Report # 11

West Kootenay Climate Vulnerability and Resilience: Lessons Learned

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1.0 INTRODUCTION

Recent reports by the International Panel on Climate Change (IPCC) confirm that global climate change is underway, and likely to accelerate over the coming decades unless humans make drastic cuts to global greenhouse gas (GHG) emissions (IPCC 2007). In British Columbia, analysis of the last hundred years of climate data confirms that parallel climatic changes are also occurring in this province (Spittlehouse 2008), and in the Columbia Basin (Murdock et al. 2007). Apparent visible evidence of changes in climate are also becoming increasingly apparent to local people in the West Kootenays – witnessed through a wide range of changes in broad variety of different indicators.

The British Columbia government has recognized that the uncertainties associated with climate change demand a forest management approach that differs from the traditional (MoFR 2008). With the establishment of the Future Forest Ecosystems Initiative (FFEI) in 2006, the province began a move toward looking for ways to adapt the forest and range management framework with respect to potential future climates. The province established the Future Forest Ecosystem Scientific Council[1] (FFESC) in 2008 to deliver research grants to support the objectives of the FFEI. This report summarizes some of the findings of one project[2] that was among those funded by the FFESC under their 2009 call for proposals.

The project has three integrated objectives:

- to undertake an ecological vulnerability assessment using local climate predictions for the West Kootenays, under three recommended climate change scenarios;
- to work with local forest practitioners, and science experts, to collaboratively learn about the range of climate futures and their potential implications for the West Kootenay ecosystems; and,
- to case study the application of various concepts within this field – in particular, vulnerability assessment and resilience. In addition, we include assessment of concepts of risk management and structured decision-making.

In undertaking this complex project, the project team engaged in a wide range of sub-projects, and as a result we have compiled a summary of key learnings from each of the various aspects of the project.

In this report - #11 – for the project, we organize the key lessons learned below, in the following categories:

- approaches to assessment and decision-making,
- collaborative learning
- climate change impact modeling and interpretation,
- ecosystem vulnerability assessment
- barriers, incentives and opportunities

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[1] Further information on FFESC: http://www.for.gov.bc.ca/hts/future_forests/council/index.htm

[2] Resilience and Climate Change: Adaptation Potential for Ecological Systems and Forest Management in the West Kootenays. For further information on the project: http://kootenayresilience.org

2.0 APPROACHES TO ASSESSMENT AND DECISION-MAKING

2.1 Vulnerability

1. A vulnerability assessment framework provides a structure for assessing vulnerabilities in social and ecological systems. Although an 'integrated' approach is recommended, assessments have often (typically) been undertaken separately for ecosystem and social elements. We found that terminology was often confusing between ecological and social realms (e.g. adaptive capacity and how to apply it to both realms in the same analysis).

2. We undertook an ecosystem vulnerability assessment and found that definition of concepts was also relatively poorly defined in application to the ecological system (e.g. overlap between sensitivity, adaptive capacity and external pressures), which we assume to be a result of scale and indicator differences amongst projects, and also the relatively early development stage of this type of work.

3. Irrespective, the vulnerability assessment approach provided a relatively easy to use framework for organizing an approach to assessment of climate change impacts and in determining vulnerabilities. We found it easier, as a team, to apply this framework than to use the 'resilience' assessment approach.

4. The lack of a clear theoretical framework for assessing ecological vulnerabilities however, required us to develop our own approach to understanding vulnerabilities to ecosystems with climate change. Efforts to consolidate ecological assessments into a more systematic framework with consistent terminology are needed. In addition, we used theoretical concepts of resilience to help interpret the significance of the predicted ecosystem shifts.

5. Overall we found the Vulnerability Assessment model to be a useful one, and relatively straightforward to apply. Additional organization work is needed to make it readily applicable in a forest management context.

2.2 Resilience

1. The 'resilience' concept is a catch-all for (at least) three different concepts: a) an approach to assessment (e.g. the Resilience Alliance workbooks), b) a wide range of ecological theories that have been brought together under the auspices of the adaptive management cycle leading to ways to consider resilience, and c) a management approach – managing for 'resilience' which may (or may not) expressly consider a) and b).

2. Resilience Assessments: We attempted to utilize the Resilience Alliance workbooks, but even internally as a working team, found this to be a very time-consuming and difficult process. The RA workbook is organised in a non-linear way - making it difficult to work through it, and to integrate the disparate pieces. Took significant time to process the workbook within our team, and finally changed the approach with our clients to one based on a vulnerability framework (as above).

3. Resilience Theory: We did find resonance with the general concepts of resilience, amongst forest practitioners, especially around concepts of transition and identifying the easiest times in the cycle to affect future outcomes, but found limited practical application of the more 'academic' aspects. Difficult to anticipate cross-scale linkages and thresholds (with the exception of the most obvious?) as requested by the approach;

4. Resilience Theory: General concepts are intuitively pleasing, but generally applied in a non-scientific way or inconsistently, and are very difficult if not impossible to test in this type of project. They therefore are useful only in providing a 'working conceptual model'.

5. Resilience assessment: Some useful concepts that are highlighted within the resilience approach include:

    a. Social-ecological-systems (SES) are highlighted within resilience theory. The literature promotes the idea that all members of a working group must learn to think outside their individual silos of expertise. This is no doubt very useful in the long run – but also very challenging to apply. Perhaps most useful for the organisers of the process but really difficult to have sufficient time for clients to become engaged across realms.

    b. Drivers – identifying drivers is promoted as a preliminary step in the process. We spent time with practitioners and found it generally use, but difficult to integrate the more detailed work into the process. Useful mental step, but needed more time in order to more fully integrate these factors. However, this work did provide a rationale for focusing in certain areas. Whether worthwhile for the time spent is difficult to assess.

    c. Concept of thresholds embedded in resilience ideas. Very useful to consider thresholds in a general sense in this form, and a few may be intuitively obvious – such as moisture deficit thresholds for tree growth. The types of thresholds identified within the resilience literature are very difficult to predict in advance however, so their utility as a predictive tool is likely weak.

    d. Regime shift – useful concept and a place for integrating thresholds, drivers, and historic condition. We used this concept in interpreting the results of our ecological vulnerability assessment.

    e. Resilience itself can be non-intuitive, for example where an ecosystem may be highly resilient but not the desired outcome (e.g. cod example, or knapweed field example). This can make it easy to misunderstand the concept.

2.3 Structured Decision-Making

1. West Kootenay forest practitioners were open to learning more about decision-making processes which explicitly account for uncertainty.

2. A structured decision process showed some promise to assist forest practitioners to select adaptation options, particularly in well understood aspects of the forest management system, such as road management. Adequate preparation and expertise with the tool and the context are essential to effectively use this approach.

3. Further research and testing is required to identify the most suitable assessment and decision processes in this context.

4. Vulnerability and resilience assessments do not, on their own address the decision needs of forest practitioners because they do not factor in important decision criteria such as urgency, costs/benefits, etc.

5. Structured decision-making processes should be explored further for broader application in forest management decisions in BC.

6. Each forest practitioner makes decisions in a unique combination of ecological, social and organizational values related to goods and services from forests. This means the appropriate climate change adaptation assessment and decision approach will differ amongst organizations.

7. The project team tested the SDM approach in the final workshop with practitioners. Three problem contexts were chosen: access management decisions, reforestation decisions, and decisions related to management of forests between free-growing age and maturity, with different team members facilitating groups of practitioners for each decision context. Learnings from this example included:
    a. A substantial amount of preparation was required to create the decision context information and worksheets.
    b. All participants need to have a basic familiarity with background information about climate change and potential impacts, or this information must be included explicitly up front in the process.
    c. The geographic area examined needs to be relevant to the decision context, i.e. a landscape scale is required to examine biodiversity impacts of alternatives.
    d. The knowledge and skill of the facilitator in both the topic area and the approach is important to the success of the approach.
    e. The group addressing road management successfully completed the worksheets and found the approach was valuable. Participants in the groups exploring decisions for reforestation and free-growing to mature forest management did not complete the worksheets, but were supportive of continuing to explore this approach, including hosting workshops with their colleagues for their specific operations.
    f. Participants identified the following strengths of the approach: structuring decisions, integrating values, prompting brainstorming of options, driving conversations amongst practitioners with diverse views, and *eye opening* regarding the complexity of adaptation decisions and by prompting *thinking outside the box.*
    g. Practitioners made several recommendations about simplifying the worksheets, calibrating some of the consequence measures and improving the process including having the worksheets projected so everyone could follow the facilitator's use of the worksheets.

3.0 COLLABORATIVE LEARNING

3.1 Perspectives from the Project Team

1. Originally inspired by the Resilience Alliance framework we attempted to move away from typical forest management 'presentation' style workshops to one of collaborative learning. This was a time-consuming effort – but included working through, rather than simply presenting, key ideas. The true effectiveness or learning associated with this process is difficult to assess.
2. We attempted to bring together the variety of decision-makers who are involved at the 'district level' or 'company office' level of decision-making. The broader community was not included in this project, since it was directed at forest management decision-making – this would make it a more real process, since this would likely have altered the perception of the information and risks, however would have significantly lengthened the time and effort required. However, this said, even within the relatively limited group of individuals present, a wide range of perceptions on the issues were represented, which depended at least partly on the specific element of forest management an individual was responsible for. For example, fire

management branch staff had a quite different perception around risks and priority actions than did foresters working for BCTS or a local forest company.

3. Success depends, at least partly, on providing locally relevant information on climate change projections and potential impacts. Provincial (or global) information is not seen as very useful or relevant by local managers.
4. Forest practitioners who are knowledgeable about local forest ecosystems, including the silvics/autecology of dominant tree and shrub species were comfortable charting and describing likely ecosystem changes and forest management adaptations, based only on information about projected local climate change.
5. Moving forward, Conversation Forums attended by a diverse group of forest/land practitioners can be an effective means for working toward understanding how to manage West Kootenay ecosystems with respect to climate change and associated uncertainties/impacts. Sessions would be structured such that diverse groups of people work on a single problem together. These forums require a champion to compile information, coordinate topics, attendance, and scheduling.

3.2 Listening to the Practitioners

1. Most forest practitioners that participated in the survey and workshops have observed what they believe to be climate change impacts affecting West Kootenay forests. These changes include increased insect and disease activity, drier summer conditions and more frequent extreme rainfall events.
2. Many forest practitioners in the West Kootenays believe it is important to incorporate climate change thinking into plans and operations. They understand that impacts of climate change need to be considered during forest management but require support to access relevant information and to address policy barriers.
3. Many of the practitioners that attended the workshops believe there is an urgency to include climate change impact predictions into forest/land planning and operations.
4. Forest practitioners want local (versus provincially-based) information on how climate change may impact forest ecosystems. Forest practitioners want to participate in developing forest management strategies that consider climate change impacts.
5. Forest practitioners want to see less spending on climate change science and more emphasis on development of practical strategies. Specific information related to potential climate change impacts on local ecosystems, forest health concerns, wildfire regimes as presented during workshops provides enough guidance to begin to incorporate climate change into forest management now.

4.0 CLIMATE CHANGE IMPACT MODELING AND INTERPRETATION

1. The provincial government should work toward a consolidated set of climate change science for British Columbia, encouraging scientists to work closely together to:
   - maximize benefits from limited research dollars
   - avoid producing apparently contradictory results due to differing methodologies – these will ultimately confuse practitioners and provide fuel for deniers.

4.1 Climate

4.1.1 Learnings relevant to West Kootenays:

1. All of the ten GCM/ emission scenario combinations we tested were able to reasonably simulate recent seasonal temperatures for the study area; most but not all were able to simulate the recent seasonal pattern of precipitation, and they all tended to underestimate winter precipitation, likely due to a lack of resolution and full incorporation of orographic effects.

2. All the models and scenarios tested project steadily increasing temperatures for all seasons for the coming century – the main differences are in timing and extent of the increases.

3. For the study area in general, the models project that by the 2080s, winters, springs and falls will be warmer by 2 to 5^{o}C and 10-25% wetter, and that summers will be 3 to 7^{o}C warmer, with precipitation that may be similar to today or decreased by up to 30%.

4. The limited information available on extreme climatic events project an increase in the magnitude and frequency of high intensity precipitation events, drought events and extreme maximum temperature events.

5. There is uncertainty about extent and timing of future climate change for the area, but it is possible to place some bounds on that uncertainty.

6. Choice of GCM has more effect on projected climatic changes to the 2050s than emission scenario, but variation in emission scenario begins affecting projections, along with GCMs by the 2080s.

4.1.2 Learnings relevant to Provincial / Policy

1. Climate changes vary regionally, and regional (local) assessments are warranted.

2. Regional assessments should be completed for areas that are climatically relevant (i.e. not by administrative boundaries – for example our “regional landscapes”).

3. Assessments should include the determination of the appropriateness of specific GCMs and runs for that region – through backcasting to ensure that GCM runs can reliably model past seasonal climatic considerations.

4. Seasonal rather than annual changes in temperature and precipitation are required to predict ecosystem and disturbance processes relevant to forest managers.

5. More information on climate/ weather extremes is needed.

6. ClimateWNA and PCIC’s Analysis Tool are useful easily accessible sources of current, past and projected climate information.

7. Data on historical ‘regional’ climate changes since the 1950s also need to be readily available for forest practitioners to provide an anchor and to hasten understanding of projected future changes.

8. Climate information has not commonly been used by forest practitioners in decision-making in recent decades. Background information about how to interpret climate information (e.g. how climate is measured and analyzed; very small changes in seasonal climate data between observably different

climates) needs to accompany historical and projected climate information to aid interpretation and application by forest practitioners.

4.2 Fire

4.2.1 Learnings relevant to West Kootenays:

1. The average annual area burned is likely to increase dramatically over the next few decades (by at least 3 or 4 times by 2050), and these predictions apply to all ecosystems within the study area.

2. There is significant variation in projected changes in average annual area burned for coming decades, but all GCMs and emission scenarios indicate significantly increasing trends.

3. Fire regimes in some areas may result in major ecosystem regime shifts (e.g. from forests to grasslands, from forests dominated by gap replacement to forests dominated by moderately frequent stand-replacing fires). Managing for this transition may be required for some systems, in order to reduce the risk of an abrupt shift, or even catastrophic ecosystem collapse.

4. Fire suppression, fuel management treatments and emergency preparedness will have to continue to be significantly ramped up if many forest values are to be maintained.

5. The projected increases in fire will have implications on all aspects of forest and land management.

4.2.2 Learnings relevant to Provincial / Policy

1. Climate change has the potential to overwhelm present fire suppression capabilities, at least in some portions of the province.

2. There is a significant need for strategic provincial level planning for the impacts of climate change on fire suppression, fuel management and emergency preparedness policy and implementation.

3. The priority for effective fuel management in settlement interface fire zones is quickly increasing; this likely extends to many other areas with values that may be potentially damaged by wildfire.

4. There is a need for reassessing natural disturbance regimes and habitat protection measures, especially old growth management areas, wildlife habitat areas and protected areas, to ensure they remain effective into the future.

5. There would likely be planning benefits from repeating these kinds of fire assessments in other regions of the province; the information for doing the assessments is readily available.

4.3 Bioclimate Envelope Modeling

4.3.1 Learnings relevant to West Kootenays:

1. By the 2080s, the climate envelopes in most low elevation areas near Creston and between Fauquier and Trail, are projected to shift from those typical of drier ICH forested ecosystems to envelopes typical of grasslands and steppe ecosystems (likely linked to increasing temperatures and decreasing summer precipitation, increasing incidence of severe droughts, and a change in the fire regime).

2. By the 2080s, most other valley bottom areas climate envelopes are projected to shift from those of moist to wet ICH forests, to climate envelopes more typical grassland/ steppe of dry forests dominated by Douglas-fir, grand fir and/or Ponderosa pine (likely linked to increasing temperatures and decreasing summer precipitation, and a change in the fire regime).

3. By the 2080s, many mid elevation areas climate envelopes are projected to shift from those of moist to wet ICH forests, to climate envelopes more typical of warmer/ drier forest types, but the extent of shift is uncertain (ranging from grassland/steppe to dry montane spruce or moist ICH). The degree of shift will primarily depend on the magnitude of change in summer precipitation and summer temperatures.

4. By the 2080s, projected climate envelope shifts for upper elevations are highly uncertain. Moist to wet ESSF and alpine parkland/ alpine climate envelopes may shift to drier Douglas-fir and ICH, or types ranging from modified alpine tundra envelopes to climate envelopes more typical of CWH and coastal transition CWH/ICH (likely linked to increasing temperatures and changing snow depths).

5. The specific outcomes of shifts in climate envelopes are difficult to predict. There are many factors to consider, including: changes in disturbance regimes (fire, wind and insects/disease), competition between species, and poorly understood autecological responses to average and extreme new climates.

4.3.2 Learnings relevant to Provincial / Policy

1. Assessments of potential bioclimate envelope shifts should utilize ecosystem and climate data for all of western North America to ensure the widest possible opportunities for identifying contemporary climatic conditions that are similar to projected conditions (Mexico and Central America may be useful for some coastal ecosystems).

2. All assessments of bioclimate envelope shifts should include assessments of the degree of similarity between projected climate variables and the climate variables of the projected ecosystem – rather than simply identifying the 'next closest' system without any guide on similarity. Assessments should include the identification of potential novel or non-analogue climates.

3. It would be useful to gain more information about the disturbance regimes and functioning of the ecosystems with bioclimate envelopes projected for future occurrence in BC. This information could assist with adaptation planning.

4. There is a need to reassess the use of BEC zonation for assessing representation in protected areas, old growth management areas and other habitat conservation programs; this could potentially be replaced by a system more closely tied to regional landscape-scale enduring features relevant to the distribution of regional climates (such as those used to define 'regional landscapes' in this analysis).

5. Bioclimate envelope shift assessment should utilize a level of ecosystem classification relevant to the level of land management questions being asked. For example forest management projects should be sufficiently detailed to assess tree species distribution.

6. Evaluate forest management options for the valley bottom forests that are projected to shift to grassland/steppe to evaluate the potential benefits of investments in costly reforestation. This includes examining stocking standards and species acceptability.

4.4 Tree Species Shifts

4.4.1 Learnings relevant to West Kootenays:

1. Tree species climate envelopes are generally shifting upslope and to the north.
2. At low and mid elevations drought- and fire-resistant species and genotypes will likely be more successful in the future. Other than riparian areas, many low elevation sites, especially in the southern portion of the study area, may become unsuitable for trees,
3. At higher elevations spruce will likely become an ecologically unsuitable species before 2100.
4. Reforestation that includes a diversity of species will likely decrease risk.
5. Pest-resistant species and genotypes will likely be more successful in the future.

4.4.2 Learnings relevant to Provincial / Policy

1. Reassess seed transfer rules.
2. Reassess various seedling and provenance trials.
3. Work with US counterparts to negotiate future seed transfers.
4. Need to acquire more information on the autecology of species and provenances.
5. Re-evaluate stocking standards and species acceptability across regional landscapes.

4.5 Forest Health

4.5.1 Learnings relevant to the West Kootenays

1. Insects with potential to expand due to climate change in mature West Kootenay forests in the short- to mid-term are: spruce bark beetle, Douglas-fir beetle, western balsam bark beetle, and western hemlock looper. These insects are capable of mortality across large expanses of mature forest during outbreaks.
2. Some insects and diseases that up until now have only been observed in rare instances in the West Kootenays may expand to outbreak levels as annual temperatures warm and summer drought becomes more common. These include: western false hemlock looper and spruce leader weevil.
3. Some pathogens may cause more damage as annual precipitation increases, especially in the spring. Potential species of concern include pine stem rusts, larch needle blight and cast, Swiss needle cast and dothistroma.
4. Armillaria root disease may cause more mortality as trees experience greater stress caused by drought and increased outbreak intensity of other insects and diseases.
5. Decline syndromes may increase causing significant damage to forests.

6. The mixed species composition of most West Kootenay forests provides some resilience from changes in forest health. However, the West Kootenays have already seen significant mortality for some species that may or may not be climate related. This includes white pine, whitebark pine, lodgepole pine, birch and western redcedar particularly on drier sites. The long-term implications of these changes – even for a relatively resilient system – are as yet unknown.

4.5.2 Learnings relevant to Provincial / Policy

1. There is tremendous uncertainty associated with potential impacts of climate change on forest health because of the complex interactions between climate, host and forest health agent. Therefore predicting trends and outbreaks is challenging and requires expanded resources.

2. Coordinated annual monitoring of forest health agents in mature forests as well as young stands is required. An effective program would be systematic and would evaluate health, mortality and growth.

3. Insect and disease hazard and risk rating systems that incorporate climate change may help reduce losses by focusing efforts in areas with highest risks.

4. Flexible policies are required that allow fast response during outbreaks.

5. Flexible stocking standards that permit maximizing tree species diversity in new stands may help reduce losses to insects and disease.

6. Tree breeding programs can be used to develop insect/disease resistance in some species.

5.0 ECOSYSTEM VULNERABILITY ASSESSMENT

5.1.1 Learnings relevant to the West Kootenays:

1. The low elevation assessment unit in the North Subregion, currently dominated by Moist and Wet ICH is highlighted as one of the most vulnerable systems (High to Very High) in the West Kootenays. These systems are predominantly NDT1 forested ecosystems that are projected (by both bioclimate shifts and fire dynamics) to potentially become NDT 3 / 4 - frequent fire dominated systems. In addition, there is the potential for catastrophic regime shift in these systems.

2. The low elevation unit in the South Subregion – currently a mix of NDT 3 and 4 – is projected to shift to hotter drier climates, with all three scenarios projecting shifts to NDT 4 grassland/ savanna bioclimate envelopes for a significant portion of the area. However the vulnerability ratings are all Low and Medium – despite significant human-related impairment of adaptive capacity – because suitable species for recovery are likely to be present. In general we expect these systems to be less likely to move into a 'stall' state, however, there is significant risk that invasive species could colonize sites after a disturbance event, so preventing a typical return to a more productive successional pathway, which would warrant a potentially higher vulnerability rating.

3. Mid elevation systems in the South Subregion are given a 'high vulnerability' rating for one scenario, since the magnitude of predicted natural disturbance shifts is much greater (from NDT2 to NDT 4).

4. In the Mid Subregion, the mid elevation bands are given similar ratings to the wetter ecosystems in the North (High or Very High vulnerability), because of the similar predicted regime shift. The lower and

highest elevation bands of the Mid are given lower vulnerabilities since the change in natural disturbance regime is less likely to result in a catastrophic regime shift.

5. In terms of consistency of the projections from the three scenarios, the low elevation in the North Subregion and mid elevation in the Mid Subregion are most consistent – and predicted to have consistently the highest vulnerabilities. Alternatively, the highest elevation bands in the South, North and to a slightly lesser extent the Mid, have consistently Low and Very Low vulnerability ratings. In theory then, this information provides managers with potentially consistent predictions on what the future may have in store. Alternatively, the mid elevation band in the North (from Low to Very High) and South mid elevation band (Very Low to High) have variable ratings by scenario. For these systems, choosing ecologically appropriate adaptation strategies will be particularly challenging.

6. There is clear evidence that climate change can induce threshold responses in ecosystems – but the basic science around these thresholds, in particular prediction of potential threshold responses in advance of them occurring, is not well developed and hard to test. Further basic science on understanding the dynamics of forested ecosystems could improve basic understanding of how systems may respond into the future.

7. Evidence of thresholds has often come from arid systems. Our analysis supports this, as the driest forest systems potentially change to non-treed systems presumably as moisture thresholds are crossed. However, our results were also intuitively unexpected because systems not considered close to such a threshold (e.g., drier areas of the wet ICH at low elevation) were also projected to change state towards grassland. The learning from this is that the scope of climate change being predicted by these three scenarios is of sufficient magnitude that anticipation of potential thresholds appears to require us to think considerably outside the scope of what may at first glance appear reasonable.

8. Climate scenarios to 2080 provide a snapshot of the future, but there’s no suggestion that the rate and direction of climate change will slow after 2080. This stresses the need to begin to apply what we learn here sooner rather than later, If there is continued directional change in climate far into the future, we will need to quickly gain experience on how to manage with ongoing uncertainty.

9. Looking for and understanding potential feedback loops appears critical – since critical thresholds are those that, once crossed, propel the system through a state where feedback moves the system quickly into new dynamics and potentially then regime shift.

10. The concepts of resilience, multiple stable states and thresholds appear to be useful in understanding, or at least developing a theoretical framework for understanding the potential dynamics of West Kootenay ecosystems. These ideas “appear to work”, but are hard to test, making it hard to undertake due diligence on the science aspects, especially with the urgency of making ecologically appropriate management decisions for the future today.

5.1.2 Provincial / policy

1. Use a climate appropriate assessment unit for analysis. For this project, we generated a unit based on enduring features. This was based on topographic breaks and uniform elevational sequences of currently mapped biogeoclimatic units resulting in what we predict to be relatively homogenous regional climates.

2. We applied the vulnerability assessment framework, but modified for ecological systems. We had to define terms to provide consistency for our analysis, because the literature does not provide a standard framework at this time.

3. We used resilience theory to aid in understanding the significance of projected changes. This includes assessing whether there likely to be a) no regime shift, b) a non-catastrophic regime shift where the system continues along a common successional pathway or c) a catastrophic regime shift – where the system potentially moves into a stalled or arrested place of development and can remain there for significant periods (or only very slowly 'recover').

6.0 BARRIERS, INCENTIVES AND OPPORTUNITIES

6.1.1 Regional time, information, research and collaboration

1. **Time and money constraints** – The down-sizing of regional government operations and the financial stress in the forest sector makes it very difficult for practitioners to prioritize non-essential tasks, which includes climate change adaptation for many practitioners. Innovative design of materials and activities is required to mainstream climate change adaptation in these conditions.

2. **Compilation and accessibility of currently available literature –** The research and literature on climate change adaptation that is relevant to West Kootenay forest management is significant, and continues to grow. This project shows that much can be accomplished by compiling what is available and making it readily available to practitioners via workshops and a website. These efforts should be continued. Presentations to interested groups, webinars and workshops with smaller groups are other alternatives to overcome the time and resource constraints of practitioners.

3. **Moving beyond early adopters** – Given the plethora of psychological barriers to climate change adaptation, the identified barrier of individual personalities and mindsets, in addition to the real time and resource limitations of local forest practitioners and managers, there are many reasons why some practitioners (e.g. BCTS, conservation organizations, managers) did not participate in the project. , Non-participants should be queried to better understand their barriers and find ways they can become involved. Particular attention should be paid to senior government and industry managers, as no managers participated in the project, and practitioners rated optimism bias about future conditions as a barrier.

4. **Focus now on 'what to do'** – Making decisions about climate change adaptation is a complex process that requires more time and resources than were available in this project. The practitioners identified not knowing 'what to do' as one of the highest priority gaps at this stage. Continuing the information sharing, conversation forums and structured decision approaches with local practitioners is recommended to fill this gap. Exploring options for climate-wise silviculture prescriptions and monitoring/management of fires, pests and diseases are suggested first priorities. Processes should explore and understand the psychological reasons for preferences as well the technical reasoning. Creating adaptations that are jointly supported by government, industry and local interest groups will expedite their acceptance by the provincial government and the public, possibly overcoming the perceived inability to influence appropriate political levels.

5. **Joint regional science-management adaptation partnership** – Climate change destabilizes much of the existing knowledge about ecosystems, challenges existing forest planning processes and creates questions about appropriate adaptation practices. Collaborative initiatives involving science and practitioners exploring regional socio-ecological systems strengthen adaptive capacity. This type of collaboration does not exist in the current forest management system. It should be a long-term goal of the next steps of this project to create this partnership. Similar partnerships will be needed at regional scales across the province.

6.1.2 Provincial forest management

1. **Wildfire management and community wildfire protection** – Recent high impact fire seasons have prompted changes in wildfire management practices and resources, and implementation of community wildfire protection. However, West Kootenay practitioners continue to identify these changes-to-date to be inadequate given projected climate impacts. This should be a priority topic for next steps in this project and provincially.

2. **Climate-sensitive silviculture prescriptions** – Inflexible regulations, tension in the implementation of professional reliance, unfamiliarity with writing rationales including climate change adaptation and the short-term focus on removing free-growing liabilities are barriers to creating climate-sensitive silviculture prescriptions. As this is a first priority in creating a more resilient forest, immediate attention is needed to overcome these barriers. Participation will be needed at the provincial and regional levels in both government and industry to expedite solutions. In the West Kootenays, initially these processes should focus on the highly vulnerable valley-bottom/ mid-elevation landscapes where forests could be significantly altered in the near term.

3. **Monitoring** – This project identified that "information management" systems are inadequate, particularly in relation to general monitoring for climate change impacts, and in relation to forest conditions post free-growing. These gaps are particularly of concern given the projected increase in pest and disease impacts. While some solutions may be found at the regional level, provincial resources are needed to fully address this gap.

4. **Climate-sensitive land management plans** – Current land management directions contained in the KBLUP and other legislated direction do not account for climate change, raising concerns about the adequacy of protected areas, connectivity, biodiversity and riparian management practices. Some of these values may be left at significant risk and an assessment of the risks to landscape values from climate change is needed to identify potential challenges and appropriate adaptation actions moving forward.

6.1.3 Public views

1. **Verifying support for adaptation** – Practitioners identified public support and pressure for adaptation in local forest management as a strength. This was echoed in the South Selkirk survey. However, when the needed adaptations are fully understood, (e.g. priority harvesting of some types of vulnerable forests, extended backcountry closures during high fire hazards) the public generally, and those directly affected by these adaptations may not be so supportive. Involvement of the public in the next steps in the process will be essential to ensure their views are incorporated, and trust is built in the discussions and decisions about 'what to do'.

6.1.4 Probing the social aspects of forest management adaptation in BC

1. **Expand research and knowledge transfer on social dimensions of adaptation** – To date, research on climate change adaptation in BC forest management has largely focused on the bio-physical impacts and vulnerabilities, with less emphasis on the social aspects. As adaptation is essentially a human activity, and must be supported across the many organizations and diverse interests in BC's forests to be swiftly implemented, fully understanding the social and psychological barriers to adaptation, and ways to overcome these barriers is crucial, and deserves more attention moving forward. However, the effort and resources required to undertake this type of work should not be under-estimated.

7.0 REFERENCES

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