.

GENERAL PLANNING TERMS

Uncertainty – is not knowing for certain what the future will be like, regarding the condition and functioning of our future forests.

Scenarios – are internally consistent views or narratives of what the future might turn out to be – not predictions, but plausible alternative futures.

Assumptions – are explicitly identified to bridge knowledge gaps and uncertainties (based on the best available science), allowing the K2 team to explore performance of indicators and targets (possibly of strategic objectives) over time.

Risk – is the likelihood that an undesirable outcome will occur, considering the consequences associated with that outcome.

FOREST MANAGEMENT PLANNING TERMS

Goal – is the overall intention for management with linkage back to values and key principles.

Strategic Objectives – are the strategic conditions that need to be attained to achieve a forest management goal within the TSA (over time, considering climate change and the changing nature of the forests).

Indicators - are measurements or trends of interest that best reflect the progress toward strategic objectives.

Targets – are measurable direction for management actions designed to ensure that indicators remain favourable over time (and strategic objectives are therefore achieved).

DETAILED DEFINITIONS

Sensitivity

Sensitivity – is the potential capacity for, or the degree of, a response when exposed to the projected outside influence of climate change.

Our Approach to Sensitivity – In K1 we considered two types of sensitivities – ecological sensitivity and management sensitivity to two climate change scenarios¹. In K2 we will continue to explore sensitivities in response to bounded climate change scenarios to explore assumptions associated with those sensitivities.

Other Details - ecological sensitivities describe the inherent potential response to climate change of ecosystems and their elements or features, while management sensitivities are elements that are tied directly to our goals for relevant forest management values.

Vulnerability

Vulnerability - of a system to climate change is a function of the exposure, the sensitivity of the system and the adaptive capacity of the system.

Adaptive Capacity – is the ability of a system to adapt to the exposure (in our case – climate change). Adaptive capacity may refer to ecological systems, or management systems. When referring to management systems – it considers both the ability to adapt and the likelihood or willingness that a manager will adapt.

Our Approach to Vulnerability – Unlike K1, K2 is not a vulnerability assessment. However, as it explores assumptions and projections in K1 and alters projected sensitivities and management actions, projected management vulnerabilities identified in K1 may be adjusted.

Other Details - Because sensitivity and adaptive capacity may both refer to either ecosystems or management, vulnerability may be used to describe both. When using the term ecological vulnerability, the assumption is “in the absence of management”.

¹ as bookend best/worse cases to represent the range of climate impacts

Uncertainty

Uncertainty – is not knowing for certain what the future will be like, regarding the condition and functioning of our future forests.

K2 and Uncertainty – K2 will explore, as much as possible, the range of plausible futures through scenario analysis, to understand potentially how undesirable or unacceptable² future conditions may become, so that robust strategies can be designed to maintain future options.

Other Details³ - Uncertainty about the condition and functioning of our future forests in a changing climate stems in part from the uncertainty about how and at what rate climate will change; how the various aspects of climate (temperature, rain, snow, wind, growing season, extremes of weather) will change and interact; how those changes will affect forest ecosystems; how management responses will perform under new and uncertain climatic conditions; and how people will respond globally to the risks of climate change and thus mitigate or further exacerbate those risks.

For this project uncertainties exist in many forms:

1. **Statistical variability and quality of data** – The biological and environmental data that will be used in K2 have different degrees of variability around “averages”. When it comes to climate and weather - averages may be misleading. Rare extremes may be more significant, or have the most influence on the features we are most interested in.
2. **Functional relationships** – Include those associated with climatic factors and biological processes that influence the ability of plants and animals to survive, grow, reproduce and remain healthy. Also, there are many ecological relationships which have their own uncertainties, like the relationship between habitat structures and/or landscape features and patterns and the well-being of associated animal species.
3. **Scoping or bounding** - Uncertainties may arise because of the inability to consider all potential limitations or opportunities because they are outside of the scope of the project. Some examples include economic influences and emerging demographics.
4. **Unknownables** – The world is diverse and unpredictable, and frequently presents surprises. Some examples include: changes to the geopolitical landscape globally; changes to social preferences for the environment; or new technologies that radically shift the way we use energy and/or forest products.

In this project we will try to address some of the uncertainties associated with (1) statistical variability and quality of data and (2) functional relationships. We will use computer models that will allow us to consider webs of interactions at various scales that are too complex to think through any other way. Even so, numerous assumptions will be necessary using expert opinion based on the best available science, and some uncertainties such as #3 and #4 above will not be explored at all.

The future forest strategy for the Kamloops TSA will still be uncertain in spite of K2. Forest management over long time periods will always be too complex to allow prediction of the future

² Determine based on goals and objectives

³ Based on: Fletcher C. 2009. Making decisions under uncertainty. BC Ministry of Forests and Range. Strategic Initiatives, Forest Analysis and Inventory Branch, Victoria BC.

with any certainty, and climate change only adds to that fact. Nevertheless, K2 intends to address some of that uncertainty to make our choices for adaption more robust.

Scenarios

Scenarios – are internally consistent views or narratives of what the future might turn out to be – not predictions, but plausible alternative futures.

K2 and Scenarios – K2 is not trying to predict the future. It is trying to explore the future with a greater array of tools than K1. The computer models used in K2 will allow exploration of scenarios that include a variety of management actions interacting with each other and natural disturbances across landscapes, all in the context of a changing climate. The intent is to become aware of what could happen, so we can design management strategies that are more likely able to deal with what will happen.

Other Details - Scenario analysis allows planners and decision-makers to address uncertainty by systematically anticipating and assessing the range of plausible alternative futures in which today's strategies and plans will be implemented. Scenarios are not variations on a base case, such as high, medium and low. Instead, they represent different assumptions about uncertain influences and their plausible impacts.

Assumptions

Assumptions – are explicitly identified to bridge knowledge gaps and uncertainties (based on the best available science), allowing the K2 team to explore performance of indicators and targets (possibly of strategic objectives) over time.

K2 and Assumptions – to document and clarify our assumptions at every step in the project.

Other Details - Management of an ever-changing, highly complex, forested landscape for a broad array of values, that often conflict, is difficult. To avoid being paralyzed by the unknowns and uncertainties, we must make assumptions based on the best available science. Iterative cycles of planning, implementation, monitoring and research may clarify these assumptions over time. Some assumptions need to be explored over long time periods, and that exploration will surface additional questions. Therefore management of natural systems will never likely occur in the absence of assumptions. However, continuous learning and improvement of practice (adaptive management) through iterative exploration of assumptions may bring us ever closer to achieving our goals.

Risk

Risk – is the likelihood that an undesirable outcome will occur, considering the consequences associated with that outcome⁴.

K2 and Risk – K2 will not try to assess the likelihood or risk of climate changing in one way or another within the TSA over time. Rather, K2 may explore forest related probabilities (such as the probability of tree mortality in certain stand types), or risks (such as fire risk in urban interface settings) under selected climate change scenarios.

Other Details - Uncertainty and risk are often used interchangeably. They are related but quite different. Uncertainty is generally described but not quantified. Risk attempts to quantify the “likelihood” and “consequences” of uncertain outcomes to determine a preferred course of action. Risk is related to hazard but they are not the same. A hazard is an inherent property (in our case within the forest), regardless of the influences on it. For example, excessive logging slash poses a fire hazard. Fire risk considers both fire hazard and the exposure to relevant influences of concern (drying and chance of ignition) to determine a likelihood of fire.

Probabilities or likelihoods cannot be confidently assigned to many of the trends and hazards associated with climate change. Within the K2 project, risk or likelihood will only be utilized when climate change and other influences are assumed to fit with a particular scenario for those influences (see scenario). Considering a range climate change scenarios will enable the K2 team to consider plausible impacts, and design prudent strategies even though the actual future impacts are unknown.

Goal

Goal - is the overall intention for management with linkage back to values and key principles.

K2 and Goals – Goals for the TSA were assumed in K1 starting with provincial goals and LRMP goals, and then interpreted through the broad array of strategies and plans within the TSA. However, some general goals for key TSA values are still not entirely clear. Where this is the case, K2 will make some assumptions (assumed interpretations) to design strategic objectives, indicators and targets.

Other Details - Expressed as ultimate desires, goals are less tangible than objectives and often need interpretation to be well-understood. These tend to endure over long time periods, but may

⁴ It is useful to separate the “likelihood” or “probability” of an event occurring from the risk(s), which considers both the likelihood and the consequences, or the degree of unacceptable or undesirable impact from that event.

be altered as management toward them proves them to be unrealistic, or the values that they are connected to change. For example, a general goal for management of biodiversity may be – No net loss of species over time due to factors that may be controlled by the forest managers⁵.

Because K2 is not a planning process but an exploration of existing adaptive direction for climate change, explicit assumptions about goals will be useful if and when a planning process follows up on the robust strategies suggested in K2.

Strategic Objectives

Strategic Objectives – are the strategic conditions that need to be attained to achieve a forest management goal within the TSA (over time, considering climate change and the changing nature of the forests).

K2 and Strategic Objectives – The “direction” that emerged from K1 was mostly in the form of strategic objectives as defined above. With K2 we will explore these strategic objectives, using proposed indicators and targets to provide measurable elements and timelines.

Other Details – Strategic objectives are more tangible than goals and link goals to the conditions or situation being managed over time. Often one goal requires a number of objectives. Objectives are made measurable with timelines by indicators and targets (so you know when you have achieved them). The suite of objectives for one particular goal will change over time with the changing landscape being managed.

Hypothetical Example:

Using the hypothetical goal outlined above of “no species loss” for biodiversity, an initial analysis of the local forest over time reveals that the biggest emerging concerns are: continual decline of birch in one ecosystem type; loss and deterioration of old growth habitat in another; and loss of large old or dead ponderosa pine in another ecosystem type, all because of a concern regarding loss of sensitive species who rely on those habitats. A simple suite of strategic objectives linked to the example goal above (for no loss of species) may be:

- in one subunit - expand establishment of birch over time, and gradually increase presence of hardier broadleaf species to maintain key habitats for several sensitive species;
- in another subunit - design a strategy to maintain and encourage old growth features over time to maintain key habitats for several sensitive species;
- across the other subunit, more rapidly encourage the development of large ponderosa pine with old growth features (using silviculture) appropriately distributed to maintain key habitats for several sensitive species.

Note that the strategic objectives are much more tangible than the broad goal, but are not yet measurable, and lack meaningful timeframes – thus requiring the design of indicators and targets to facilitate implementation and monitoring.

⁵ This means that - Prudent steps will be taken where possible to reduce impacts from climate change and maintain species on the landbase.

Indicators

Indicators - are measurements or trends of interest that best reflect the progress toward strategic objectives.

Other Details - Indicators are useful both in modeling scenarios and in subsequent field-monitoring to evaluate potential and actual performance, and ultimately, success. Indicators used in modeling may differ from those used in monitoring since modellers often must incorporate assumptions to evaluate potential performance in the modeling environment. Monitoring indicators more directly measure actual performance on the ground.

For example, monitoring indicators for the strategic objective related to the conservation of biodiversity (suggested above) may be built around responses of sensitive species, and will need to be assessed in the field over long periods of time. In the meantime, modeling indicators associated with the same strategic objectives may use indices and trend-lines for stand and landscape features (as a surrogate for the actual well being of the species), based on the best science that links these features to species responses.

There is a perception by some that indicators can be created that would be valid province-wide. While it may be possible to set indicators provincially to assess performance of broad provincial goals, indicators of performance for strategic objectives on a forest must be designed specifically for those local objectives and environmental conditions using specialist advice and the best available science.

Targets:

Targets – are measurable direction for management actions designed to ensure that indicators remain favourable over time (and strategic objectives are therefore achieved).

Other Details - Targets differ functionally from indicators in that they become the desirable operational direction for management actions. Sometimes targets and associated indicators are similar or exactly the same – possibly as in targets and indicators for tree species diversity in young plantations.

Sometimes targets differ considerably from their associated indicators. Using the same example above for indicators (for conservation of biodiversity strategic objectives) – targets may include specific thresholds for stand and landscape features to be attained in management activities (e.g., 20% in block retention). Because we cannot wait to see how some targets will influence some indicators over time, targets are explored and improved using computer models to forecast and compare scenarios. Operationally, targets are usually monitored for compliance, while indicators are monitored to see if, and when, associated targets need to be changed, or if strategic objectives (or even associated goals) are realistic.

A5. Key Modelling Questions Proposed by Client Groups

Key K2 Questions by Model(s)

June 27, 2010 Version 1.1

TACA - related questions

1. What is the regeneration success of each key species over time?

- a. There are two aspects to this question – one short term (for planting right now or over the next 10 years and considering their growth over time), and one long term to show how regeneration risks of species changes over time (this is mostly to facilitate modeling over time across the landscape). It may help to portray output in a table of species that shows a risk ranking for regeneration /establishment, success (SEE EXAMPLE BELOW).

Species	BEC Variant	Prob of Successful Regeneration (Planted 2010-2020)			Long Term (2050) Productivity Rating (% of no CC scenario)			Long Term (2080) Productivity Rating (% of no CC scenario)		
		Wet	Mesic	Dry	Wet	Mesic	Wet	Dry	Mesic	Wet
Fd	IDF xh									

- b. Species of interest include Fd, Py, Pl, Lw, Cw, Bl, Sx, Pw, At, Act, Ep, Yc, Pa (white barked pine)
- c. The species could be grouped by BEC variant and then into wet, dry, mesic categories for each (these can later be aggregated for use in the landscape model)
 - i. We should use the new 2006 version of BEC (as there are currently no stocking standards for this and this table could help inform options) – using “groups of site series” – dry, wet, mesic.
- d. The table should include a “when” component – ranked risk of mortality (low, mod, high) to help decide *when* the spp. should be planted – e.g., use four time points for the same output: present, 2020, 2050, 2080.

2. Where can we push some species?

- a. Which species will go be able to go where and what is their ability to adapt?

3. Are there non-native species that would be useful to explore? (e.g. Jeffrey pine)

4. Can we explore detailed information that will inform regeneration success (and growth over time of species - slope, elevation, aspect?)

FORECAST related questions

NOTE – some of these may also need to be modeled with the landscape model to answer completely.

5. **Can we explore detailed information that will inform regeneration success (and growth over time of species - slope, elevation, aspect?**
6. **How will adaptive strategies be applied at the stand level to leave structure – can we model several scenarios and compare? (i.e. what are harvesting options to consider?)**
 - a. **To what extent can we look at partial-harvesting? What are we most interested in?**
7. **Can we characterize a risk to mature stands – mortality related to drought and other related influences? Which stands are most vulnerable (and when) – so we can allocate harvesting priorities over time.**
 - a. It's very difficult to make the mortality call, but risk can be ranked using expert opinion, based on the various stress from the models. If we want to do this, it would be a next step of exploration...i.e. making calls about mortality
 - i. We could run a few scenarios that we think are possible where we assign mortality based on stress and what we know now about existing disturbance agents, to see what happens (at landscape level) and where over time
 - ii. Then we can identify target stands to harvest (there is lots of complexity here...what size stands, how much of a stands, etc?). Its complicated, but we need to ask questions on stands at risk (by age class, composition) and put into risk categories
 - iii. First pass could inform a scenario and *then* we introduce a rule
 - iv. simplest approach is to introduce a rule whereby after a certain level of stress over a certain amount of time, certain spp. die. (we would need forest health people to help determine the stress level)
 - v. stress index can help inform about mortality and also help inform some targeted harvesting to pick off lower performing stands
 - b. We could list stands by risk category
 - i. By species age, and Biogeoclimatic location.
 - ii. Need to create risk categories, i.e., what constitutes High, Medium and Low risk
 - iii. Begin with moisture stress from the models.
 - iv. At risk to what? Will require expert opinion – e.g., Armillaria, Beetles...to propose levels of mortality.

- v. The idea being these will help inform management scenarios – i.e., target high risk stands at some point.

8. How does climate change influence insects, rusts and diseases in different stands?

- a. How do we make assumptions for these?
- b. How do we incorporate uncertainty?
- c. How does climate change impact insect life cycles and synchronicity with host phenology and how quickly will the insects adapt?
- d. What are the key disturbance mechanisms (beyond fire) will hit the key tree species of concern:

e.g. Fd – Armillaria, phellinus, bark beetles, budworm, tussock moth.

e.g Pli – bark beetles, rusts, gall, stalactiform etc., pitch moth, dothistroma and other blights, mistletoes, root collar weevil and terminal weevil.

Can we look at historical trends for susceptibility to different bugs? How useful is this?

- e. What about other abiotic disturbances?
 - i. Increased extremes in wind, snow, and ice storms.
 - ii. Especially if they become a vector for other impacts – insects etc.
 - iii. What about the impacts of early and late frosts on regeneration of trees in conjunction with phonological cycles that are out of sync with climate change.

FPS related questions (landscape modelling)

9. What happens to our indicators if we continue with business as usual (Current Practices)?

10. How is climate change going to impact AAC's and what can we do to influence this expected future?

- a. **Do we also want to look at harvest flow by tree species (or age/size classes) as some sort of value characterization?** (*Anne Comment – Yes can do that*)
- b. What will drive timber flow over time? Will it be influenced more by objectives or by context (changing conditions of the landbase) – how do we find a balance?
- c. What happens to timber flow if we wait to harvest the existing pine?

11. How will the size and nature of the THLB change over time? Where will we harvest, when and how?

12. If we manage more yellow pine in lower elevations, can we get enough of it to make it a valued species? What are the economic considerations here?

- a. Should we be looking at other alternatives such as more drought resistant Douglas-fir or other (different strains of Py)?

13. How much native (undisturbed) habitat is out there now? (as a starting point)

- a. Need Anne and Laurie to define some habitats or habitat elements to track – based on stand structure / terrain characteristics.

14. How will adaptive strategies applied at the stand level to leave structure influence habitat and biodiversity over time?

- a. What if we are totally reactive and clearcut and salvage with minimum legal obligations for retention and reserves?
- b. What if we have a strategy where we have a higher level of reserves and retention,
 - i. With a salvage strategy?
 - ii. With a pre-emptive harvesting?
- c. When we model this how do we distribute this retention?
 - i. We decided to take another look at the Tolko retention strategy with a few folks like Dennis and others.
- d. What is cost to habitat structures and pattern is we harvest vulnerable stands pre-emptively?

15. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?

16. How will disturbances be influenced by climate change and how will this influence patterns and structures across the landbase? – many other questions are related to this.

- a. How will natural disturbance influence structure and composition of stands and structure and patterns cross the landscape?
- b. How will harvesting (and associated management activities) influence structure and composition of stands and patterns across the landscape.
- c. With different harvesting strategies – salvage, pre-emptive harvest of susceptible stands.
- d. How does natural disturbance overlap with harvesting and influence it (salvage)?

17. What will happen to the broadleaf component across the landscape?

- a. Extent?
- b. How likely will it be able to reach old age – for habitat.

18. What might be the impact of fuel management activities on habitat and biodiversity at the landscape level?

- a. Are we actually reducing the risk of fires under the more severe climate change scenario?

- i. For Habitat and Species?
 - ii. Or for people and property, timber values and other values?
 - b. What if we undertake these fuel management activities but it doesn't help with extent, impact and intensity of fire – are we wasting money and having a large impact on habitat?
 - c. What is impact of fuel management just around communities versus widespread?
- 19. FPS does not have ability to easily do light surface fires versus stand replacing fires, so if we want surface fire in the model will have to create those results some other way. Would FPS have to burn a whole area or is it able to leave patches? Do fires that have high impacts on people also have high impacts on habitat and wildlife? If not, should we differentiate?**
- 20. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time**
- a. Log susceptible stands
 - b. Follow extensive disturbance with extensive salvage.
- 21. If we develop mortality scenarios, can we look at ECA limits that occur w/in a (or some) watershed(s)?**
- a. Will water questions be a driver?

A6. Modelling Indicators to Explore Modelling Questions

DRAFT - K2 Initial Modeling Indicators for Resource Management Goals

Jan 5, 2011

Background

Indicators

In a strategic planning environment indicators are measurements or trends of interest that best reflect the progress toward strategic objectives. Because K2 is not a strategic planning exercise per se, but rather an investigation of questions posed by clients, the indicators are linked to both those questions, and the broader goals established for K2. These questions and goals were clarified by the K2 team and the clients at a workshop in Kamloops in June of 2010.

Indicators are useful both in modeling scenarios (as in K2) and in subsequent field-monitoring to evaluate potential and actual performance, and ultimately, success in achieving the strategic objectives. Indicators used in modeling may differ from those used in monitoring since modellers often must incorporate assumptions to evaluate potential performance in the modeling environment. Monitoring indicators more directly measure actual performance on the ground.

Indicators are often tied to thresholds that are known or estimated to be acceptable based on current knowledge. Often they are just trend indicators of interest based on their trend up or down relative to the current or some other baseline situation.

The Management Goals

The following goals were chosen to provide context for the project when modeling to answer project questions, thus guiding the establishment of indicators. We may in the end have some feedback to refine these goals at the end of the project, depending on how realistic they appear in light of potential climatic impacts.

These goals fit with our definition of goals under the definitions established for this project¹. They also have linkages to the intent provided by current 2008 CSA SFM guidance for certification within the TSA. The Timber objective also fits with the stated current provincial direction for the Ministry of Forests, Lands and Mines.

OVERARCHING
(ULTIMATE)
PROJECT GOAL

– Encourage resilience within the ecosystems to maintain productive, “healthy” forest that will continue to be able to provide future benefits (for timber, biodiversity, etc.) in spite of the disturbances (and surprises) that may result from climate change.

¹ From K2 Definitions Feb 4-10 – Goals are the overall intention for management with linkage back to values and key principles.

1. TIMBER – *Maintain or increase the flow of timber volume and/or value over time.*
2. HABITAT / BIODIVERSITY – *No loss of native species due to management over time.*
3. FIRE – *Minimize fire risk to people and property.*

The Management Questions

Complementary to the management goals, management questions were formulated to express key interests of Kamloops TSA clients within each broad management goal (File: *Questions with Comments June 27-10 V 1.1*). Management questions were consulted during the development of indicators to ensure that client interests were being addressed. A complete set of indicators were then built for each goal to ensure all key aspects of the goal itself would be measured.

Relevant questions are referenced for each indicator in the sections that follow. Some indicators have no questions referenced as they were built to complete the indicator set for the goal, without having a clear connection to a client question.

The Approach

The following indicators are based on the four broad management goals and the associated modeling questions that emerged through discussions with project clients in Kamloops. An indicator may be mostly related to the goal itself; or both the goal and questions from clients. The indicator should ensure the output is judged based on the best available science (within the constraints of the modeling);

The following indicators are based on a combination of the following:

- a. Indicators used for modeling in other BC planning processes based on best available science and expertise (TSR, and other selected SFM planning processes);
- b. The FREP Report #20 (*Monitoring Forest and Rangeland Species and Ecological Processes to Anticipate and Respond to Climate Change in BC*).
- c. The ability of the K2 suit of models to provide reasonable outputs (with assumptions) that can be used to examine the indicators.

Some of the indicators used in the FREP Report #20 helped formulate indicators for the K2 modelling exercise. Many of the FREP indicators are relevant for field monitoring of climate change impacts over time, but are not suited for a modelling exercise – these were therefore not used or substituted for indicators that could be modelled.

NOTE: This paper illustrates the current thinking in the K2 team for indicators. These indicators may be altered or substituted for alternates during the modelling process, as required.

A. Indicators for Timber Harvesting

GOAL = Maintain or increase the flow of timber volume and/or value over time.

Interpretation – This is a common goal for timber and is still used today. The balance between value and volume has been the focus of much debate and is yet unclear because timber value changes with markets and products. A reasonable approach to addressing value might be to maintain a “balanced portfolio” with a good range of species and timber sizes.

For the purposes of this project, it is considered reasonable to view the maintenance of volume flows as being the primary objective, with value as a secondary objective (see indicator 5). The volume flows being maintained will be those based on the recent TSR 4.

A1. Harvest Flow over Time

Indicator	• Harvest flow in m³/year established for short, mid, and long term.
Threshold or Trend	<ul style="list-style-type: none">• Threshold – undesirable if it drops below projected BAUBC² levels (the base case).• Trend – More is better.
Modeling Scale	<ul style="list-style-type: none">• Assessed at landscape with possible subreporting by Ecological Subzone Groups to explore trends.

Rationale for indicator A1

This indicator most directly links to the timber management goal providing an overall view of impact on what is considered to be a key timber management concern.

A2. Size of the Timber Harvesting Landbase

Indicator	Changes in Area (ha) – based on stand volumes / productivity that drop below a threshold for a potential economic harvest.
Threshold or Trend	<ul style="list-style-type: none">• Threshold – undesirable if it drops below BAUBC levels (expected with BAUCC).• Trend – More is better (but there may be little that can be done).
Modeling Scale	<ul style="list-style-type: none">• Tallied and reported at landscape level – based on information from stand level FORECAST modeling. The landscape model will receive information on what stands

² BAUBC – Business as Usual Base Case

	have dropped below a threshold – and will tally.
Associated Question(s) (June 27, Version 1.1)	12. How will the size and nature of the THLB change over time? Where will we harvest, when and how?

Rationale for indicator A2

This indicator gets at one of the important questions linked to the timber management goal – that of impacts on the size of the productive forest due to climate change.

A3. Trends in timbered landscape condition over time.

a. Indicator – Species profile	<ul style="list-style-type: none"> • Area and/or proportion of species and stand types on the THLB and the NTHLB. • AS REQUIRED (to look at trends of interest)
Threshold or Trend	<ul style="list-style-type: none"> • Trend indicator – No target. The long term trend will be carefully judged against the current situation, which could be favourable (or not) right now.
Modeling Scale	<ul style="list-style-type: none"> • Rolled up at the landscape level based on changing species composition from stand level FORECAST modelling. • As required (where we see trends we want to look at) – may be reported for a specific ecological unit.

b. Indicator – Age class profile	<ul style="list-style-type: none"> • Area and/or proportion of age classes on the THLB and the NTHLB • AS REQUIRED (to look at trends of interest)
Threshold or Trend	<ul style="list-style-type: none"> • Trend indicator – No target. The long term trend will be support inferences and rationales for other trends (AAC and biodiversity trends).
Modeling Scale	<ul style="list-style-type: none"> • Rolled up at the landscape level based on changing age-class composition from stand level FORECAST modelling. • As required (where we see trends we want to look at) – may be reported for a specific ecological unit.

c. Indicators – Mortality	<ul style="list-style-type: none"> • Amount of mortality occurring on the THLB and the NTHLB
Threshold or Trend	<ul style="list-style-type: none"> • Trend indicator – No target. The long term trend will be carefully judged against the current situation, which could be favourable (or not) right now.
Modeling Scale	<ul style="list-style-type: none"> • Assessed at landscape, reported by present NDT category and/or Ecological Subzone Group level.

Associated Question(s) (June 27, Version 1.1) for Indicators 4a- 4c:
<p>8. Can we characterize a risk to mature stands – mortality related to drought and other related influences? Which stands are most vulnerable (and when)?</p> <p>17. How will disturbances be influenced by climate change and how will this influence patterns and structures across the landbase?</p>

Rationale for indicator A3

This is a very important group of indicators (3a-c) that addresses a number of complex questions. It provides a picture of the changing landscape. It could be used to assist in an assessment of value, based on the “diverse portfolio” concept of maintaining a range of sizes and species across the landbase. It will also provide information at the landscape scale that can be used to assess other goals related to biodiversity, and fire management. Therefore output should be considered carefully to address indicators set for those goals as well. The output will provide a learning opportunity when compared against the expert derived narratives of the future speculated in K1.

A4. Trends in growing stock volume over time.

Indicators	<ul style="list-style-type: none"> • Volume of growing stock (timber volume) on the landbase over time.
Threshold or Trend	<ul style="list-style-type: none"> • Trend - Expect to see less growing stock over time if harvesting continues as in BAUBC and increased mortality is also occurring. <ul style="list-style-type: none"> ○ If growth and harvesting are in balance on the THLB in the long term, we will see a consistent amount of growing stock (steady state condition). This is often used as a feedback mechanism to set the long term harvest level.
Modeling Scale	<ul style="list-style-type: none"> • Rolled up at the landscape level based on changing growing stock volumes from stand level FORECAST modelling. • As required (where we see trends we want to look at) – may be reported for a specific ecological unit.

Associated Question(s) (June 27, Version 1.1)	<p>8. Can we characterize a risk to mature stands – mortality related to drought and other related influences? Which stands are most vulnerable (and when)?</p> <p>17. How will disturbances be influenced by climate change and how will this influence patterns and structures across the landbase?</p> <p><u>Comments</u></p> <p>See landscape condition comments (indicator suite 3)</p>
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Rationale for indicator A4

This is a key indicator used in TSR analysis to help inform options for long term harvest levels.

A5. Timber Values (also see indicator #3).

<i>Potential Indicator</i> ³	<ul style="list-style-type: none"> Timber Values in \$/m³.
Threshold or Trend	<ul style="list-style-type: none"> Threshold – undesirable if it drops below projected BAUBC levels. Trend – More is better.
Modeling Scale	<ul style="list-style-type: none"> Assessed at landscape using stand specific values assigned based on species distribution and average species values over a nominal period.
Associated Question(s) (June 27, Version 1.1)	<p>Mostly the timber goal – and:</p> <p>13. If we manage more yellow pine in lower elevations, can we get enough of it to make it a valued species? What are the economic considerations here? Should we be looking at other alternatives?</p>

Rationale for indicator A5

This indicator is a direct measure of timber value. However, it is based on past trends for value of species and sizes, and may be misleading. Nevertheless, it is a useful starting point for a value discussion.

A6. Economics of Harvesting and Associated Development (TENTATIVE).

These indicators are being considered but have not been confirmed as some discussion is required to ensure that that appropriate conclusions will be drawn from the results.

³ *Potential Indicators set in italics* – may be tracked depending on the ability of the models, which will be clearer once modeling is underway.

<i>TENTATIVE Indicator</i>	<ul style="list-style-type: none"> • Costs in \$/m3. • Focused specifically on those costs that are most likely to fluctuate due to climate change.
Threshold or Trend	<ul style="list-style-type: none"> • Threshold – undesirable if it rises above projected BAUBC levels. • Trend – Less is better.
Modeling Scale	<ul style="list-style-type: none"> • Assessed at landscape, BUT it is not clear which landscape model will be suitable or if it indeed will be modeled
Associated Question(s) (June 27, Version 1.1)	None – just the timber goal.

Rationale for indicator A6

This indicator addresses the second part of the economic question – that of harvesting and related costs. A detailed analysis of fixed and variable costs over time can be very complex. For our purposes we will try to keep this reasonably simple, but first will need to confirm the usefulness of the output.

A7. Regeneration Success

Indicator	<ul style="list-style-type: none"> • Likelihood of successful regeneration and productivity over time by species and general site type for each subzone grouping.
Threshold or Trend	<ul style="list-style-type: none"> • Trend – Comparisons of projections against what we might consider normal today. • Will use TACA and FORECAST to develop tables showing probability of successful regen and productivity at various time intervals. See comment – this may help link back to point one. • NOTE: This links to other indicators - productivity changes due to regeneration success will be reflected in landscape modeling and ultimately in other indicators (e.g. growing stock changes over time).
Modeling Scale	<ul style="list-style-type: none"> • Stand level (TACA and FORECAST) by stand unit and ecological group. • Will link to the landscape level by helping to <u>rationalize</u> changes in landscape indicators BUT is not modeled or

	reported at that level.
Associated Question(s) (June 27, Version 1.1)	1. What is the regeneration success of each key species over time? 2. Where can we push some species? 5. Can we explore detailed information that will inform regeneration success (and growth over time of species - slope, elevation, aspect?

Rationale for indicator A7

This indicator addresses a key question from practitioners – one that relates as much to the other management goals as the timber goal, since it will influence the composition of the stand units that will comprise the future landscape. While this indicator may provide some clues relating to trends with other indicators, it will also be of direct benefit to local practitioners – providing guidance for more resilient regeneration planning over time.

B. Indicators for Habitat and Biodiversity

GOAL = *No loss of native species due to management over time.*

Interpretation –This goal reflects the current 2008 CSA Criterion 1 (Biological diversity) - *Conserve biological diversity by maintaining integrity, function, and diversity of living organisms and the complexes of which they are part.* Because there are many influences within and outside of the TSA that could affect biodiversity and the range of species, we have specified “no loss due to management” – meaning forest management within the TSA. This statement recognizes that climate change may alter biodiversity in ways we can’t change or manage, but emphasizes that we don’t want the management of our forests to exacerbate those changes and also recognizes that management can improve species adaptability to climate change.

An obvious and likely the best way to monitor for this goal is to design indicators for key sensitive species⁴. However, due to the limitations of the proposed modeling there is a need for surrogate measures for “no loss of species”. These are in the form of key ecological and habitat elements and attributes at various scales.

B1. Old Forest Habitats.

Indicator	• A level of old forest over the Case Study area by ecological subzone group.
Threshold or Trend	<ul style="list-style-type: none">• A graduated set of thresholds will be designed based on the best available science with:<ul style="list-style-type: none">○ A baseline set based on the Biodiversity Guidebook thresholds for the range of BEOs (see ANNEX 1).○ Other “thresholds” based on thresholds used elsewhere in BC combined with best science.• Will include the THLB and NTHLB combined.
Modeling Scale	<ul style="list-style-type: none">• Assessed at landscape
Associated Question(s) (June 27, Version 1.1)	<p>16. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</p> <p>20. Would the landscape model have to burn a whole area or is it able to leave patches?</p> <p>21. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time</p>

⁴ For example using a well designed field sampling approach.

Rationale for indicator B1

Concern over old forest derives mostly from the amount of time it takes for such stages to develop. Old seral forest are home to many organisms, some respond to the microclimatic conditions (e.g., many lichens and bryophytes,) some respond to the stand structures of older forests. There are well-documented relationships between many species and the stand structures of older forest. Sometimes, particularly for vertebrates, if these structures are retained, then younger forests can serve as habitat. Often reasons why organisms prefer old growth are unclear (e.g., many invertebrates) and probably are a mix of microclimate, structures that take a long time to develop (e.g., large limbs, shedding bark) time for biomass to accumulate, and time for dispersal and growth to occur (e.g., many lichens).

B2. Broadleaf forest habitats.

Indicator	• Percent broadleaf as a proportion on the landbase
Threshold or Trend	<ul style="list-style-type: none">• Trend – near current levels or• Slightly higher is better.
Modeling Scale	<ul style="list-style-type: none">• Rolled up and reported at landscape level, based on FORECAST information fed into the landscape model.
Associated Question(s) (June 27, Version 1.1)	<p>16. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</p> <p>18. What will happen to the broadleaf component across the landscape?</p> <p>21. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time</p>

Rationale for indicator B2

Maintaining broadleaf trees, and allowing broadleaf species to become old, is very important for maintaining biodiversity. Broadleaf trees develop heartrot earlier than do conifers and thus provide cavity sites for a wide variety of species at a relatively early age. Inclusion of a broadleaf tree component throughout the landscape over time may also help to provide potential fire breaks and additional cavity nesting habitat and CWD.

B3. Connectivity/ Patch Size / Fragmentation (Edge to Interior ratios).

Indicator	<ul style="list-style-type: none">• NONE – not to be used at this time, since disturbance will not be modelled spatially under FPS.• We were considering an indicator of % interior forest conditions (mature or old forest > 100m from a managed and/or younger edge). Right now this is considered out of scope. May be able to do something with Dynaplan (not yet clear).
Associated Question(s) (June 27, Version 1.1)	<p>16. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</p> <p>20. Would the landscape model have to burn a whole area or is it able to leave patches?</p> <p>21. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time</p>

Rationale for indicator B3

Concern over patch size distribution originated with concern over effects of habitat loss and fragmentation. There is clear evidence of effects on species as habitat is reduced (that is as patches of habitat get smaller), there is also evidence that breaking up of habitat into smaller pieces or patches, without actual habitat loss, has some (negative?) effect on organisms.

Generally, concern over patch size is primarily a concern over size of old forest remnants or size of young forest openings. The concern is about keeping enough habitat and making sure similar habitats are not isolated from each other (to allow movement and dispersal). There are no ideal distributions of patch size and shape.

Keeping old forest and forest interior is more important, and ensuring that old forest will be generated in sizable pieces, with some connections is important. These effects are usually expressed through effects of edges and loss of forest interior and effects of isolation as distances between patches of habitat become large. Patch sizes and forest interior amounts will have changed with some frequency during the variety of past disturbances. However, increased disturbance due to climate change and harvesting may reduce the amounts of forest interior naturally found in the TSA.

Forest interior is defined as areas away from the effects of edges. It may be beneficial to maintain interior habitat because although edges benefit some species, some are sensitive to edges and affects of nearby openings. Reviews of edge effects (Kremsater and Bunnell 1999) suggest that microclimate variables (radiation, wind, relative humidity) can be influenced up to 200 m into a forest by adjacent openings, but most effects taper off by 100 m into the forest. The depth of the microclimatic edge effects depends on the exposure of the edge. South-facing edges tend to have longer depth of edge than those with northern

exposures. (there is more info on this that should be added sometime based on work at the various silvicultural system trials in the Kamloops region)

B4. Retention and Distribution of Mature-to-Old Trees / Patches.

Indicator⁵	<ul style="list-style-type: none"> • Amount of mature and old across the landbase. • Perhaps reported by ecological unit – as required. • We were considering an indicator to look at distribution of retention. This is not possible and out of scope at this point. May be able to do something with Dynaplan (not yet clear).
Threshold or Trend	<ul style="list-style-type: none"> • Trend up or down – May be more specific - to be determined.
Modeling Scale	<ul style="list-style-type: none"> • Rolled up at the landscape level based on changing age-class composition from stand level FORECAST modelling. • As required (where we see trends we want to look at) – a report is produced for that unit.
Associated Question(s) (June 27, Version 1.1)	<p>15. How will adaptive strategies applied at the stand level to leave structure influence habitat and biodiversity over time?</p> <p>16. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</p> <p>20. Would the landscape model have to burn a whole area or is it able to leave patches?</p> <p>21. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time</p>

Rationale for indicator B4

Species richness and functional dispersal seem to be positively influenced by the degree of connectivity throughout the landscape (Collinge 1998, Haddad 1999, Schmieglow et al. 1997, Wolff et al. 1997). However, elegant reserve designs with functional connective corridors may be easier to create in theory than in practice (Bunnell 1998, Feldman et al. 2002 and Franklin et al. 1997). Indeed, retention of important stand structures during harvesting is central to such an approach. In addition to the enhancement of connectivity in the managed landscape, Franklin et al (1997) identified two other important functions of stand level retention: “lifeboating” species and processes immediately after logging and before forest cover is re-established; and “enriching” re-established forest stands with structural features that would otherwise be absent.

⁵ *Potential Indicators set in italics* – may be tracked depending on the ability of the models, which will be clearer once modeling is underway.

As uncertainty increases with influences such as climate change, it becomes more important to retain more structure to allow organisms refuge and capability to move in response to the variety and intensity of disturbance. As well, this priority should influence how much and in what pattern trees are salvaged from wildlife areas and areas attacked by insects. Simply put, as areas of disturbance increase within a landscape, more structure at the stand level should be retained.

B5. Dead standing trees (snags).

Indicator	<ul style="list-style-type: none"> Proportion of larger/ older trees dead across the Case Study area (using snags/ha).
Threshold or Trend	<ul style="list-style-type: none"> Trend against current levels
Modeling Scale	<ul style="list-style-type: none"> Assessed at stand unit level, and rolled up to landscape
Associated Question(s) (June 27, Version 1.1)	<p>15. How will adaptive strategies applied at the stand level to leave structure influence habitat and biodiversity over time?</p> <p>16. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</p> <p>20. Would the landscape model have to burn a whole area or is it able to leave patches?</p> <p>21. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time</p>

Rationale for indicator B5

The importance of snags for habitat and general biodiversity is well known. In the Kamloops TSA, several red- and blue-listed species utilize snags for key life stages and functions. Larger snags are generally considered more useful to a wider range of species for a broader range of uses than smaller snags. While large snags can be maintained relatively simply, they are difficult to create over time. Retention as well as recruitment of large trees is important to ensure a sufficient supply of large snags and large down wood in the future.

B6. Coarse Woody Debris.

Indicator	<ul style="list-style-type: none"> CWD in m³/ha on THLB.
Threshold or Trend	<ul style="list-style-type: none"> Trend over time (against current situation) – on the THLB Possibly reported at the Ecological Unit level as required if there is an interesting trend to explore.
Modeling Scale	<ul style="list-style-type: none"> Assessed at stand unit level and rolled up to landscape.

Associated Question(s) (June 27, Version 1.1)	<p>15. How will adaptive strategies applied at the stand level to leave structure influence habitat and biodiversity over time?</p> <p>16. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</p> <p>21. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time</p>
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Rationale for indicator B6

The scientific literature provides little guidance on how much coarse woody debris (CWD) to retain in forested stands. This is partly because studies assessing down wood have found very high variability among sites in similar ecosystems, and partly because vertebrates show inconsistent and variable responses to CWD volumes (Bunnell et al 1999).

Just as for snags, however, simple abundance of down wood is not an adequate measure. For habitat, often the value is in keeping large pieces. Whereas a certain volume may be quite adequate to maintain many species, if that volume does not include many larger diameter pieces then it will not provide habitat for some more sensitive organisms. It should also be noted that large CWD pieces are far less of a fire hazard than small pieces and may not need to be removed during fuel management activities.

B7. Ungulates (designated winter ranges).

Indicator	<ul style="list-style-type: none"> • % of UWR area meeting providing cover habitat according to the age criteria in the current GAR Order.
Threshold or Trend	<ul style="list-style-type: none"> • Trends against the current situation. • Note changes in structure of UWRs - % cover etc – if required.
Modeling Scale	<ul style="list-style-type: none"> • Assessed at landscape
Associated Question(s) (June 27, Version 1.1)	<p>16. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</p> <p>20. Do fires that have high impacts on people also have high impacts on habitat and wildlife? If not, should we differentiate?</p> <p>21. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time?</p>

Rationale for indicator B8

For widely dispersed ungulate species in the TSA, winter range habitat is considered as the most constrained critical habitat to sustain healthy populations. Therefore, understanding how climate change will influence the nature of these habitats is an important consideration. It is reasonable that this consideration will be tempered within the context of the changing requirement for high quality winter range, as climate change may reduce the need for thermal cover and/or snow interception for some ungulates (deer).

B9. Species at risk or of concern (tentative).

<i>Potential Indicator</i>⁶	<ul style="list-style-type: none"> It may be possible to develop a (post hoc table – after modelling) listing species at risk in one column and noting direction of change to their habitat. (e.g. below)
Threshold or Trend	<ul style="list-style-type: none"> Trend over time (against current situation) – by ecological subzone group. <i>Note: without spatial information regarding retention or forest interior, this can only be done using the amount of retention left.</i>
Modeling Scale	<ul style="list-style-type: none"> Stand level – reported post hoc – not part of modelling.
Associated Question(s) (June 27, Version 1.1)	<p>15. How will adaptive strategies applied at the stand level to leave structure influence habitat and biodiversity over time?</p> <p>16. How will the cumulative footprint of natural disturbance and harvesting disturbance and management impact habitat and biodiversity over time?</p> <p>21. How will the “Climate Change Adaptive Harvesting Strategies” impact habitat and biodiversity over time</p>

Species at risk	Habitat 1	Direction of Habitat 1	Habitat 2	Direction of habitat 2	Overall
Flammulated owl	Large Ponderosa Pine	▼	Thickets of shrubs	▼	▼
etc					

⁶ ***Potential Indicators set in italics*** – may be tracked depending on the ability of the models, which will be clearer once modeling is underway.

C. Indicators for Fire Management

GOAL = Minimize fire risk to people and property.

Interpretation – To minimize fire risks in the urban rural interface, and in or near areas with concentrated infrastructure and recreational activities. It will be useful to check with Nikki Rivette (the fire management specialist in Kamloops Region) to determine if we are missing anything.

C1. Area burned over time, and potential consequences.

Indicators	<ul style="list-style-type: none">• Area burned (ha) over time. <p>Note: We wanted to look at size and the distribution of fires across the landscape - but right now that is out of scope. May be able to do something with Dynaplan (not yet clear).</p>
Threshold or Trend	<ul style="list-style-type: none">• Trends against current or past 20 to 30 years?
Modeling Scale	<ul style="list-style-type: none">• Assessed at landscape
Associated Question(s) (June 27, Version 1.1)	19. What might be the impact of fuel management activities on habitat and biodiversity at the landscape level?

Rationale for indicator C1

Southern and central parts of B.C. are expected to experience drier summers thereby potentially increasing the frequency, severity and intensity of fires. The length of the fire season, as defined by climatic variables within the Fire Danger Rating System is a useful mechanism to reflect the potential for more frequent, and more severe wildfires.

C3. Change in Annual Fire Severity Ranking.

Potential Indicator	<ul style="list-style-type: none">• % change in fire severity by ecological group over time
Threshold or Trend	<ul style="list-style-type: none">• Trends against current situation.
Modeling Scale	<ul style="list-style-type: none">• Assessed at ecological unity level. Separate modeling completed by CraigNitschke
Associated Question(s) (June 27, Version 1.1)	17. How will disturbances be influenced by climate change and how will this influence patterns and structures across the landbase? 19. What might be the impact of fuel management activities on habitat and biodiversity at the landscape level?

Rationale for indicator C3

The fire severity classes reflect potential changing impacts from fire.

C2. Fire Return Interval

<i>Potential Indicator</i>	<ul style="list-style-type: none">• Mean length of the fire return interval (years) over time.
Threshold or Trend	<ul style="list-style-type: none">• Trends against current or past.
Modeling Scale	<ul style="list-style-type: none">• Assessed at ecological unit level. Separate modeling completed by CraigNitschke
Associated Question(s) (June 27, Version 1.1)	19. What might be the impact of fuel management activities on habitat and biodiversity at the landscape level?

Rationale for indicator C2

Southern and central parts of B.C. are expected to experience drier summers thereby potentially increasing the frequency, severity and intensity of fires. The length of the fire season, as defined by climatic variables within the Fire Danger Rating System is a useful mechanism to reflect the potential for more frequent, and more severe wildfires.

C2. Fire Season (tentative) – not confirmed yet – may not be required

<i>Potential Indicator</i>	<ul style="list-style-type: none">• The annual length of the fire season.• As defined by climatic variables affecting the Fire Danger Rating across the Case Study area.
Threshold or Trend	<ul style="list-style-type: none">• Trends against current or past 20 to 30 years?
Modeling Scale	<ul style="list-style-type: none">• Assessed at ecological unit level. Separate modeling completed by CraigNitschke
Associated Question(s) (June 27, Version 1.1)	19. What might be the impact of fuel management activities on habitat and biodiversity at the landscape level?

Rationale for indicator C2

Southern and central parts of B.C. are expected to experience drier summers thereby potentially increasing the frequency, severity and intensity of fires. The length of the fire season, as defined by climatic variables within the Fire Danger Rating System is a useful mechanism to reflect the potential for more frequent, and more severe wildfires.

D. Other Non-Timber, Non-Habitat Indicators

While these indicators may not be directly related to any of the management goals, they may be instructive regarding impacts on other values in the Kamloops TSA (beyond the key management goals for this project).

D1. Allowable Disturbance for Visual Quality.

Indicator	<ul style="list-style-type: none">• The proportion of the area in Modification, Partial Retention, and Retention VQOs that continues to meet the % disturbance requirements.
Threshold or Trend	<ul style="list-style-type: none">• Thresholds – maximum disturbance percentage greater than a given height as assigned to each visual polygon in the Case Study area, calculated according to <i>Procedures for Factoring Visual Resources into Timber Supply Analyses (MoFR 1998)</i>.
Modeling Scale	<ul style="list-style-type: none">• Assessed at landscape
Associated Question(s) (June 27, Version 1.1)	

Rationale for indicator D1

The % disturbance by height class is a common method to assess landscape level attainment of visual quality objectives.

D2. ECA in Community and Domestic Watersheds.

Indicator	<ul style="list-style-type: none">• The proportion of the upper 60% of community and domestic watersheds that continues to meet the % ECA requirements.
Threshold or Trend	<ul style="list-style-type: none">• Thresholds – maximum of 20% ECA in the upper 60% of these watersheds.
Modeling Scale	<ul style="list-style-type: none">• Assessed at landscape
Associated Question(s) (June 27, Version 1.1)	

Rationale for indicator D2

ECA is a common method to assess impact of harvesting on water flows.

E. Potential Indicator of Resilience - Proposed – status to be determined at end of modelling

It may be useful to build an “index of resilience” to address the over-arching project goals in a more formalized or quantitative way. To fit with the emerging paradigm of resilience-based management (Gunderson and Holling 2002⁷, Walker and Salt 2006⁸, Chapin et.al. 2009⁹), it would be helpful to bring together a number of the indicators used here into an index to reflect availability or foreclosure of management options over time, and changes to diversity and complexity across the landscape. This index would involve a spreadsheet ranking exercise rather than modelling

These indicators may include:

- A2- size of the timber harvesting landbase
- A3 – productive capacity of the timber harvesting landbase
- A4 – trends in growing stock
- A7 – regeneration success
- B1 – representation in unmanaged habitats
- B2 – old forest habitats
- B3 – broadleaf forest habitats
- B4 – connectivity / patch size / fragmentation
- B5- retention of wildlife trees and patches
- Possibly others

⁷ Gunderson, L.H. 2002. Panarchy: understanding transformations in human and natural systems. Island Press. 507 pp.

⁸ Walker, B. and Salt, D. 2006. Resilience thinking: sustaining ecosystems and people in a changing world. Island Press. 174 pp.

⁹ Chapin, F.S., G.P Kofinas, C. Folke. 2009. Principles of ecosystem stewardship: resilience-based natural resource management in a changing world. Springer Science and Business Media. 401 pp.

ANNEX 1 – Guidance from the Biodiversity Guidebook that will be used as a starting point to examine trends for Habitat and Biodiversity Indicator #1.

Below are targets and definitions of mature and old for various Natural disturbance types and Biodiversity Emphasis Options (low, medium, high) taken from the old Biodiversity Guidebook. They are a starting point to help assess or guide scenarios.

	NDT2							
	definition	definition	targets					
	mature	old	Mature+old			old		
BEO			L	M	H	L	M	H
BEC								
ICH	>100	>250	15	31	46	9	9	13
SBS	>100	>250	15	28	46	9	9	13
ESSF	>120	>250	14	28	42	9	9	13
Interior						10 %	25%	25%

	NDT3							
	definition	definition	targets					
	mature	old	Mature+old			old		
BEO			L	M	H	L	M	H
BEC								
ICH	>100	>140	14	23	34	14	14	21
SBS	>100	>140	11	23	34	11	11	16
ESSF	>120	>140	11	23	34	14	14	21
SBPS	>100	>140	8	17	25	7	7	10
MS	>100	>140	14	26	39	14	14	21
Interior						10 %	25%	25%



	NDT4							
	definition	definition	targets					
	mature	old	Mature+old			old		
BEO			L	M	H	L	M	H
BEC								
ICH	>100	>250	17	34	51	13	13	19
IDF	>100	>250	17	34	51	13	13	19
PP	>120	>250	11	23	51	13	13	19
Interior						25 %	50%	50%

A7. Clearwater & Barriere Outreach Report

During the week of April 19, 2010, three members of the K2 Research Team spent time in Clearwater and Barriere, BC to share the initial findings of the project, and to hear observations about climate change from residents *We thank everyone for their participation and contributions in this collaborative effort!*

On April 21, a public presentation and discussion was held with over 40 participants of all ages and affiliations. We compared key findings from the initial project (K1) with local observations on the ground. (For a review of the initial project, please visit <http://k2kamloopstsa.com/background-2>).

The following day, members of the K2 team met with nearly 60 people in seven discussion sessions. Participants included:

- BC Ministry of Forests and Range
- BC Timber Sales
- Clearwater Community Forest
- Woodlot licensees
- Junior Council of high school students
- Tourism Wells Gray
- Official Community Plan Steering Committee and District Council
- Clearwater Ski Hill Society and Wells Gray Outdoors Club
- Barriere folks (including the Mayor and a Councilor).

Presentations/Background Information – See links below

Findings

It was confirmed that a number of the project findings for forests do in fact reflect what people in Clearwater are seeing, namely:

- At lower elevations, on drier areas, cedar is dying out, whether it is planted, naturally regenerated and mature
- On south facing slopes around Vavenby, Douglas fir is failing, as did in the Dustbowl era
- On the dry plateau areas, 2/3 of lodgepole pine older than 30 years has been attacked by mountain pine beetle; practices have shifted to mixed species planting of spruce lodgepole pine, Douglas fir, and western larch to avoid widespread impacts in the future
- In the wet, higher elevation areas, bark beetle and budworm are attacking balsam more

Click here for a listing of local observations of changing conditions (*Local obs feb 16-17 apr 21-22*)

Suggested project priorities

At the forestry sessions participants were asked to identify priorities for the K2 project to examine. These included:

- Mid-term volume supply impacts
- Future harvesting locations
- Regeneration
- How to anticipate disturbance risks
- Interface fuel management options
- Stand tending treatments, density and heavy snow impacts
- Management beyond free growing status
- Strategic planning

Working Groups are being developed to refine the project priorities. For more information about these Working Groups, including becoming a member, please visit [page not yet developed].

Community impacts and adaptation actions

Discussions with community groups in Clearwater and a small group in Barriere highlighted that community's knowledge of possible impacts from climate change is growing, and people are quick to think about potential actions. In Clearwater, groups will be considering how to include climate change in the tourism sector, for example the impacts of less snow at lower elevations, and the Official Community Plan will examine flood and wildfire risks. The K2 project team is available to support community adaptation.

We will return to the community late in 2011 to share findings from the K2 project and check again whether they reflect the observations of community members.

Information links

Below are links to presentations, handouts and reference information provided during the these sessions :

About the project

- Project description – (*K2 project description for april 2010 events*)
- Initial project findings – (*K1 project resultsy*)

Climate change information

– Introduction presentation (*Introduction to CC and RAC...*)

- ClimateBC Modelling and Future Ecosystem Climate Mapping Version 2.0 (*This should be somewhere in the K1 project files*)

Forest changes

- Summary presentation (*KKFS Clearwater pres apr-10 2*)
- Ecological Narratives and Summaries - (*Appendix 3 in the K1 files*)
- Summary Table (*Developing Questions table dec 15 09*)

Tourism information

- Possible impacts and actions (*Possible tourism impacts*)
- Assessment approaches (*Tourism assessment*)

Community information

- Introduction presentation (*Clearwater Climate Change Adaptation Community Info*)

Information from other sources suggested during the sessions

- Climate Overview 2007 – Hydroclimatology and Future Climate Impacts in BC (<http://pacificclimate.org/docs/publications/PCIC.ClimateOverview.Revised.March2009.pdf>)
- A Summary of Climate Change Effects on Watershed Hydrology Extension Note (<http://www.for.gov.bc.ca/hfd/pubs/docs/En/En87.pdf>)
- BC Snow Trends Report (*attached*)
- [Integrated Ecological Impact Assessment](#): Climate Change and BC's Forest and Range Ecosystems (*attached*)
- Climate Change and Canada's Forests (http://nofc.cfs.nrcan.gc.ca/bookstore_pdfs/29616.pdf)
- From Impacts to Adaptation: Canada in a Changing Climate 2007 (http://adaptation.nrcan.gc.ca/assess/2007/index_e.php)

A8. Summary of Lessons and Challenges

Project Lessons and Challenges

1. **It is challenging to engage clients in a project like K2, when there is no operational strategic planning process into which K2 and its recommendations can be incorporated.**

The initial K1 project identified the lack of such a process as a major adaptive capacity issue for implementation of adaptive strategies for climate change. For some K2 clients, the exposure to modelling process and knowledge emerging from it is sufficient to effectively engage them. It is much more difficult to engage others - particularly Forest Company licensees who are under significant economic pressures, and agency specialists who are under time constraints do not see K2 as directly relating to their responsibilities.

2. **Communicating models is challenging yet essential for developing a common understanding and managing expectations; it should not be rushed.**

Effective communication of the model framework gives clients a clear understanding of model assumptions and limitations allowing them to ask appropriate questions that can be incorporated into the modelling process. However, this can be challenging, especially if the audience has no previous experience with the models. Effective communication includes managing expectations of what the models can actually deliver within the scope of the project and conveying the computational complexity of exploring every interesting scenario that could possibly be explored.

3. **The best modelling indicators require some context.**

The most useful modelling indicators require some context based on a thorough exploration of potential future forest issues, and subsequent management goals and questions that are of most interest to the clients. The time spent within the project to address this challenge was worthwhile as it permitted the development of a suite of indicators that are both meaningful to the clients and relevant for the modelling process. Fundamental, however, is a shared understanding amongst clients and researchers of the models, their assumptions and limitations.

4. **It is critical to anticipate the range of potential modelling runs in advance to set limits and priorities.**

The number of potential modelling runs can become unworkable, when scenario options for climate change are combined with temporal reporting options (2050, 2080 etc) and options for management and/or modelling assumptions. It is important to narrow down the priorities for potential runs to focus the time and effort. This links back with a previous lesson that it is important to communicate the modeling framework effectively to manage expectations. It was useful for

this project to develop a “menu,” so to speak, of management/climate scenarios from which the clients could select what they were most interested in examining. The slide shown in Figure 5 was presented during a client workshop in Kamloops (February 10, 2010) to illustrate the fact that options for the modelling scenarios were limited by what was practical.

Modelling Challenges

3. The use of a new model can lead to unexpected obstacles

While FORECAST and ForWaDy have been extensively applied FORECAST Climate is new and its application in the K2 project has been slowed by a few unexpected challenges related to calibrating the feedback from climate variables to stand growth rates. We have been able to address these obstacles and anticipate that the results from the dendroclimatology study will provide additional confidence in the model output.

4. The complexity of the climate change scenarios can lead to ballooning combinations of runs

The inherent complexity of the climate change scenarios when considered in the context of the 21 core stand units can create unreasonably high numbers of run combinations to be simulated and evaluated with FORECAST Climate (Figure 5). We have had to invest a considerable amount of time in narrowing down the options to those that will provide the greatest level of insight with respect to the long-term implications of climate change in the Kamloops study area.

5. The use of a new uncirculated model can present some challenges.

This situation created a couple minor issues for the project. When K2 no longer had a modeller to work with DYNAPLAN, a replacement modeller was sought. It was clear that finding someone to work with DYNAPLAN would take some time, so the project switched to FPS, which could be run by Forsite Consultants who were already part of the K2 team. Nevertheless, the K2 team has not completely ruled out the use of DYNA-PLAN since a researcher was recently acquired by UBC to run the model. As an option, it may be used to compare results of some scenarios with FPS.

6. Modelling adaptive scenarios for climate change at the landscape level is complex. Assumptions that are needed to expedite the process must be transparent.

While it is always desirable to try to simulations in a realistic fashion that remains true to ecological processes and likely human choices, often some assumptions must be made to simplify the modelling and stay within timeframes and budgets. It is critical that these assumptions are clear so that results can be interpreted within the appropriate context.