Guidance to Adapt Forest Management for Climate Change in the Kamloops TSA.

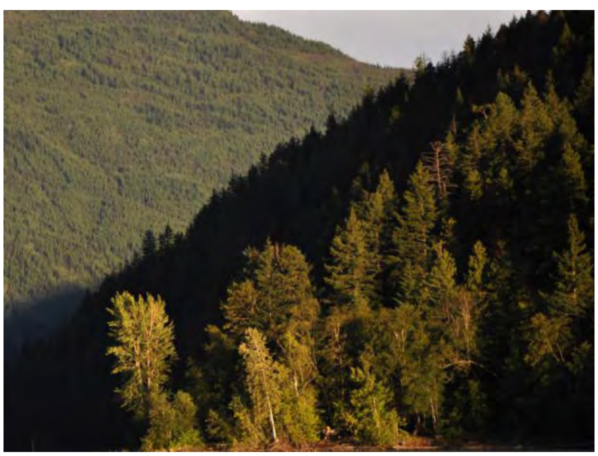
FIRST APPROXIMATION (June 7, 2012) which should be viewed as a continuous work in progress.

Based on:

Validating Impacts, Exploring Vulnerabilities, and Developing Robust Adaptive Strategies under the Kamloops Future Forest Strategy (K2-2011) – Future Forest Ecosystems Scientific Council (FFESC) Interdisciplinary Climate Change Adaptation Research for Forest and Rangeland Ecosystems.

And

Adapting Forest Management in the Kamloops TSA to Address Climate Change – The Kamloops Future Forest Strategy (K1 – 2009)



Forest Resources Management

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Background

WHO IS THIS DOCUMENT FOR? – Operational Forest Managers developing (and/or approving) strategic and/or operational plans in the Southern Interior of BC.

INTENT – To provide initial guidance for a range of ecological units to assist operational planners with management planning and practices to reduce vulnerability to climate change. Specifically, the guidance provided here should be a starting point to help managers set strategic objectives and targets in the context of climate change for:

- Species preferences and stocking standards for regeneration;
- Strategic harvest planning to replace high risk stands with more resilient stands;
- Incremental silviculture;
- Managing increasing risk of stand replacing wildfires;
- Landscape level retention for biodiversity.

SOURCE - The following recommendations are based on two climate change adaptation projects completed in the Kamloops TSA from 2007 to 2011.

- See APPENDIX 1 for a relatively detailed explanation of the rationale behind these recommendations, based on a comparison of projected trends from both projects (K1 and K2) using as a starting point the current business-as-usual strategies and practices.

- For more information on K1 (2007-2009) – SEE http://www.for.gov.bc.ca/hcp/ffs/kamloopsFFS.htm#Final_Report

- For or more information on K2 (2009-2011) – SEE http://k2kamloopstsa.com

Introduction

Sustainable management of public forest lands requires a vision over time for the mix of structures, stands and landscapes to reasonably fit with multiple objectives and ecosystem processes. Global climate change challenges this vision with tremendous uncertainty. To address this challenge, a team of researchers from the University of British Columbia and consultants working with Symmetree Consulting Group explored forest management vulnerabilities and potential risks associated with future climate uncertainty on a highly diverse case study area, over 370,000 ha in size in the middle of the 2.7 million ha Kamloops TSA management unit in Southern British Columbia.

Project A – K1

The ultimate goal was to increase the understanding of potential climate change impacts on local forests, and design an adaptive strategy to improve resilience and reduce vulnerabilities. The team completed this using a range of global climate projections which informed opinion-based analysis using local experts and practitioners. Narratives of potential future forest conditions were crafted and initial adaptive strategies to improve resilience in key ecosystems were designed. This project has become known as K1.

Project B – K2

In a second project, dubbed K2, sensitivities and vulnerabilities from phase one were tested using scenario forecasting with a suite of computer models operating at a variety of spatial scales. The project is unique in that stand-level growth and development over time is driven by a tree species establishment model (TACA) and a ecosystem process model (FORECAST CLIMATE) that are both tied to a hydrological water balance model making them directly sensitive to changing climate conditions over time. From K2, the team gained valuable insights to enrich their narratives and refine the initial adaptive strategies. The summary of direction and trends reflects these insights as K2 is compared with the original projected trends and direction from K1.

The focus for the K2 modeling was on the implications of climate change for current practices (business-as-usual). TSR-type timber harvesting assumptions and silviculture practice, as reflected by recent provincial RESULTS data were modelled forward for this analysis. The intent was to better understand the impacts of business-as-usual on future forest values. One alternate scenario, where planted species mixtures were diversified (with other species mixed in at a reasonable rate) was modelled to test whether species modifications would show improved conditions within the modeling time frame. As an outcome of the project it was noted that many more scenarios and sensitivities could be run, as numerous questions arise when analyzing the modeling outputs.

For more information about the project, see the webpage: http://k2kamloopstsa.com

WARNING #1 – *Do not Confuse our Precision and Implied Certainty with Accuracy* – Throughout this document terms such as "will" and "will not" are used to indicate trends in forest conditions and processes under a moderate-to-pessimistic view of climate change (moderate to high degree of carbon emissions). These conditions and process changes have considerable uncertainty and could be "better" or even "worse" than described. The description however allows managers one reasonable glimpse of how significant the change in future conditions could be, so that we can start to address the vulnerabilities in our forests today.

Also - The increases and decreases in area impacted, productivity, stress and volumes are reported in the K2 project and in Appendix 1 of this document as precise numbers. This allows for a useful comparison between ecozones. The precision by which these trends are reported should not be construed to be "accurate" forecasts – see comments related to uncertainty above. We believe that a focus on precision over accuracy is a necessary attribute of modeling for climate change with an uncertain future.

The Climate Change Context – K1 vs. K2

It is important to consider that the "worst case" or "high change" carbon emission scenario (A1B) driving the global climate change data in K2 is significantly less "worst case" or less "high change" than other scenarios that could have been chosen. The A1B represents a future where, although economic and population growth is rapid, energy use is balanced across all sources, both fossil and non-fossil fuels (IPCC 2000). The A1FI scenario was used as the "highest change" or "worst case" in K1. It represents a similar rapid growth scenario but with a fossil fuel intensive approach to energy use. Recent data for carbon emissions suggests that we are currently on a trajectory with much higher carbon emissions than any of the emission scenarios used in K1 or K2.

WARNING #2 – *Our Climate Projections are Uncertain* – Be aware that relative to the projected climate used to design this direction, the future climate could actually have: significantly more precipitation in summer; more or less in the winter; more precipitation year round; with some variation in temperature in summer and winter.

To deal with this uncertainty, we need to focus management on reducing key risks and vulnerabilities to potential impacts of real concern, without compromising our forests if these impacts do not emerge. We felt that the warmer-drier summer projection likely holds the most significant impacts for forest management in the Kamloops TSA. Prudent management would reduce risks associated with this projection by promoting treatments that would otherwise be useful or at least relatively benign if such a situation does not arise. Managers should each use this test, along with their own local knowledge, as a filter for the direction that follows.

Background - Numerous global climate models (GCMs) have been developed to project climate based on the earth's climate system. All have been developed and calibrated similarly, but each have their own unique assumptions. All are continuously updated and improved. Due to lack of time in K2 only one data set was used from one pairing of GCM and carbon emission scenario (described above). The GCM designed by the Hadley Centre in Britain is known to predict drier summers here than most of the other models. Note, that there is much more uncertainty among climate scientists regarding future precipitation projections than there is for temperature, due to necessary assumptions regarding complex climate and weather processes and patterns.

Other Important General Assumptions:

FIRE - the amount of area burned within specific ecogroups was increased proportionally by adjusting fire return intervals from the Biodiversity Guidebook to account for the climate change scenarios used in the K2 project (Nitschke and Innes 2007, 2008b[1]). Past historical fire patterns were used to determine the baseline area and distribution of fires as a baseline. The assumptions for this work were relatively rough and could be significantly improved over time.

HARVESTING – Unlike TSR, harvesting was only modelled over the 100 year simulation period rather than using a much longer timeframe to determine the level where harvest rates and growing stock balance[2]. As growing stock in the K2 modelling is showing a slight decline over the modelling period, it is suspected that the harvest rate is above that which would be sustainable.

INSECT OUTBREAKS – As we know with mountain pine beetle, surprise episodic insect outbreaks can have a large impact on the forest growing stock, composition and structure. Though expected to increase with climate change, K2 could not anticipate and model such surprise events, although some increases in mortality rates were made where it was expected that increased moisture stress would trigger such an increase with insects and disease. The team suspects that the mortality assumed by the model may underestimate what will occur and that more work needs to be done in this area.

REGENERATION – Because the modelling was calibrated locally, based on weather station data, and these stations are in open conditions, regeneration results were based on open clearcut conditions. In many of the drier zones, as regeneration success dropped with the modelled drier summer conditions, presumably a switch to partial-cutting with some overhead shelter would occur allowing for greater regeneration success. This was not modelled.

Broad Forest Management Direction and Priorities for Climate Change in the Kamloops TSA.

The two climate change projects in Kamloops underscored the need to adjust forest management in a number of different areas. First and foremost, for many of the southern interior ecological landscapes (ecozones), we need to link species preferences at reforestation to identified vulnerabilities within the varying units. Changing the nature of our forest through reforestation will take a long time. Indeed in K2 we found that after a 100 year simulation period, alternate regeneration strategies had yet to affect sufficient area for a long enough period to significantly impact indicators related to maturing stand

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[1] Nitschke CR, Innes JL (2008). *A tree and climate assessment tool for modelling ecosystem response to climate change*. Ecological Modelling, 210, 263–272. AND Nitschke CR, Innes JL (2008b). *Integrating climate change into forest management in south-central British Columbia: An assessment of landscape vulnerability and development of a climate-smart framework*. Forest Ecology and Management, 256, 313–327.

[2] Note the shorter period was chosen due to the high level of uncertainty of climate impacts beyond 100 years.

types. This highlights the importance of getting started right now, because the longer we wait the longer it will take to build resilience into mature stands.

A simple change that would increase resilience significantly would be to reduce our reliance on lodgepole pine for reforestation. In most subzones a priority would be to stop the conversion of Douglas-fir and other non-lodgepole (pine) stand types to lodgepole pine stands. The K2 modeling suggested that lodgepole will be significantly stressed in many of these ecozones (drier ecozones and dry sites in moist ecozones) and much more susceptible to mortality from a range of damaging agents. K2 also dramatically portrayed how much we might change our forested landscapes if we continue with our current pine-biased approach to reforestation. Note that there are some data to suggest that planting preferences are moving away from pine in the last few years. Regardless, we feel that it is critical to emphasize the importance of continuing to avoid a lodgepole pine bias for reforestation in a range of ecozones.

Harvesting should be strategically directed toward stand types that will be most vulnerable to impacts from drought, insects, disease and wildfire - allowing for reforestation to more resilient stand conditions. Currently in BC we rarely use strategic harvesting to address these types of forest management issues. We normally target least costs stands with species and log product profiles most valued in the marketplace at a particular time. Moving to a strategically directed harvesting plan would likely require some form of incentive or commitment to motivate licensees to adjust their stand selection approach (within reasonable economic limits).

Incremental silviculture options (activities beyond “basic silviculture”) exist to help reduce risk of fires and convert non-resilient stands before they are lost. Depending on the management unit, these activities may also help to address current midterm timber supply challenges, and possibly prevent future timber falldowns.

A variety of silvicultural systems and retention approaches will be important as climate change continues. Partial cutting will be necessary in warm dry subzones to allow for reliable seedling establishment, and may be needed in cool dry subzones to protect seedlings from early or growing season frost damage. Increased retention levels (from stand to landscape) may be necessary to provide refugia and means for species to move as their habitats shift. A diversity of harvesting and regeneration approaches will help diversify stands to protect against extensive insect and disease outbreaks.

Some support work emerged from K2/K1 that will take several years to organize, gain support for, and implement. As a top priority the province needs a functional forest management planning process in every management unit that links desired strategic outcomes with operational practices that need to be implemented to achieve the outcomes. Such a process would: tie local landuse goals to anticipated forest conditions; formulate sound strategies with the best information and tools; link these strategies to clear tactical planning so that we know where, when, and what is going to happen over time; and monitor outcomes to measure progress. Without such planning much of what is suggested in this document will be difficult to implement in an integrated and adaptive fashion and therefore likely less effective over the long term

As part of such strategic planning it would be very helpful to build on the recent BC Fuel Hazard Assessment and Abatement Fire Risk Mapping[3] and other fire risk mapping to: project risks over time with climate change; and to build in considerations of forest level, and not just stand level, consequences. Such mapping should be tied to wildfire management strategies that are linked to landscape and stand level retention strategies for biodiversity. In this way harvesting and other stand interventions can be planned along with retention and reserve networks to best reduce risks for a range of values.

Such strategic planning, in each management unit across the province, would also benefit from some ongoing climate change modeling (as in K2), perhaps in each geographic region (Coast, Southern Interior, Northern Interior) to continuously explore assumptions, uncertainties, and emerging questions for management. Other research questions would emerge from this planning – questions that could help focus research organizations on the most pressing issues that might hamper implementation and allow managers to manage for a range of values in a changing climatic context.

WARNING #3 – *This Direction is a First Step but not "The Answer".* – We believe that much of the direction that follows could be argued as being prudent for a number of reasons no matter which track future temperatures and precipitation trends settle into. We also believe that this direction is a good first step and is better than assuming climate change is not happening.

HOWEVER - We also think that there is danger in believing that this direction is the final answer in adapting our management for climate change in the Kamloops TSA. We see a pressing need in BC to have regional research teams who can support management planning by continuously testing assumptions (like those we are making in this project) with ongoing: research, gathering of better data, incorporation of better tools, monitoring, and modeling. This is classic adaptive management. It is the only way to adequately address the tremendous uncertainty that climate change presents for resource managers who manage over very long time frames.

[3] http://bcwildfire.ca/Industry_Stakeholders/industry/Assessment_Abatement.htm

Specific Management Recommendations by Ecozone

NOTE REGARDING THE INTERPRETATION OF THE "ECOZONES" - The following recommendations are suggested by "ecozones". Biogeoclimatic subzones were amalgamated into ecozones based on their common ecological response to climate change across broad ecological landscapes, providing six ecozones in the Kamloops projects. Examples of the relevant biogeoclimatic subzones in the Kamloops TSA are provided in brackets beside the ecozone name.

The ecozones are then each described for their broad characteristics so that recommendations can be interpreted in other TSAs for other similar ecological units, and modified where needed to fit with slightly different circumstances and conditions. This should be done carefully, with input from knowledgeable ecologists.

ECOZONE - Dry Douglas-fir / Ponderosa pine (e.g. PPxh, IDFxh):




Ecological Notes:

- This ecozone includes subzones where Douglas-fir regenerates in its own understory on mesic sites, and growing season conditions are too hot and dry for lodgepole pine.

- Ponderosa pine may be found on mesic or drier sites. Note that some trends and recommendations below may be relevant in similar more northerly subzones where ponderosa pine is not found. Work with local ecologists to interpret accordingly.

Key Projected Trends with Climate Change – by 2065[4]

- Note that moisture stress induced mortality will increase by 25% throughout this ecozone by 2065 and by 100% by 2080. Ponderosa pine will cope better than Douglas-fir.
- Douglas-fir regeneration is forecast to become rare or infrequent without some level of intermittent overhead shelter beyond 2065, while ponderosa pine regeneration will remain relatively successful except on the driest sites. Ensuring a significant component of ponderosa pine through this landscape should allow for systems that provide successful natural regeneration of both Douglas-fir and ponderosa pine beyond 2065.
- By 2065 trembling aspen decline could be a significantissue. As a critical habitat component for cavity excavating and nesting birds, as well as other species, maintaining aspen as long as possible on the landscape may help dependant species to migrate to other suitable ecosystems.
- Fire disturbance in terms of area burned is projected to more than double beyond 2065 with current approaches to management and practices. There may be added mortality from tussock moth and perhaps budworm but this is difficult to project.

- *For more detailed information on these trends from both K2 and K1 – see Appendix 1*

REGENERATION STRATEGIES:

Increase the proportion of stocking in ponderosa pine.

- Include a proportion of ponderosa pine in strategic targets, and/or increase the species status for target stocking from *acceptable* to *preferred* as per the standard BC silvicultural survey and stocking methodology.
  - *On drier-than-mesic sites* - Increase ponderosa pine stocking to encourage ponderosa pine - Douglas-fir mixes – target a 50-50% ponderosa pine/ Douglas-fir mixture as a starting point, and look for appropriate opportunities to occasionally increase it.
  - *On mesic sites* - Increase ponderosa pine stocking to encourage Douglas-fir ponderosa pine mixed stands – target 25-30% of ponderosa pine as a starting point.

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4 Based on results from the K2 modeling suite. For more information on methods and the approaches used – see *Validating Impacts, Exploring Vulnerabilities, and Developing Robust Adaptive Strategies under the Kamloops Future Forest Strategy* - press here for weblink to report

Maintain presence of trembling aspen at the landscape level.

- Avoid removal of aspen through brushing activities and through strategic use of stratification to provide stocking standards that include aspen as a preferred species in situations and circumstances where aspen is concentrated and will freely sprout from root suckers.
  - The intent is to maintain aspen as a source of habitat as long as possible through vegetative reproduction over time. .

HARVESTING:

- Reduce fuels with commercial thinning and/or juvenile spacing (under a well designed fire management strategy), to reduce stand level moisture stress and fire risk by maintaining overall stand stocking at low (may even consider 10-14 m^2/ha – on the driest / high risk sites) to moderate (consider 14-18 m^2/ha - mesic and moderate risk sites) levels.
  - With the loss of lodgepole pine dominated stands in adjacent areas these subzones will become increasingly important for timber supply. Yet, because of their location near main valleys they are also important for a range of other values and interests. It will therefore become increasingly important to reduce the risk of stand replacing fires to protect timber values, habitat, community safety and property.
  - However, silvicultural systems that maintain overstory cover using low stocking will increasingly be important to allow for establishment and reduce moisture stress on individual trees over time. Silvicultural systems should be used to encourage an uneven-aged or irregular stand structure to provide ongoing shelter for understory trees, while servicing habitat and other values.
  - There will need to be a balance between the desire for regeneration and the avoidance of ladder fuels. As well, to successfully establish regeneration it will be necessary to strike the right balance between an open canopy for adequate moisture and light penetration, and to reduce budworm damage, with enough overhead shelter to mitigate heat and drought.
  - Stocking and structural goals suggested here should be discussed with a range of specialists and refined accordingly over time. Consult USA literature for Py/Fd from Montana and Southern Idaho, as these stand/climate combinations could provide examples of our potential future climates. Integrate with other values such as winter range.
  - Note that open overstories may require some repeated underburning at regular intervals to avoid re-establishment of overstocked understories. Work with experienced southern interior ecosystem restoration specialists to design the best approaches.

- Continuously improve and refine the range of partial-cutting options as overhead shade will increasingly become important for establishment.

INCREMENTAL SILVICULTURE

Incremental activities require a strategic context so the guidance provided below must be integrated into a strategic plan intended to best direct funding for incremental activities. The guidance below is intended as options based on the vulnerabilities present in these zones from climate change.

- As recommended above (under harvesting), in Douglas-fir stands with high densities of small diameter trees, non economic for timber, reduce fuels and stocking with spacing (combined with commercial thinning where there is sufficient stocking in mid diameter and larger sizes classes available) to reduce fire risk and stand moisture stress, resulting in healthier residual stands.
  - Target high risk stands near communities and private property first.
  - Next target other high risk stands that are a priority for treatment on the timber harvesting landbase (THLB). As these forest types increase in extent, on the management unit, forest level risks for timber and habitat supply increase. Incremental funding may be targeted at reducing stocking in these stands, not just to address the significant fire risk, but also to fill an existing midterm timber supply gap. More importantly, it may help prevent a new timber supply problem further out. At the same time, it may help protect some critical habitats, property, lives, quality of life close to communities and possibly some rare or endangered species.
  - Involve silviculturists and wildlife biologists and ensure climate change context is considered.
  - Explore mechanisms with Branch specialists in Victoria to design special timber sales and other opportunities to help facilitate the combination of commercial thinning and spacing, which currently seems challenging under our existing tenure and appraisal systems.

OTHER

- Engage in a continuous process to challenge and explore both the direction provided here, and the assumptions behind the direction – in this way practices will continue to evolve and adapt in a suitable manner.
- Update and refine recent fire risk mapping[5] to determine the high risk areas within the TSA – now and with climate change.
- Update/design a fire management strategy that considers the climate change trends described in Appendix 2, and the treatments described above. Work with wildfire management branch specialists and integrate with other objectives.

[5] Was recently completed and released by WMB (April 2012) http://bcwildfire.ca/Industry_Stakeholders/industry/Assessment_Abatement.htm

- Encourage researchers to investigate increased use and range expansion of a number of key southern interior species such as ponderosa pine and western larch.
- Use a variety of silvicultural systems and partial cutting intensities to allow for establishment of regeneration across the range of sites over time. Support with appropriate incentives, monitoring, training and other support.
- Track amounts of old forest and make adjustments for OGMAs that may have burned or been affected by severe insect attacks (and associated salvage logging). Consider stand types best suited to persist and recruitment of future OGMAs.
- Encourage researchers to investigate a broad use of lower overall stand stocking levels with partial cutting silvicultural systems to: encourage uneven-aged and irregular stand structures; lower stand level moisture stress; reduce fuels and fire risks in dry Douglas-fir / ponderosa pine stands. The current BC ecosystem restoration program and similar work conducted in the USA may be a helpful starting point.

ECOZONE - <u>Dry subzones with lodgepole pine stands</u> *(e.g. IDFdk and MSxk)*

Ecological Notes:

- This ecozone includes subzones that are somewhat moister and/or cooler than the Dry Douglas-fir Ponderosa pine ecozone. Douglas-fir may still regenerate in its own understory on mesic and drier sites, however lodgepole pine also can be found either mixed in with Douglas-fir or in pure stands, although pine beetle has significantly reduced presence in mature stands. Aspen is much more abundant than in the Dry Douglas-fir/Ponderosa pine ecozone, and spruce will be found on mesic and moister sites. In Kamloops the IDFdk was most typical of this ecozone.

Key Projected Trends with Climate Change – by 2065[6]

- It is expected that between one-third and one half of the area in this ecozone will have stands with high moisture stress by 2060 (compared to very little area today), and lodgepole pine stands will be particularly stressed since it is projected to be outside of its normal climate envelope. It was projected that lodgepole pine will become increasingly vulnerable to a range of bark beetles, other insects and diseases.
- Both Douglas-fir and lodgepole pine regeneration will continue to regenerate successfully in the open on mesic or moister sites However, lodgepole pine regeneration will become absent in the open on drier sites beyond 2065, while Douglas-fir will require intermittent overhead shade on such sites.
- By 2065 trembling aspen may be significantly stressed. As a critical habitat component for cavity excavating and nesting birds as well as other species, and as a major component of this landscape, maintaining aspen as long as possible on the landscape may help aspen-dependant species to migrate to other suitable ecosystems.
- Fire disturbance in terms of area burned is projected in K2 to significantly increase, beyond 2065. Although the increase is expected to be less than in the Dry Douglas-fir / Ponderosa pine lower down, fires may also spread from that ecozone, further increasing the vulnerability of this ecozone (dry subzones with lodgepole pine). K1 suggested further mortality from insects as well with increasing moisture stress.

- *For more detailed information on these trends from both K2 and K1 – see Appendix 1*

REGENERATION STRATEGIES:

Avoid conversion of Douglas-fir and other non-lodgepole stands to lodgepole pine.

<u>For cutblocks that WERE NOT lodgepole pine leading stand types preharvest:</u>

- Strategically limit lodgepole pine to be a minor stand component, and where possible avoid lodgepole pine altogether:
    - A simple approach, to facilitate this objective at the stand level, is to restrict lodgepole pine to "acceptable" rather than "preferred" status as per the BC silviculture survey methodology and associated approach to stocking standards.

[6] Based on results from the K2 modeling suite. For more information on methods and the approaches used – see *Validating Impacts, Exploring Vulnerabilities, and Developing Robust Adaptive Strategies under the Kamloops Future Forest Strategy* - press here for weblink to report

    - Another approach is to restrict lodgepole pine to a maximum of 20-30% of the species composition for regeneration at the stand level and a lesser amount over the landscape. This may be more challenging to implement and control.
    - On sites that could experience growing season frost damage if clearcut, consider partial cutting silvicultural systems to help establish non-pine species.

In cutblocks that were pine-leading prior to harvesting - Avoid establishment of pure lodgepole pine stands, and encourage as much diversity as possible.

<u>Accordingly, in cutblocks that WERE lodgepole pine leading stand types preharvest:</u>

- Increase non-lodgepole stocking to encourage greater stand diversity, as much as is practically possible.
    - First determine which stand/site combinations offer opportunities to increase stocking of other species. On some sites, in some subzones, few options may exist to establish anything other than lodgepole pine, as few other species are suitable and natural regeneration of lodgepole may dominate the site.
    - Set strategic targets for specific sites within these subzones and monitor over time. Where options are available to increase the proportion of non-pine species – a 25-30% stocking of Douglas-fir, ponderosa pine or spruce is a good starting target.
        - Consider Douglas-fir and/or spruce (possibly western larch) on mesic sites. Monitor spruce carefully for weevils and other insect pests.
        - Consider introduction of ponderosa pine on drier-than-mesic sites, in subzones deemed suitable. Mix in a small amount (e.g., 20%) and consider higher planted stocking when sufficiently comfortable with survival and maintenance of vigor over time.

Maintain presence of trembling aspen at the landscape level.

- Avoid removal of aspen through brushing activities and through strategic use of stratification to provide stocking standards that include aspen as a preferred species in situations and circumstances where aspen is concentrated and will freely sprout from root suckers.
  - As in the dry Douglas-fir/Ponderosa pine, the intent is to maintain aspen as a source of habitat through vegetative reproduction over time.

HARVESTING:

- Target stands where ladder fuels, stand mortality, and location on the landscape make them more vulnerable to fire (with climate change) as a priority for harvesting, retaining those stands that are less vulnerable for future passes and other objectives.

INCREMENTAL SILVICULTURE

Incremental activities require a strategic context so the guidance provided below must be integrated into a strategic plan intended to best direct funding for incremental activities. The guidance below is intended as options based on the vulnerabilities present in these zones from climate change.

- FERTILIZATION TO PROMOTE SHORT ROTATIONS ON EXISTING YOUNG PINE STANDS - Target young lodgepole pine stands, that were too young/small to be damaged by mountain pine beetle in the recent epidemic, for multiple treatments over the next 20-40 years to cycle these stands quickly so that they may be harvested and replaced with a more resilient species mixture for the future climate.
  - NOTE – this may be an especially useful strategy in management units facing a midterm timber supply gap from the recent mountain pine beetle infestation.
  - The decision to use this practice will depend on projected forest conditions and the amount of area that presents this opportunity.
- FUEL MANAGEMENT AND DENSITY CONTROL – In appropriate high fire risk stands (for fire with climate change) reduce fuels and stocking with spacing, possibly combined with commercial thinning to reduce wildfire risk and stand moisture stress.
  - Target high fire risk stands near communities and private property first.
  - Next target other high fire risk stands that are a priority for treatment on the THLB. As these forest types increase in extent on the management unit, forest level risks for timber and habitat supply increase. Incremental funding may be targeted at reducing stocking in these stands, not just to address the significant fire risk, but also to fill an existing midterm timber supply gap. More importantly, it may help prevent a new timber supply problem at some point in the future. At the same time, it may help protect some critical habitats, property, lives, quality of life close to communities and possibly

some rare or endangered species. Involve silviculturists and wildlife biologists and ensure climate change context is considered.

  - Explore mechanisms with Branch specialists in Victoria to design special timber sales and other opportunities to help facilitate the combination of commercial thinning and spacing, which currently seems challenging under our existing tenure and appraisal systems.

OTHER

- Engage in a continuous process to challenge and explore both the direction provided here, and the assumptions behind the direction – in this way practices will continuous to evolve and adapt in a suitable manner.
- Update and refine recent fire risk mapping[7] to determine the high risk areas within the TSA – now and with climate change.
- Update/design a fire management strategy that considers the climate change trends described in Appendix 2, and the treatments described above. Work with wildfire management Branch specialists and integrate with other objectives.
- Develop a retention strategy (with tactical guidance) for biodiversity at a number of scales (or refine an existing one) to maintain and recruit acceptable levels of old forest habitats and attributes across this ecological landscape.
  - The intent is to ensure we are reserving and recruiting old and mature stands and attributes appropriately on the landscape so that these features have a better chance to persist to meet our management intent, while we are harvesting those stands that are more likely to incur high levels of mortality within the short term.
  - This strategy should become an evolving harvest/landscape reserve / stand level retention strategy that is frequently revisited with the involvement of silviculturists, planning foresters, entomologists, habitat biologists, fire management specialists, and others. It is most important that the tactical guidance is carefully thought through to reduce the chance of unintended consequences for all intended management objectives. Ongoing research support will help as the background climate continuous to change.

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[7] Was recently completed and released by WMB (April 2012) http://bcwildfire.ca/Industry_Stakeholders/industry/Assessment_Abatement.htm

ECOZONE - <u>Dry Transitional subzones</u> *(e.g. IDFmw, ICHdw)*




Ecological Notes:

- These are the subzones that are transitional from the Douglas-fir subzones to the western redcedar/western hemlock subzones. Douglas-fir may still regenerate in its own understory on dry sites with warm aspects, however generally there are more broadleaf species, much higher levels of root disease and an increasing presence of western redcedar, spruce and birch on mesic or moister sites.

Key Projected Trends with Climate Change – by 2065[8]

- It is expected that one third of the area in this ecozone will have stands with high moisture stress by 2060 (compared to very little area today), and lodgepole pine stands will be particularly stressed since it is projected to be outside of its normal climate envelope. It was projected that lodgepole pine will become increasingly vulnerable to a range of bark beetles, other insects and diseases.

[8] Based on results from the K2 modeling suite. For more information on methods and the approaches used – see *Validating Impacts, Exploring Vulnerabilities, and Developing Robust Adaptive Strategies under the Kamloops Future Forest Strategy* - press here for weblink to report

- Intermittent overhead shade will become more important for regeneration of some species, particularly on drier sites
- While not nearly as vulnerable as in drier subzones, aspen may experience some decline from added stress over time.
- Fire disturbance in terms of area burned is projected in K2 to more than double in this ecozone. K1 suggested large mortality pulses from a combination of drought, insects and disease, especially threatening mixedwood stands where these disturbances are already significant.

- *For more detailed information on these trends from both K2 and K1 – see Appendix 1*

REGENERATION STRATEGIES:

Avoid conversion of Douglas-fir stands and other non-pine stands to lodgepole pine.

<u>For cutblocks that WERE NOT lodgepole pine leading stand types preharvest:</u>

- Strategically limit lodgepole pine to be a minor stand component (and generally avoid lodgepole on drier-than-mesic sites).
    - A simple approach to facilitate this objective is to restrict lodgepole pine to "acceptable" rather than "preferred" status (BC silvicultural survey methodology and associated approach to stocking standards) in these stand units.
    - Another approach is to restrict lodgepole to a maximum of 20-30% of the species composition for regeneration at the stand level and a lesser amount over the landscape. This may be more challenging to implement and control.
    - Monitor drier sites for increased growing season frost damage when clearcut. If such trends start to develop, consider partial cutting silvicultural systems or nurse crops of broadleaf species.

In cutblocks that were lodgepole pine-leading prior to harvesting - Avoid establishment of pure lodgepole pine stands, and encourage as much diversity as possible.

<u>Accordingly, in cutblocks that WERE lodgepole pine leading stand types preharvest:</u>

- Increase non-lodgepole stocking to encourage greater stand diversity – e.g., target a 25-30% stocking of Douglas-fir, ponderosa pine, western larch and/or white pine at the block level.
    - Set strategic targets for this group of subzones and monitor over time. Look for opportunities now and over time to increase these diversity targets

where it makes ecological sense on the landscape. Work with local ecologists.

  - Introduce ponderosa pine (with Douglas-fir) on drier-than-mesic sites (possibly with some western larch). Mix in western larch and blister-rust resistant white pine (with Douglas-fir) on mesic and moister sites.
    - Where introducing a species that are "new" to this subzone, start with a small amount (20-30%) and consider higher planted stocking when sufficiently comfortable with survival and maintenance of vigor over time. See also the Chief Forester's seed transfer guidelines.
  - Include some overstory retention of non-lodgepole species – to provide for key habitat elements and a seed source for the next crop.

Maintain presence of trembling aspen at the landscape level.

- Maintain concentrated patches of aspen through strategic use of stratification and stocking standards.
  - The intent is to maintain aspen as a source of habitat through vegetative reproduction over time.

HARVESTING:

- Identify and target for harvesting in the short term (e.g., over the next 10 years) - mixedwood stands with an older Douglas-fir component that are at high risk of increased mortality (due to a number of factors) and possible transition to a non-economic status over time with climate change.
- Test, refine, test and continuously improve the application of partial-cutting options in drier-than-mesic stand types as overhead shade will increasingly become important for establishment.
  - Note that continuous shade is not implied here, but rather intermittent shading from the afternoon sun. Seedlings will also need moisture penetration through canopy gaps for adequate survival and growth.
- Identify and target for harvesting in the midterm (e.g., over the next 20-40 years) – stands that are currently, or will be (with climate change) highly vulnerable to wildfire.

INCREMENTAL SILVICULTURE

Incremental activities require a strategic context so the guidance provided below must be integrated into a strategic plan intended to best direct funding for incremental activities. The guidance below is intended as options based on the vulnerabilities present in these zones from climate change.

- FERTILIZATION TO PROMOTE SHORT ROTATIONS ON EXISTING YOUNG PINE STANDS - Target young lodgepole pine stands (that were too young/small to be damaged by mountain pine beetle) for fertilization (perhaps multiple treatments) over the next 20-40 years to cycle these stands quickly so that they may be harvested and replaced with a more resilient species mixture for the future climate.

  - NOTE – this may be an especially useful strategy in management units facing a midterm timber supply gap from the recent mountain pine beetle infestation.
  - The decision to use this practice will depend on projected forest conditions and the amount of area that presents this opportunity.

- FUEL MANAGEMENT AND DENSITY CONTROL – In Douglas-fir dominated stands on drier sites where there is a high fire risk (considering climate change) reduce stocking through a combination of spacing and possibly commercial thinning to both reduce fuel loading and stand moisture stress. Explore mechanisms with Branch specialists in Victoria to design special timber sales and other mechanisms to make this possible.
  - Target high risk stands near communities and private property first.
  - Next target other high fire risk stands that are a priority for treatment on the THLB. As these forest types increase in extent on the management unit, forest level risks for timber and habitat supply increase. Incremental funding may be targeted at reducing stocking in these stands, not just to address the significant fire risk, but also to fill an existing midterm timber supply gap. More importantly, it may help prevent a new timber supply problem at some point in the future. At the same time, it may help protect some critical habitats, property, lives, quality of life close to communities and possibly some rare or endangered species. Involve silviculturists and wildlife biologists and ensure climate change context is considered.
  - Explore mechanisms with Branch specialists in Victoria to design special timber sales and other mechanisms to help facilitate the combination of commercial thinning and spacing, which currently seems challenging under our existing tenure and appraisal systems.
  - Note: There may be fewer opportunities for this treatment than in drier ecotypes.

OTHER

- Engage in a continuous process to challenge and explore both the direction provided here, and the assumptions behind the direction – in this way practices will continue to evolve and adapt in a suitable manner.
- Update and refine recent fire risk mapping[9] to determine the high risk areas within the TSA – now and with climate change.

[9] Was recently completed and released by WMB (April 2012) http://bcwildfire.ca/Industry_Stakeholders/industry/Assessment_Abatement.htm

- Update/design a fire management strategy that considers the climate change trends described in Appendix 2, and the treatments described above. Work with wildfire management Branch specialists and integrate with other objectives.
- Encourage researchers to investigate increased use and range expansion of ponderosa pine in the Southern Interior.
- Encourage researchers to investigate a range of stand types and stocking levels to reduce fire risks.
- Develop a retention strategy (with tactical guidance) for biodiversity at a number of scales (or refine an existing one) to maintain and recruit acceptable levels of old forest habitats and attributes across this ecological landscape.
    - The intent is to ensure we are reserving and recruiting old and mature stands and attributes appropriately on the landscape so that these features have a better chance to persist to meet our management intent, while we are harvesting those stands that are more likely to incur high levels of mortality within the short term.
    - This strategy should become an evolving harvest/landscape reserve / stand level retention strategy that is frequently revisited with the involvement of silviculturists, planning foresters, entomologists, habitat biologists, fire management specialists, and others. It is most important that the tactical guidance is carefully thought through to reduce the chance of unintended consequences for all intended management objectives. Ongoing research support will help as the background climate continuous to change.

ECOZONE - <u>Moist transitional subzones</u> *(e.g. ICHmw, ICHmk)*




Ecological Notes:

- This ecozone includes moist subzones that tend to be transitional to the wet cool subzones (ICHvk and ICHwk) of the inland temperate rainforest[10].
- This transitional landscape has western redcedar and western hemlock as climatic climax species (similar to the inland rainforest). However, more widespread and common disturbance and edaphic conditions encourage a wider range of other seral species in this ecological landscape prompting more diversity than is found in the wetter, cooler inland rainforest.
- Moist, yet warm, growing seasons make this a very productive landscape.

Key Projected Trends with Climate Change – by 2065[11]

- It is expected that one half of the area in this ecozone will have stands with high moisture stress (compared to very little area today). Both lodgepole pine and Douglas-fir stands may see increases in stress by 5-10 times. It was projected that

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[10] As described in Stevenson, *SK, H.M. Armleder, A. Arenault, D. Coxon, S,C, Delong, and M. Jull. 2011. British Columbia's inland rainforest. UBC Press. University of BC. www.ubcpress.ca*

[11] Based on results from the K2 modeling suite. For more information on methods and the approaches used – see *Validating Impacts, Exploring Vulnerabilities, and Developing Robust Adaptive Strategies under the Kamloops Future Forest Strategy* - press here for weblink to report

lodgepole pine will become particularly stressed on submesic sites, and regeneration success will decline. Spruce is expected to see significant moisture stress on both mesic and subhygric sites.

- Douglas-fir regeneration success will decline somewhat, benefiting perhaps from some intermittent overhead shade.
- Paper birch regeneration will decline significantly and spruce will be challenged for regeneration. Cottonwood could also be challenged on mesic sites beyond 2035. Maintaining broadleaf presence here will be important for habitat especially due to declines in other adjacent ecozones.
- Fire disturbance is expected to expand in a major way - more than 150% by area burned.

- *For more detailed information on these trends from both K2 and K1 – see Appendix 1*

REGENERATION STRATEGIES:

Avoid conversion of Douglas-fir and other non-pine stands to lodgepole pine .

<u>For cutblocks that WERE NOT lodgepole pine leading stand types preharvest:</u>

- Strategically limit lodgepole pine to be a minor stand component, and where possible avoid lodgepole pine altogether on submesic sites.
    - A simple approach to facilitate this objective, at the stand level, is to restrict lodgepole pine to "acceptable" rather than "preferred" status as per the BC silviculture survey methodology and associated approach to stocking standards. Note however that the amount of lodgepole pine that this approach provides may be considered too high to meet diversity targets this ecozone can achieve..
    - Another approach is to restrict lodgepole to a maximum of 20-30% of the species composition for regeneration at the stand level and a lesser amount over the landscape. This may be more challenging to implement and control, but may more effectively keep deployment of this species within suitable ranges.

Avoid creation of spruce leading stands on mesic and subhygric sites,

- Mix in western redcedar and/or other species to reduce the proportion of spruce.
- Reduce reliance of spruce for reforestation on these sites over time (beyond 2025).

Encourage as much species diversity as possible across the landscape.

- Encourage species mixtures by planting combinations of Douglas-fir, ponderosa pine, western larch and western white pine.
    - Set strategic targets for this group of subzones and monitor over time.
        - Look for opportunities over time to further increase diversity.
    - Target introduction of ponderosa pine on drier-than-mesic sites. Mix in a small amount (e.g., 20-25%) and consider higher planted stocking until sufficiently comfortable with survival and maintenance of vigor over time. Once comfortable with managing ponderosa pine in these subzones, consider increasing stocking in new plantations.
    - Target a broader use of western larch and/or blister rust resistant white pine as a component (25-40%) of stands on mesic sites.

Maintain presence of broadleaf species (trembling aspen, cottonwood and paper birch) at the landscape level.

- Maintain concentrated patches of aspen, cottonwood and birch through strategic use of stratification where appropriate, and stocking standards (possibly with aspen as a preferred species on some selected sites).
    - The intent is to maintain broadleaf species on drier sites as a source of vegetative reproduction in the future when regeneration from seed will be very challenging. Also, maintaining the presence of broadleaf species as a significance component across this ecozone may help to reduce the associated habitat impacts considering broadleaf declines in adjacent ecozones.
- Over time (e.g., over the next 10 years), consider strategic targets for establishment of broadleaf stands at the landscape level to fit with wildfire management and biodiversity landscape strategies while considering the future climate.

HARVESTING:

- Identify and target for harvesting in the short term (e.g., over the next 10 years) - mixedwood stands with an older Douglas-fir component that are at high risk of increasing mortality and possible transition to a non-economic status over time (with climate change).
- Identify and target for harvesting in the midterm (e.g., over the next 20-40 years) – stands that are currently, or will be (with climate change) at a high fire risk.

INCREMENTAL SILVICULTURE

- Nothing specific for climate change adaptation.

OTHER

Over Time:

- Engage in a continuous process to challenge and explore both the direction provided here, and the assumptions behind the direction – in this way practices will continuous to evolve and adapt in a suitable manner.
- Update and refine recent fire risk mapping[12] to determine the high risk areas within the TSA – now and with climate change.
- Update/design a fire management strategy that considers the climate change trends described in Appendix 2, and the treatments described above. Work with wildfire management Branch specialists and integrate with other objectives.
- Develop a retention strategy (with tactical guidance) for biodiversity at a number of scales (or refine an existing one) to maintain and recruit acceptable levels of old forest habitats and attributes across this ecological landscape.
    - The intent is to ensure we are reserving and recruiting old and mature stands and attributes appropriately on the landscape so that these features have a better chance to persist to meet our management intent, while we are harvesting those stands that are more likely to incur high levels of mortality within the short term.
    - This strategy should become an evolving harvest/landscape reserve / stand level retention strategy that is frequently revisited with the involvement of silviculturists, planning foresters, entomologists, habitat biologists, fire management specialists, and others. It is most important that the tactical guidance is carefully thought through to reduce the chance of unintended consequences for all intended management objectives. Ongoing research support will help as the background climate continuous to change.

[12] Was recently completed and released by WMB (April 2012) http://bcwildfire.ca/Industry_Stakeholders/industry/Assessment_Abatement.htm

***ECOZONE - Plateau** (e.g. MSdm, SBSmm and ESSFdc)*

Note – in the K2 report this ecozone was frequently referred to as the "dry plateau", which we find is a bit of a misnomer in light of the fact that relatively speaking it is much moister than the other ecozones that have the descriptor of "dry" in them. For this reason we will just refer to it as the plateau ecozone.

Ecological Notes:

- These are the moist but cool subzones that transition to moist, cold upper elevations.
- This landscape shares characteristics of both upper and lower elevations. Spruce and subalpine fir are common, but Douglas-fir can also be found especially at lower elevations.
- Lodgepole pine has a strong presence, and may be more common than in adjacent ecozones.

Key Projected Trends with Climate Change – by 2065[13]

- The area of stands under moisture stress in this ecozone will see a general decline with climate change. Moisture stress over time may increase slightly for some species like subalpine fir, but even that will be highly variable.
- Both lodgepole pine and spruce are expected to see a 25% drop in regeneration success in open conditions. Subalpine fir regeneration success in open conditions is expected to be reduced by 50%.
- Fire disturbance is expected to expand significantly in area by almost 150%. K1 expected episodic spruce bark beetle events (such as that experienced recently in the Cahilty basin) to increase, however K2 could not model such events.
- Impacts of climate change on aspen do not appear to be large, however aspen presence here will be important for habitat especially due to declines in other ecozones.

- *For more detailed information on these trends from both K2 and K1 – see Appendix 1*

REGENERATION STRATEGIES:

Avoid conversion of non-lodgepole (pine) stands (e.g., Douglas-fir and Spruce/Balsam stands) to lodgepole pine.

<u>For cutblocks that WERE NOT lodgepole pine leading stand types preharvest:</u>

- Strategically limit lodgepole pine to be a minor stand component, and where possible avoid lodgepole pine altogether:
  - A simple approach to facilitate this objective is to restrict lodgepole pine to "acceptable" rather than "preferred" status (BC silvicultural survey methodology and associated approach to stocking standards) in these stand units.
  - Another approach is to restrict lodgepole to a maximum of 20-30% of the species composition for regeneration at the stand level and a lesser amount over the landscape. This may be more challenging to implement and control.
  - In clearcuts on drier sites, monitor for growing season frost damage. If increasing trends are evident, consider partial cutting silvicultural systems.

[13] Based on results from the K2 modeling suite. For more information on methods and the approaches used – see *Validating Impacts, Exploring Vulnerabilities, and Developing Robust Adaptive Strategies under the Kamloops Future Forest Strategy* - press here for weblink to report

Encourage tree species diversity as much as possible across the landscape.

- This may be accomplished with a diversity of stand types across the landscape and/or by increasing stand level diversity.
    - First determine which stand/site combinations offer opportunities to target for stocking mixtures at the stand level. On some sites options may be limited.
    - Set strategic targets for specific sites within these subzones and monitor over time.
    - Use historic ranges as a starting point. Look for opportunities over time to further increase diversity.
    - Target introduction of more Douglas-fir on suitable sites and stands at the lower end of these subzones where there is some chance for success. Growing season frosts may require use of overhead shelter with partial-cutting. Start with small targeted projects and work up from there.

Maintain presence of trembling aspen at the landscape level.

- Maintain concentrated patches of aspen through strategic use of stratification, and stocking standards (possibly with aspen as a preferred species).

HARVESTING:

- Monitor old spruce/balsam dominated stands for increased moisture stress. As well, study/monitor climatic effects on bark beetle populations for local threats to older stand types, and the changing risk of fire in these landscapes. Note recommendation below under "other" for a retention strategy.

INCREMENTAL SILVICULTURE

- FERTILIZATION TO PROMOTE SHORT ROTATION ON EXISTING YOUNG PINE STANDS - Target young lodgepole pine stands (that were too young/small to be damaged by mountain pine beetle in the recent epidemic) for fertilization (perhaps multiple treatments) over the next 20-40 years to cycle these stands quickly so that they may be harvested and replaced with a more resilient species mixture for the future climate.
    - NOTE – this may be an especially useful strategy in management units facing a midterm timber supply gap from the recent mountain pine beetle infestation.
    - The decision to use this practice will depend on projected forest conditions and the amount of area that presents this opportunity.

OTHER

Over Time:

- Engage in a continuous process to challenge and explore both the direction provided here, and the assumptions behind the direction – in this way practices will continuous to evolve and adapt in a suitable manner.
- Update and refine recent fire risk mapping[14] to determine the high risk areas within the TSA – now and with climate change.
- Update/design a fire management strategy that considers the climate change trends described in Appendix 2, and the treatments described above. Work with wildfire management Branch specialists and integrate with other objectives.
- Develop a retention strategy (with tactical guidance) for biodiversity at a number of scales (or refine an existing one) to maintain and recruit acceptable levels of old forest habitats and attributes across this ecological landscape.
    - The intent is to ensure we are reserving and recruiting old and mature stands and attributes appropriately on the landscape so that these features have a better chance to persist to meet our management intent, while we are harvesting those stands that are more likely to incur high levels of mortality within the short term.
    - This strategy should become an evolving harvest/landscape reserve / stand level retention strategy that is frequently revisited with the involvement of silviculturists, planning foresters, entomologists, habitat biologists, fire management specialists, and others. It is most important that the tactical guidance is carefully thought through to reduce the chance of unintended consequences for all intended management objectives. Ongoing research support will help as the background climate continuous to change.

[14] Was recently completed and released by WMB (April 2012) http://bcwildfire.ca/Industry_Stakeholders/industry/Assessment_Abatement.htm

ECOZONE - <u>Wet Cold Engelmann Spruce / Subalpine Fir</u> *(e.g. ESSFwk)*




NOTE: K2 DID NOT MODEL THIS ECOZONE – RELIABLE CLIMATE STATION DATA WAS NOT AVAILABLE

Ecological Notes:

- These are the cold, wet subalpine forests in the BC Interior.
- These landscapes are dominated by Engelmann spruce and subalpine fir.
- Lodgepole pine is absent as it is heavily damaged by snow.
- NOTE – K1 INCLUDED THE COOL WET ICH IN THIS ECOZONE (ICHwk and ICHvk)

Key Projected Trends with Climate Change – by 2065 (based on K1 only)

- Moisture stress is not expected to be an emerging issue in this ecozone. In fact, warming temperatures with abundant moisture may see significant growth increases.
- Spruce and subalpine fir regeneration is expected to continue to be successful and conditions may become suitable for Douglas-fir and/or western red-cedar in the lower elevations of this ecozone.

- May see some increase in area impacted by fire, during bad fire years especially. However this trend will be highly variable and will likely be more related to the juxtaposition with ecozones more vulnerable to fire, and the potential for spread into this ecozone.
- There may be a significant increase in incidence of spruce weevil in young stands, and bark beetles in older stands.

- *For more detailed information on these trends from both K2 and K1 – see Appendix 1*

REGENERATION STRATEGIES:

Encourage tree species diversity as much as possible across the landscape.

- Spruce will continue to be a good choice for regeneration, although weevil problems could become evident over time at the lower elevations in this ecozone.
  - Therefore, look for opportunities to mix in western redcedar, possibly Douglas-fir at lower elevations.

Conserve expansion of broadleaf species into this ecozone at lower elevations.

  - Over time with climate change, it is likely that aspen and birch will creep into the lower fringes of this ecozone (possibly beyond 2025). Protect and encourage these species as this occurs, to help offset declines in broadleaf species (and associated habitat losses) in other ecozones.

HARVESTING:

- Monitor old spruce and/or balsam stands for increased moisture stress and mortality (especially beyond 2025) – target these for harvesting before a bark beetle infestation. Work with regional entomologists on a strategy. Ensure it fits with a landscape level retention strategy for biodiversity.
- Consider designing roads, bridges, culverts and other infrastructure considering more frequent and severe flood events. Increased precipitation in this ecozone could have profound impacts on peak flows, flooding and infrastructure damage in this ecozone and downstream in other ecozones.

INCREMENTAL SILVICULTURE

- Nothing specific to climate change.

OTHER

- Engage in a continuous process to challenge and explore both the direction provided here, and the assumptions behind the direction – in this way practices will continuous to evolve and adapt in a suitable manner.

GENERAL DIRECTION ALL ECOZONES – Determining AACs

- Establishing Annual Allowable Cuts (AAC) in the future will need to increasingly consider the impacts of climate change on our forests. The current approach to setting AAC's in BC minimizes the risks associated with uncertainty (i.e. getting the AAC wrong) by reassessing / revisiting the decision frequently (every 5-10 yrs). This allows any errors in assumptions or improvements in knowledge to be incorporated over time and ensure that harvest levels do not get widely off track. This approach will help to address the uncertainty around climate change. Climate change will impact:

  1. Stand growth (site productivity). In K2 this is projected to improve in some stands and decline in other –with an overall net increase for the study area.
  2. Stand mortality (drought stress, root diseases, etc). In K2, this is predicted to increase with a portion of it recognized in the stand level modeling that suggested overall higher productivity in the study area. There is expected to be additional mortality that was not modeled. Uncertainty around the true impacts of increased stand stress is mod-high.
  3. Landscape level mortality (fire, MPB, etc). K2 predicts substantial increases and therefore significant losses of merchantable timber and a ongoing salvage program. Uncertainty around the actual scale of losses is high because of the challenge with predicting these events and our reaction to increased risks over time (e.g. are more resources put into fire suppression?).

- On balance, the greater stand productivity is likely outweighed by the increased mortality (unsalvaged losses) expected in the study area. Also, impacts to the non THLB may require increased retention in the THLB. It is likely that for the K2 area, a reduction in AAC may be warranted once natural disturbance events begin to have a larger impact on the landbase.

- During the setting of an AAC, the decision maker would be well served to have similar information as was presented in K2, so that the upward and downward pressures expected from climate change can be considered along with the typical factors leading to a determination. Ideally climate change impacts would be characterized for each of the Regions in BC every 5 years using the best available information on climate change and its impacts on forests. The repeated assessment of these key drivers over time, combined with on the ground monitoring, will lead to transparent and durable decision making which incorporates climate change.

APPENDIX 1 - TRENDS PROJECTED BY K1 & K2 (COMPARED) WITH CLIMATE CHANGE

A COMPARISON OF GENERAL TRENDS NOTED BETWEEN K1 AND K2.

Much of what was found as broad trends by the K2 modelling, was predicted to a certain extent with K1 expert opinion. However, there were some differences in the output from the two projects that are noteworthy. These differences underline the benefit of following an expert-driven process with a more comprehensive and robust modelling approach.

The most noticeable difference in the two projects is that K2 reported trends with a level of precision not used in K1. K1 generally used broad terms like "significant impact", "significant increase", and large decrease. As a modelling exercise, K2 reported trends in precise quantitative terms. This does not imply a greater accuracy (as noted in warning 1 inthe main report), but it helps compare ecological units relative to one another in a way that was difficult with expert opinion alone.

As a modelling exercise with ecosystem process models, K2 also was able to report trends that could not be envisioned by expert opinion. For example, K2 used a transpiration deficit index in its stand level modelling to report out on moisture stress in different stand types. This was especially helpful to project increased susceptibility across ecozones to mortality from drought, insects and pathogens.

K2 also was able to project and display the impacts of climate change on stand replacing wildfire disturbance and the resulting forest conditions. K2 showed variable disturbance levels of fire disturbance over time. Some ecozones showed higher levels of fire disturbance than expected from expert opinion in K1. For example, the moist transition ecozone showed much higher levels of disturbance than the dry lodgepole pine (Douglas-fir) ecozone, considered to be due to the higher potential fuel loads present in the moist transitional ecozone as it enters a warmer drier climate with a longer, more severe fire season. Overall, K2 found that the high levels of disturbance due to wildfire and harvesting encourage an age class distribution across the case study area that by 2110 is highly concentrated in stands less than 80 years old, setting the stage for a serious timber supply falldown in the 22nd century.

Yet, K2 was more optimistic than K1 regarding the impact of future climates on timber volume production. This may be due in part to the less pessimistic climate scenario. But also the dramatic declines in productivity anticipated by K1 due to a hotter drier growing season were somewhat offset in our K2 modelling by an extended growing season with warmer moister conditions in the spring and fall. While K1 expected a contraction of the Timber Harvesting Landbase (THLB) in the drier subzones with climate change, this was not evident from the K2 output.

Lastly, as a modelling exercise, K2 was able to highlight the problems associated with current regeneration strategies that favour lodgepole pine in many of the ecozones. Under current practice many non-pine stands in the TSA will be converted to lodgepole pine over the next 50-60 years with these strategies. This has dramatic implications for management under climate change in some of these ecozones where pine will be in a less favourable climate than it is adapted to.

Note: We determined "current practice" based on 10-year average rates of establishment from the provincial database for the 21 stand types we used in our project. Recent comparisons between harvest volume billed, previous stand types and area planted in the Kamloops TSA suggests that the trends suggested in this project are starting to change and fewer stand conversions are occurring. We emphasize this issue to underline the importance of minimizing future conversions to lodgepole pine.

TRENDS BY ECOZONE

WARNING – Trends and output are described precisely in the following text. This does not mean these are accurate. These conditions and process changes have considerable uncertainty and could be "better" or even "worse" than described. The description however allows managers one reasonable glimpse of how significant the change in future conditions could be, so that we can start to address the vulnerabilities in our forests today.

The following trends are suggested by "ecozones" for the period beyond 2065 using current practices in the Kamloops TSA under a climate change scenario that many would suggest is "optimistic" (see Appendix 1). Biogeoclimatic subzones were amalgamated (as indicated below) to simplify reporting. The grouping into "ecozones" was done based on a common ecological response to climate change across a broad ecological landscape. This provided us with six ecozones for the Kamloops TSA.

The approach below is to report out on trends emerging from K2 with comparisons back to K1.

ECOZONE - Dry subzones dominated by Douglas-fir and Ponderosa pine (e.g. PPxh, IDFxh):

Regeneration beyond 2065 with climate change:

- K2- Douglas fir regeneration becomes rare or infrequent in the open and is absent on dry sites over time (except in partial shade and/or edges of existing stands).
  - Similar to what was projected in K1
- K2- Ponderosa pine has fairly frequent regeneration success except on the driest sites, where some shade during the heat of the day may be necessary.
  - An adaptive management scenario with Fd planting reduced from 65% to 35% and replaced with Py showed increased productivity.
  - Similar to what was projected in K1

Stand stress beyond 2065 with climate change

- K2 - There will be high levels of stress in an increasing number of stands.
  - Roughly 25-38% of stands with a Douglas-fir component will have high levels of stress in the Douglas-fir.

    - K2 and K1 - Aspen stands will be particularly stressed K2 modelling suggested the area in stressed stands would continuously increase for the next 70 years but will taper off somewhat afterwards for two reasons - water-stress induced mortality will open up these stands enough that competition for moisture will lessen.
    - With partial-cutting (that will likely occur), regeneration will likely be more successful possibly maintaining higher stocking – without stand density interventions stress levels could remain high.
- K2 - Water-stress induced mortality – about a 25% increase (over normal) in 2060 and double the mortality by 2080.
    - Greater numbers of large snags (> 30 cm) and logs – possibly with fuel implications for wildfire.
- K1 – Generally suggested the same as the above, but with less precision.

Fire and other natural disturbances beyond 2065 with climate change

- K2 - Fire disturbance –area burned between 2065 and 2110 will see a large increase by 167% compared to average area burned with no climate change. Increased fuel may suggest greater intensity of fires as well.
- K1 suggests more mortality from tussock moth and budworm (at least up to 2060).
    - K2 - This was difficult to include in modeling. It may provide more mortality in episodic events which we did not model.

Forest Structure and productivity beyond 2065 with climate change

- K2 - Disturbance will encourage a much greater proportion of area in age classes less than 80 years old (roughly two thirds of the ecozone) by 2110.
- K2 – Ponderosa pine will likely increase as a proportion of species in this ecozone, but Douglas-fir will remain strong.
- Both K2 and K1 suggest - After stand replacing disturbances, hot drier conditions may see much more open and patchy stands with longer regeneration delays.
- K2 – Showed increased productivity in the next 50 years especially from young stands (0-50 years old) mostly due to an expanded growing season.
- K2 -Beyond 2065 (especially) – the impact of climate change is negative on stand productivity (mostly due to summer drought, even though this effect is somewhat buffered by an expanded growing season).
    - However, the K2 modeling is assuming that stands are clearcut and planted contributing to a gradual reduction in densities (poor survival) beyond 2035. This presumably wouldn't happen if partial-cutting was employed – so the drop may not be as significant.
    - Note that the expanded growing season (favourable shoulder spring/fall conditions) favour increases in younger stands mostly. Such productivity gains declined with stands older than 50.
    - No increase in volume production was noted for stands that are > 80years old in 2012.
- K1 suggested that the THLB would shrink significantly due to a much more pessimistic view of reduced productivity and volume production – this was not

supported by K2 modelling – while volume production was declining in the latter part of the next 100 years, it did not contribute to a reduction in THLB.

ECOZONE - Dry subzones dominated by Lodgepole pine (e.g. IDFdk and MSxk)

Regeneration beyond 2065 with climate change:

- K2- Trembling aspen regeneration will increasingly be challenged.
- K2- Douglas-fir and lodgepole pine will regenerate frequently on mesic or moister sites.
- K2- Douglas-fir regeneration success will be reduced and lodgepole pine will be absent on drier sites.
- K1 – Generally suggested the same as the above, but with less precision.

Stand stress beyond 2065 with climate change

- K2 – Moisture stress over time will generally increase by about 30%. Roughly 38%-45% of the THLB will have stands throughout it with high moisture stress (compared to relatively little area of high stress stands without climate change). This is projected to lessen considerably by 2080-2100 since the increase in water-stress induced mortality will open up these stands enough that competition for moisture will lessen.
    - Note – lodgepole pine stands may be especially stressed.
    - Aspen stands will see decline
    - Also note – that the model is assuming clearcutting with reduced survival.
- K2 - Water-stress induced mortality – about a 50% increase (over normal) in 2060 to 2080.
    - Greater numbers of large snags (> 30 cm) and logs.
- K1 – Generally suggested the same as the above, but with less precision.

Fire and other natural disturbances beyond 2065 with climate change

- K2 - Fire disturbance –area burned between 2065 and 2110 will see a moderate but significant increase by 77% compared to average area burned with no climate change. Increased fuel may suggest greater intensity of fires as well.
    - K1 assumed more fire disturbance than projected by K2.
- K1 suggests gappy mortality from tussock moth, budworm and bark beetles.
    - K2 - episodic events were not modeled in K2 (and it could be significant), however some increased background insect mortality with increased moisture stress was added.

Forest Structure and productivity beyond 2065 with climate change

- K2 - Disturbance will see much higher proportion of younger stands (<80 years old) moving from only 31% (currently) to 64% by 2100.

- K2 – by 2065 the component of Pl-leading stands in the THLB will more than double to comprise 42% of the THLB in this landscape using the business-as-usual approach which favours lodgepole pine for regeneration. It will decline beyond this point as survival of Pl will decline[15].
- K2- volume production in stands less than 40 years old at the start of the simulation were positively impacted by climate change after 50 and 100 years of growth.
- K2- Future natural stands dominated by Douglas-fir show an increase in productivity from 30-40% at age 100 despite small drops in density of stands initiated post 2035.
- K2 – managed stands show declining productivity as overall densities drop in Pl stands (to 27% by 2035 and to 0 by 2065) and in Douglas-fir stands (to 68% in 2035 and 63% in 2065)
    - However, the K2 modeling is assuming that stands are clearcut and planted contributing to a gradual reduction in densities (poor survival) beyond 2035. This presumably wouldn't happen if partial-cutting was employed in Douglas-fir stands and if planting of pine was phased out as survival become poor.
    - Note that the increase in productivity is due to an expanded growing season (favourable shoulder spring/fall conditions) and improved soil fertility.
    - No increase in volume production was noted for stands that are > 80years old in 2012.
- K1 suggested that the THLB would shrink significantly due to a much more pessimistic view of reduced productivity and volume production – this was not supported by K2 modelling – while volume production was declining in the latter part of the next 100 years, it did not contribute to a reduction in THLB.

ECOZONE - Dry Transitional subzones (e.g. IDFmw, ICHdw)

Regeneration beyond 2065 with climate change:

- K2- The regeneration success (from seed) of paper birch, and spruce is reduced by 1/3 from the current time period in open conditions.
- K2- Douglas-fir, lodgepole pine, and ponderosa pine regeneration success is slightly lower than the current time period in open conditions – some partial shade will help.
- K2 - In submesic stand types where regeneration was switched from 75/25 (Fd/Pli) to 50/50 Fd/Py, volume production was increased substantially when grown over 50 years due to better survival. Improvements in productivity for such a switch steadily increased for stands established beyond 2035 and closer to 2065.
- K1 – Generally suggested the same as the above, but with less precision.

[15] Note – In reality, a switch in species choice would at least occur at this point as it becomes obvious that Pl regeneration is no longer a viable option. We used the business-as-usual scenario throughout our 100-year simulation to clearly illustrate the consequences.

Stand stress beyond 2065 with climate change

- K2 – Moisture stress over time will generally increase by about 25-50% depending on the year. Roughly 30% of the THLB will have stands with high moisture stress (compared to relatively little area of high stress stands without climate change). This is projected to lessen somewhat by 2080-2100 since the increase in water-stress induced mortality will open up these stands enough that competition for moisture will lessen.
    - Note – lodgepole pine, birch (possibly aspen) may be especially stressed.
    - Also note – that the model is assuming clearcutting with reduced survival.
- K2 - Water-stress induced mortality – about a 50% increase (over normal) in 2060 to 2080.
    - Greater numbers of large snags (> 30 cm) and logs.
- K1 – Generally suggested the same as the above, but with less precision.

Fire and other natural disturbances beyond 2065 with climate change

- K2 - Fire disturbance –area burned between 2065 and 2110 will see a large increase by 149% compared to average area burned with no climate change. Increased fuel may suggest greater intensity of fires as well.
- K1 suggests significant mortality from a combination of drought, root disease and bark beetles.
    - K2 - incorporated increased background insect/disease mortality with increased moisture stress. It is quite possible that not enough mortality was factored in especially for successive drought years. Also, episodic outbreaks of concentrated mortality were not factored in.

Forest Structure and productivity beyond 2065 with climate change

- K2 - Disturbance will see much higher proportion of younger stands (<80 years old) moving from only 32% (currently) to 80% by 2100.
- K2 – by 2065 the component of Pl-leading stands in the THLB will increase by over 600% to comprise 36% of the THLB in this landscape (compared to 5% currently) using the business-as-usual approach which favours lodgepole pine for regeneration.
- K2- volume production in stands less than 40 years old at the start of the simulation showed modestly positive impacts from climate change over the 100 years.
- K2- volume production in stands more than 80 years old at the start of the simulation showed a slightly negative response to climate change due to increased mortality rates associated with elevated moisture stress and associated other mortality agents.
- K2 – Paper birch suffered higher rates of mortality in stands established pre-2011 than other species and tended to decline in most stand units.
    - Stands establishing after 2011 showed even greater declines due to problems with regeneration survival.
- K2-The submesic stand unit (Fd75/ Pl 25) showed the highest rates of mortality and suffered the greatest decline in productivity (up to a 50% decline) over the simulation.

- K2 -Productivity declines are evident in stands established between 2035 and 2065 (-7%) and beyond 2065 (-18%)
    - However, the K2 modeling is assuming that stands are clearcut and planted contributing to a gradual reduction in densities (poor survival) beyond 2035. This may not happen if partial-cutting was employed in suitable stands (such as Douglas-fir dominated stands) and if planting of pine was phased out as survival become poor.
    - For stands > 80years old in 2012 there may be a small negative impact from climate change. However both background and episodic cumulative impacts from insects and disease may take a greater toll than expected.
- K1 suggested that the THLB would shrink due to a loss of economic timber over time in current mixedwood stands from a combination of drought, insects and disease.
    - K2 modeling was not able to test this hypothesis specifically. The lessons from K2 still support the basis for this concern.

ECOZONE - Moist transitional subzones (e.g. ICHmw, ICHmk)

Regeneration beyond 2065 with climate change:

- K2- Paper birch regeneration (from seed) success is cut in half and spruce is struggling.
- K2- Douglas-fir and lodgepole pine regeneration success are one third to one half of Period 1 (2011-2035) in mesic –submesic soil types in open conditions. Some shading may help with Douglas-fir on these sites.

Stand stress beyond 2065 with climate change

- K2 – Moisture stress over time will generally increase by about 20-50% depending on the year. Roughly 46-52% of the THLB will have stands with high moisture stress (compared to 1-5% area of high stress stands in the absence of climate change). This is projected to level off a bit by 2080-2100 since the increase in water-stress induced mortality will open up these stands so that competition for moisture may lessen.
    - Both lodgepole pine and Douglas-fir stands components may see an increase in stress by a magnitude of 5-10 times with climate change.
        - Lodgepole pine will be particularly vulnerable on submesic sites.
    - Spruce may be vulnerable to water stress on both mesic and subhygric sites.
- K2 - Water-stress induced mortality – about a 100% increase (over normal) in 2060 to 2080.
    - Double the numbers of large snags (> 30 cm) and logs.
- K1 – Generally suggested the same as the above, but with less precision.

Fire and other natural disturbances beyond 2065 with climate change

- K2 - Fire disturbance –area burned between 2065 and 2110 will see a large increase by 162% compared to average area burned with no climate change. Increased fuel may suggest greater intensity of fires as well.
  - K1 – expected some increased fire, but not such a large increase.
- K1 assumed that the significant mortality from drought, root disease and bark beetles expected in the dry transition would not be noticeable in the moist transition until after 2050.
  - K2 - incorporated increased background insect/disease mortality with increased moisture stress. It is quite possible that not enough mortality was factored in especially for successive drought years. Also, episodic outbreaks of concentrated mortality were not factored in.

Forest Structure and productivity beyond 2065 with climate change

- K2 - Disturbance will see much higher proportion of younger stands (<80 years old) moving from only 40% (currently) to 85% by 2110.
- K2 – by 2065 the component of Pl-leading stands in the THLB will increase by 260%, using the current business-as-usual - to comprise 68% of the stands in the THLB.
  - NOTE – this is a significant conversion of stand types in this ecozone due to current planting preferences.
- K2- volume production in stands less than 40 years old at the start of the simulation will show positive impacts from climate change throughout the entire simulation period to 2110.
- K2- volume production in stands more than 40 years old at the start of the simulation will show a pronounced negative response (more than the dry transition) to climate change due to increased mortality rates associated with elevated moisture stress and species adapted to a moister climate.
  - K2 – Paper birch, spruce and western redcedar will be particularly vulnerable.
- K2-most future managed stands showed increased volume production with climate change, regardless of the regeneration period.

ECOZONE - Plateau (e.g. MSdm, SBSmm)

Note – in the K2 report this ecozone was frequently referred to as the "dry plateau", which we find is a bit of a misnomer in light of the fact that relatively speaking it is much moister than the other ecozones that have the descriptor of "dry" in them. For this reason we will just refer to it as the plateau ecozone.

Regeneration beyond 2065 with climate change:

- K2- Subalpine fir regeneration success is almost cut in half in open conditions. As an understory tree regeneration will likely be more successful.

- K2- Lodgepole pine (Pl) and spruce lose about 25% of their regeneration success in open conditions compared to current conditions. Some partial shade for spruce especially may be needed.

Stand stress beyond 2065 with climate change

- K2 – Moisture stress over time may increase slightly for some species like subalpine fir, but even that will vary from 0-25%. Generally the proportion of the THLB that will be under significant stress will actually decline with climate change.
    - Water stress may be a problem in dry years but the frequency of dry years (even with climate change) is low.
    - The weather station for this ecozone is on the north side of Sun Peaks and so may be moister and cooler than it should be to be representative of this landscape.
- K2 - Water-stress induced mortality – about a 40% increase (over normal) in 2060 to 2080.
    - Large snags (> 30 cm) and logs are expected to increase as a result of this mortality – possibly increasing fuels across the landscape.

Fire and other natural disturbances beyond 2065 with climate change

- K2 -Fire disturbance –area burned between 2065 and 2110 will see a large increase by 146% compared to average area burned with no climate change. Increased fuel may suggest greater intensity of fires as well.
    - K1 – expected more fire, but not such a large increase.
- K1 assumed that their will be significant episodic mortality events from bark beetles in spruce.
    - K2 - Episodic outbreaks of concentrated mortality were not factored in.

Forest Structure and productivity beyond 2065 with climate change

- K2 - Disturbance will see much higher proportion of younger stands (<80 years old) moving from almost 50% (currently) to 89% by 2110.
- K2 – by 2065 the component of Pl-leading stands in the THLB will increase by 70%, using the current business-as-usual approach favouring pine - to comprise 34% of the stands in the THLB.
- K2- volume production in stands existing in 2011, is expected to substantially increase, particularly in wetter portions of the ecozone. Younger stands will show the greatest increase. This is attributed to a substantial lengthening of the growing season with only minor increases in water stress, and a significant increase in decomposition rates.
    - K1 – underestimated this increase in productivity and likely overestimated the stress compared to K2.
- K2-most future managed stands will show a much increased volume production (sometimes dramatically) with climate change, regardless of stand age or the regeneration period.
    - These increases should be treated with caution as it could be balanced by an increase in bark beetles and other biological agents.

ECOZONE - Wet Cold Engelmann Spruce / Subalpine Fir Ecozones (e.g. ESSF)

Regeneration beyond 2065 with climate change:

- K1- Subalpine fir and spruce regeneration is expected to continue relatively unaffected except in periodic warm dry springs.
- K1 – Douglas-fir and redcedar may become suitable for regeneration at the lower portion of this ecozone past 2065.

Stand stress beyond 2065 with climate change

- K1 – It is expected that water stress in these stands will be even less than is currently projected by K2 in the Plateau Ecozone.
- K1 - Increased mortality will be episodic and related to drier climatic cycles and biotic agents such as spruce or balsam bark beetles.

Fire and other natural disturbances beyond 2065 with climate change

- K1 Fire disturbance –Likely will see an increase in fire, but it will be highly variable (from very small to moderate) and related more to the juxtaposition of this ecozone with ecozones that will have a substantial increase in risk and incidence of fire.

Forest Structure and productivity beyond 2065 with climate change

- K1 - There may be a slight increase in younger age classes over time. Note that much of this area is reserved for mountain caribou. In these old stands, there may be an increase in gaps due to some increased episodic insect activity,
- K1- volume production is expected to increase, perhaps even more so than in the Plateau ecozone.
- K1- most future managed stands will show a much increased volume production (sometimes dramatically) with climate change, regardless of stand age or the regeneration period.
    - These increases should be treated with caution - they could be balanced by an increase in bark beetles and other biological agents.