Defining Pre-Industrial and Current Disturbance Regime Parameters for the North Saskatchewan Regional Planning Area

A Technical Report Prepared for the Alberta Government in support of the North Saskatchewan Land Use Planning Process

Companion Document to "*Disturbance regimes of the North Saskatchewan Regional Plan area: A state-of-knowledge report on fire regimes and disturbance of forests, grassland, and ecotones*"(Stockdale, 2011).

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Disclaimer

As a technical document, the objective of this report is to provide concise and precise input toward a larger modelling exercise. As such, this report does not follow the format of a more traditional scientifically rigorous document. Citations are provided only where necessary and explanations on scientific issues are abbreviated. For those interested in a more detailed review of the science, please see the companion document to this project, which is a comprehensive literature review of historic disturbance regimes for the North Saskatchewan by Stockdale, available upon request.

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Introduction

The Alberta provincial land use framework represents a new standard in the evolution of the responsible management of public natural resources. Among other things, it commits to a comprehensive public consultation process, policy streamlining, the integration of public and private planning, and the maintenance of healthy ecosystems (Government of Alberta 2009). Few if any, other provincial land use-planning strategies embrace such rigour or assume as much responsibility.

The prominent commitment to regional (*i.e.*, landscape) ecosystem health is commendable, but logically problematic. The issue of *ecosystem health* is so broad and complex that it requires the application of a combination of methods and data. The needs of rare and endangered species, the resilience of the landscape to wildfires and insect outbreaks, and the sustainable supply of ecosystem goods and services such as clean water involve specific, narrow criteria. The challenge is that ecological health is a holistic property that is inadequately represented by fine-filter metrics. In fact, the reliance on fine filter indicators often manifests itself in the form of conflicting direction on individual issues. A reliance on issue-based indicators alone as measures of ecosystem health has long created these problems for natural resource managers and regulators.

This issue has been responsible for the increasing popularity of so-called *coarse-filter* indicators. Pattern-related indicators such as the size and frequency of disturbances, or the amount and sizes of old forest represent the underlying structures under which biological function occurs. In theory, the closer our disturbance and landscape patterns are to those of pre-industrial landscapes, the more likely we are to sustain pre-industrial levels of biological diversity and function. In other words, we use Mother Nature as a benchmark, although not blindly so. It is meant to be applied in concert with fine-filter metrics.

As the theory of coarse filters relates to a land use planning exercise, the nature and distance between current and past disturbance and landscape patterns is an objective, biologically relevant baseline. Deviations from historical disturbance patterns create landscape patterns that are unfamiliar to the system (Hunter 1993), which almost always translate into the loss of biological function or diversity (Noss 1998).

A natural pattern approach provides very specific baseline linked to highly tractable responses. For example, “fragmented” harvest patterns create small, equally sized and spaced disturbance patches on a landscape that historically experiences a vast range of disturbance sizes and spacing. Not surprisingly, over time this disturbance pattern creates a significant deficit of large contiguous patches of older forest. Old forest patterns can ultimately be reversed by introducing greater (and natural levels of) variation in disturbance sizes.

NRV knowledge can be used as broad guides for land use planning in at least two ways:

1) *As part of a state-of-the-landscape evaluation.* How does the current landscape, and its associated disturbance patterns compare to pre-industrial conditions? Which indicators are the least “natural”? To what degree might deviations from natural conditions be linked to existing landscape issues (such as mountain pine beetle threat or loss of critical habitat)? The first step towards finding solutions is to understand the problem.
2) *As general guides for future activities.* The objective is not necessarily to create “natural” landscapes, but rather to identify where, and how we may be able to align future disturbance activities and decisions with those of the past. NRV comparisons are the ultimate measure of ecological health, and experience suggests they are often compatible with the needs of other values.

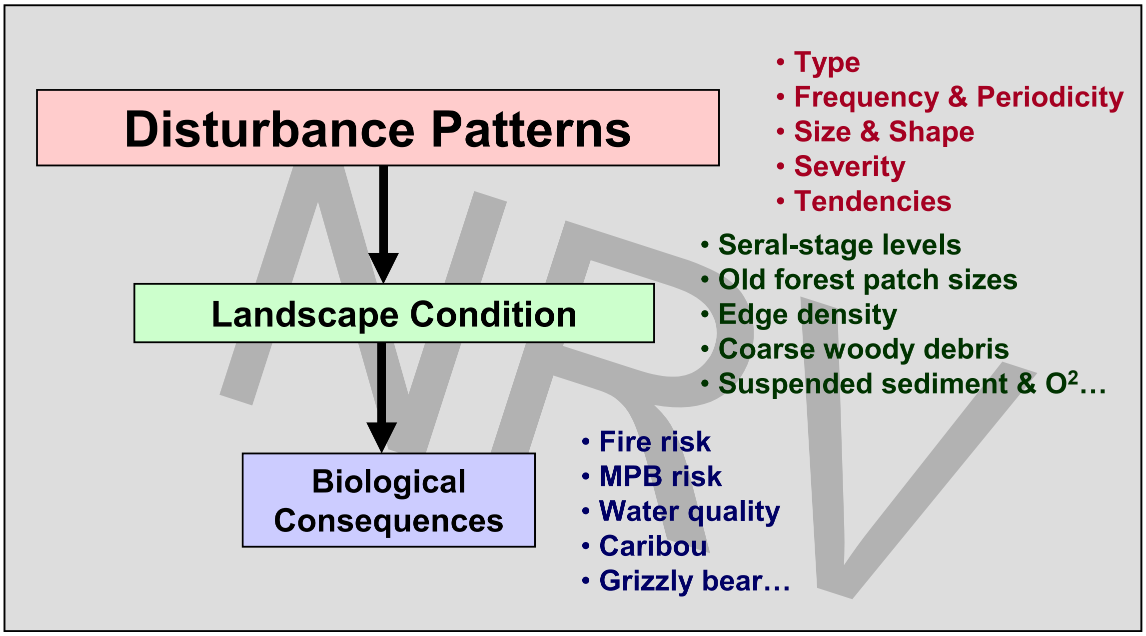
At lower levels of planning, such as sub-reigonal plans and/or strategic parks or forest management plans, NRV knowledge becomes even more relevant.

Generating NRV

Natural patterns and their associated natural range of variation (NRV) occur on three levels. At the first level are disturbance patterns or the *disturbance regime* (Figure 1). This includes the types, frequency, sizes, shapes, and severity of the disturbance events. At the second level are the *landscape conditions* that are created by the disturbance regime. The most common landscape condition is old forest levels, but this level also includes edge density, woody debris, and so on. The third and final level of NRV is the *biological consequences*, which are simply the manifestation of the landscape patterns relative to different values such as wildfire or mountain pine beetle threat, water quality, or habitat for different species.

This classification not only creates a logical flow from cause to effect, but it is also useful for understanding how each type of NRV is generated. The reality is that the natural range of both landscape conditions and biological consequences cannot be observed empirically. At best, it is possible to re-construct a single pre-industrial "natural" landscape. However, that is still just one snapshot in time out of thousands of possibilities.

Figure 1. The three levels of natural range of variation (*adapted from Andison et al. 2009*).



An increasingly common technique for generating multiple possible pre-industrial landscapes is simulation modelling. Although a variety of model types have been used for this purpose, the best model will be 1) spatial (for obvious reasons), and 2) empirical based. An empirical based model just means that the inputs include probability curves, equations, or tables describing the main disturbance regime characteristics such as frequency and size. Combined with heuristics and lookup tables on arboreal characteristics such as re-vegetation, growth, competition, and senescence, even a simple disturbance dynamics computer model can generate thousands of landscape snapshots, which can then be translated into a number of NRV frequency distributions (Andison 1998).

So the quality of the NRV estimates for both landscape condition and biological consequences relies heavily on the quality of the disturbance regime information. When disturbance regime information is missing or of questionable quality, landscape modelling can (and should) account for this by running different combinations of input assumptions to see how sensitive the landscape patterns are to various inputs. The results of this *sensitivity analysis* are presented together with the evaluation of the quality of the disturbance regime information. In situations where very little information exists on the local disturbance regime, it is not advisable to conduct simulation modelling exercises at all. Not only could the output be very wrong, but also we have no way of knowing how wrong it might be.

Thus, an NRV analysis ideally beings with a description of the disturbance regime since it dictates the type and extent of further analysis. Furthermore it includes not only creates estimates for each parameter, but an objective assessment of the confidence levels associated with each metric.

Objective

This report is a technical and scientific support document to the land use planning process for the North Saskatchewan Regional Plan landscape. More specifically, the information here will provide the best available state-of-knowledge of the natural forms (*i.e.*, it will not include harvesting, land conversion, and so on) of the pre-industrial and current, business-as-usual disturbance regimes. Furthermore, this information will be used as input for a scenario / simulation modelling exercise.

Objective: ***To provide a summary of the current state of knowledge of all key parameters of the historic and current disturbance regimes of the North Saskatchewan landscape in a model-user-friendly format.***

It is understood that this is the first step within a larger objective of defining NRV and current conditions for a range of pattern metrics for the North Saskatchewan using simulation modelling. This means that the description must be complete, and include a relative rank of confidence in, and relevance of each metric.

Methods

Defining the disturbance regimes of the North Saskatchewan (NS) landscape involved two phases. First, a literature review was completed of the disturbance regimes of the North Saskatchewan landscape (Stockdale 2011). The review included all available published and unpublished (*i.e.*,” grey”) reports from within Alberta, and beyond. This report is available from the Foothills Research Institute, and may be downloaded from their website (www.foothillsresearchinstitute.ca)

The second phase of this project involved a one-day workshop involving experts on forest disturbance, grassland, and ecotone dynamics, scenario modelling, and representatives from the Alberta government. The original goal of the workshop was to generically define the most likely regime parameters for the landscape in question. Ideally, these data would be furnished to others responsible for converting the information into model-specific calibration data required for scenario modelling.

At the workshop, it became clear that the options for suitable land use planning models were limited, and that the most likely candidate would be ALCES (Schneider *et al.* 2003). While acknowledging that this decision had yet to be made, and was beyond our control, the workshop participants agreed that it would be more efficient to hedge our bets and consider the needs of ALCES model requirements in parallel to regime definitions, potentially saving both time and resources.

This change in tactics meant that the scope of the workshop (and thus this report) expanded to include some ALCES architecture requirements in addition to the original objective of defining disturbance regimes. The results section reflects this practical dichotomy. However, the information in this report is still generic enough to be used by any spatial scenario-planning model.

The workshop produced a first draft of a quantitative regime description, which was then distributed for feedback to the workshop participants over a two-month period. The feedback strongly suggested that quantitative disturbance regime summaries alone would be inadequate and/or impossible for several reasons:

1) Some of the disturbance regime parameters are significantly linked to climatic parameters. There is no guarantee that climate will be a modelling input. It would be difficult to represent these parameters without introducing, and turning “on”, a climate change sub-routine in the model.
2) Most of the disturbance regime parameters are related. Interactions are commonplace, and the results highly complex. The confidence with which we can capture interactions empirically or probabilistically decreases significantly when multiple outcomes are involved.
3) Lack of high quality empirical evidence. Cultural activity over the last 50 years has in some cases erased any physical evidence, new agents of natural disturbance activity are present, and historical agents of disturbance no longer function.

As a group, we agreed to provide quantitative results where possible, but that narratives would also be necessary where confidence in regime information was low, or interactions were particularly complex. Whether, how, or to what degree the narratives are integrated into the scenario modelling exercise is beyond the scope of this report. There was no appetite for initiating a lengthy process of defining such interactions more precisely without some assurance that the outcome would be included in the modelling exercise.

There are at least two periods of interest for the NS land use planning process as regards disturbance regimes of natural origins: 1) pre-industrial, and 2) current. It is not known whether the likely future disturbance regimes will be used in the modelling scenarios, and this report does not include those estimates.

In this report, *pre-industrial* refers to that period pre-dating any significant large-scale industrial activity such as land conversion, forest harvesting, fire control, and high-density settlement. The exact dates associated with this period vary across the NS landscape, from ~150 years for bison extirpation, to ~90 years for land conversion, to ~60 years ago for large-scale harvesting and significant fire control efforts.

Note that *pre-industrial* in this report is not synonymous with the absence of human influence. Humans have been an integral part of this landscape for centuries. Trying to separate the historical influence of human activity from natural phenomenon is not possible with any degree of confidence. As with many other NRV studies, the term *pre-industrial* is used to differentiate between a time of low to moderate influence on a limited number of landscape elements, to the period of extensive influence.

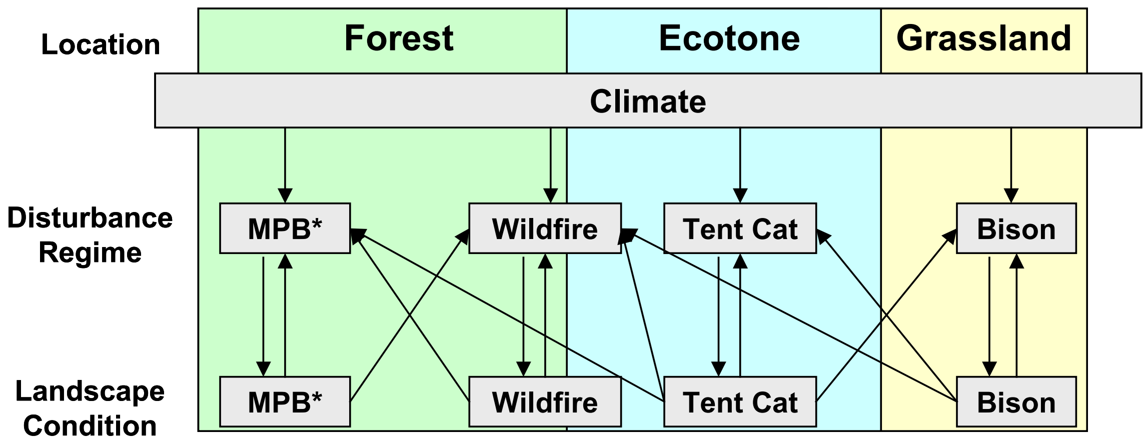
Results

The greatest challenge for the NS landscape as it relates to natural disturbance regimes is that the historical, current, and future disturbance activities all vary considerably over both space and time. Individual disturbance regimes are also extremely difficult to define in isolation. Each is a part of complex web of regional-scale dynamics involving location, climate, and post-disturbance landscape conditions. For example, the three main (natural) sources of historical disturbance on the NS landscape are forest fires, tent caterpillar, and bison (Figure 2). However, in and near the forest-grassland interface, all three are intimately linked. For instance, tent caterpillar outbreaks in pure aspen create vast areas of dead trees, which create extreme fire threats. When such areas burn, they are more likely to be grazed and trampled by bison, which in turn lowers the fuel load (and the chances of fire).

It is also important to recognize that all disturbance regimes have a strong relationship to local climatic factors such as drought. For example, the droughts of the mid 1800's were responsible for a prominent decline of bison, and a significant increase in forest fire activity.

The presence of the Rocky Mountains is another unique complication since it creates many different, closely spaced fire regimes. Fuel-types, ignition probability, and weather all change significantly from east to west. However, because this occurs over such a short distance, the burning tendencies within each regime are highly related to those of its neighbours.

Figure 2. Some disturbance regime interactions on the North Saskatchewan landscape.



** No historical evidence of Mountain Pine Beetle exists.*

Please note that in Figure 2, *Landscape Condition* refers to post-disturbance conditions associated with each disturbance type. The arrows represent the direction of significant interactions. So, for example, a significant MPB outbreak will influence the fire regime by creating a high dead fuel load. Similarly, high levels of wildfire activity will influence the MPB regime by reducing the number of hosts.

Another complication is how the natural regimes of the NS landscape have changed over time. On one hand, it has been many decades since bison influenced the grassland and ecotone areas, and associated physical evidence is rare to non-existent. On the other hand, we now have MPB where we once did not, meaning the specifics of the dynamics on the left side of Figure 2 are new, and not particularly well understood.

With all this in mind, to follow is a description of some of the details of many the disturbance regimes of the NS landscape.

a) Number of Disturbance Regimes

One of the challenges of the North Saskatchewan landscape is the complexity of historical disturbance regimes within a relatively small area. The participants of the workshop agreed that natural subregions provide an appropriate first layer of classification for disturbance regimes, but within many natural sub regions the disturbance regime can vary significantly.

Another complicating factor is that ALCES has a limit on the number of *landscape types* that it will accept. Aside from the needs of ALCES, we agreed that being forced to simplify the disturbance regimes as much as possible was appropriate given that this is a regional-scale modelling exercise. Although it may seem that more regimes equates to greater precision, the problem of how to account for spatial autocorrelation of various regime parameters between neighbouring regimes becomes overwhelming.

The workshop participants agreed that the following list would capture the majority of the regime variation.

1) Montane (all species)
2) Sub-alpine pine dominated (representing lower elevations)
3) Subalpine other-conifer dominated (representing higher elevations)
4) Foothills (Upper and Lower combined) deciduous dominated.
5) Foothills (Upper and Lower combined) pine dominated.
6) Foothills (Upper and Lower combined) other conifer dominated
7) Dry mixedwood
8) Central mixedwood (subsequently split into a) aspen-jack pine, and b) spruce-dominated).
9) Central parkland.

b) Mountain Pine Beetle (*Dendroctontus ponderosae)*

There is no significant physical or anecdotal evidence of mountain pine beetle (MPB) in the North Saskatchewan until recently, so it is not a part of NRV.

For the current and future range of variation, the MPB experts within Alberta Sustainable Resource Development will be providing SSI (Stand Susceptibility Index) models for the NS modelling exercise. However, modelling of population levels or impacts will not be included. This means that MPB interactions associated with other risks and values will not be accounted for in the modelling exercise. Potential MPB interactions with wildfire, climate change, habitat types, and ground water (for example) are likely to be significant. Not capturing these issues in a regional modelling exercise represents a critical gap.

At the very least, I would encourage accompanying the North Saskatchewan scenario modelling work with a pointed narrative of the likely MPB interactions with key values using the appropriate experts within and beyond ASRD. I would also recommend running the scenario model with climate change turned “on” to capture likely future SSI estimates if nothing else.

c) Grasslands and the Forest interface

The historical disturbance dynamics of the Central Parkland and Dry Mixedwood landscapes of the North Saskatchewan are the most complex, involving drought, fire, bison grazing and trampling, topography, humans, and forest tent caterpillar ((*Malacasoma disstrium).* For example, in forested areas, drought encourages tent caterpillar outbreaks in aspen, which in turn creates extreme fire hazards. Outbreaks followed by grazing could convert large areas of forest to grassland. In grasslands, both drought and grazing *dis*courage fire threat by reducing / removing fuel, although aspect is important to consider. Drought also creates less food for bison, lowering their numbers. Bison grazing can discourage tree growth from trampling in areas. Across both forest and grassland, human use of fire prior to the industrialization period was significant, which tends to create grasslands over forest, which in turn favours more bison grazing and trampling.

A more thorough description of these dynamics is provided in the companion document on disturbance regimes by Stockdale and will not be repeated here. The point is that all of these dynamics are happening simultaneously on different parts of the same landscape, or at the same place at different points in time as part of treeline encroachment and retreat dynamics. The number of possible combinations and outcomes is far too numerous to attempt to capture empirically with any degree of confidence. On the other hand, the net result is an important part of the history of this landscape.

Two options are possible as a way forward with the landscape modelling exercise.

1) Use one, or at most two disturbance elements as empirical surrogates for the actual dynamics. Fire is the most obvious choice since it is the one elements linked to all of the others. This will necessarily be a simplification of reality, which means most of the dynamic interactions will be lost. However, even this approach would require considerable validation of various impact and recovery heuristics to ensure they reflect our understanding of reality. For a regional modelling exercise, this strategy may create the necessary level of precision.

2) Challenge the modelling experts to work with the grassland-forest ecotone experts to find the most efficient and effective way of capturing the most important dynamics. Previous land use planning exercises have adopted this strategy, which has translated into at least some capacity in the model for grassland dynamics. The North Saskatchewan modelling exercise could build on this capacity by adding features and/or allowing the climate module to function.

As to the current condition in this area, very little of this complex natural dynamic now functions. The intensity, location, and periodicity of cattle grazing are far from perfect proxies for bison dynamics. Technically, those areas that are no longer grazed would have elevated fire threat because of increased fuel loads, although fire has been all but removed from the system. Much of the natural vegetation has been replaced with agricultural crops, and in non-cropland areas forest encroachment and densification is progressing. And lastly, because this area represents a major ecotone, the likely impacts of climate change here could significantly alter even the current dynamics.

I would suggest using the appropriate rangeland / grassland experts to help build the appropriate modelling parameters for current / future landscape scenarios, and I strong recommend including any climate change capacity in the model. All business as usual or future scenarios should also include estimates of land conversion and forest encroachment based on historical patterns. One of the more important patterns of interest worth tracking would be the percentage of each landscape in a “natural” vegetative condition, including native grasslands.

d) Wildfire

Tables 1 and 2 summarize estimates of the frequency, size, and severity of historical and current ranges of variation respectively. A detailed account of exactly how each number(s) was determined will not be given here (please see the Stockdale overview), but there are some data patterns of note.

The size of the ranges reflects both the reality of natural variability, and the confidence of the estimates. The confidence in regime parameters decreases as one proceeds from the top to the bottom in both tables. The fire regimes associated with the lowest confidence tend to be those further east. Most hard, physical evidence (in the form of tree rings, fire scars, and age data) of grassland and parkland wildfires has been eliminated by time (in that, trees do not grow old in such environments) coupled with land conversion practices. Alternative evidence in the form of historical accounts, records, and photos are rare. As one moves closer to the Rocky Mountains, forests are older, cultural activity diminishes, and physical evidence of historical fire patterns is more plentiful. Fortunately, research activities on such landscapes have been moderately well supported.

Over the last 2-5 years, our understanding of the historical disturbance regimes of the Foothills area has evolved considerably. It was originally assumed that the foothills were dominated by a stand-replacing disturbance regime, typified by infrequent, high-severity fires. However, there is growing evidence that parts, or even all of the foothills were subjected to a "*mixed"* fire regime (*i.e.,* infrequency, high severity fires intermixed with frequent, low-to-moderate severity fires). This concept is captured in Table 1 as the probability of different "*Regime No*"s. So, for example, the Montane landscape historically experienced a relatively high-severity fire every 60-80 years, and a low to moderate severity fire every 15-30 years (Table 1).

This suggestion that all or part of the foothills experienced a mixed fire regime is fairly new, and the phenomenon is still being studied (*sensu* Amoroso *et al,* submitted). The consequences of this difference should not be underestimated. Landscapes under a stand-replacing fire regime will have higher tree densities, more conifer species, and greater structural and compositional homogeneity than landscapes with a mixed fire regime. This has significant consequences for wildfire threat, MPB threat, caribou habitat, and biodiversity.

One of the greater challenges on this landscape is the physical proximity of so many different fire regimes. Many fires, and particularly the larger ones, will ignite on one area, and cross at least one of the regime boundaries (as defined in part (a) above). The fire size numbers provided are cumulative (*i.e*., fires do not stop at the boundary).

The current fire regime parameters in Table 2 were derived using a combination of data, assumptions, and current conditions. The areas with the lowest historical fire cycles tend to be those ecosystems most altered by humans, and the most inhabited areas. Most or the grassland and parkland have been converted to agriculture, and very seldom burn. The Dry Mixedwood and Central Mixedwood is moderately populated, and moderately fragmented by development and land conversion. Significant wildfire activity is unlikely.

The current fire regimes of the forested areas of the NS landscape are more difficult to portray with a high level of confidence. On one hand, Provincial fire statistics suggest that fire activity in the forest areas of the NS landscape have declined dramatically over the last 50 years, likely due to a combination of fire control and the climate being wetter than usual. However, the past 50 years is not a good measure of the current or future fire activity in the area because the forest condition has changed significantly in that time.

For example, consider that fire control is most effective at eliminating low to moderate severity fires (thus note that there are no mixed fire regimes in Table 2). The elimination of more frequent, lower severity fires will create vast areas of dense, simple, single species forest. The lack of fires in general over the same period has also created large areas of older forest. In other words, the landscape is far more susceptible to wildfire that it was 50 years ago, with fewer natural fuel changes or breaks.

Consider also that fire control is least effective on extreme fire events, which tend to create larger fires. The evidence above suggests that (climate change aside) the conditions for these extreme fire events have been steadily increasing.

Thus, overall, fire cycles are higher today than they were historically, but not as high as the wildfire data alone suggests (Table 2). The lower fire cycles in the Montane reflect the likely impact of prescribed fire programs.

Fire control efforts tend to homogenize fire sizes, but also create a greater proportion of smaller fires. Again, fire records alone are misleading because of the lack of significant fire activity on the NS landscape over the last 50 years. As above, increasing fire threat levels caused by an altered landscape condition are likely to cause a higher proportion of larger fires. The fire size numbers in Table 2 reflects all of these factors.

The proportional area in wildfire residuals declines in Table 2 (relative to Table 1) because fire control is more likely to be successful on those parts of fires that are cooler (*i.e.*, those parts more likely to leave residuals).

Finally, it should be noted that the current regime condition as described in Table 2 does not include any of the likely consequences of climate change. Although estimating future regimes is beyond the scope of this report, we do know that climate change is likely to result in more frequent, more severe, and larger fires (Flannigan *et al*. 2001). Thus, using the parameters in Table 2 does not necessarily reflect “business as usual’ in a scenario modelling exercise. If ALCES has the capacity, I would strongly recommend turning any climate module “on” for modelling current or future scenarios. Alternatively, an appropriate team of experts could develop a third Table of *future fire regime* parameters.

Table 1. Estimated Parameters for the Pre-industrial Wildfire Regime for the NS, by Landscape Type.

Natural Subregions	Leading Species	Regime No.	Probability	Fire cycle	Fire Size Classes (ha) <10	10-100	100-1,000	1-10,000	10-100,000	>100,000	% Area Residual
Montane	All	1	0.2	60-80	45	10	30	14	1	0	10-40%
		2	0.8	15-30	60	30	10	0	0	0	60-90%
Subplpine	Other conifer	1	0.2	140-200	50	22	16	9	2.9	0.1	10-40%
		2	0.8	50-100	60	25	13	2	0	0	50-70%
	Pine	1	0.2	100-140	50	22	16	9	2.9	0.1	10-40%
		2	0.8	50-80	60	25	13	2	0	0	50-70%
Foothills (all)	Pine	1	0.2	80-110	50	22	16	9	2.8	0.2	10-40%
		2	0.8	40-60	60	25	13	2	0	0	50-70%
	Other conifer	1	1	60-90	60	25	11	3	0.9	0.1	20-60%
	Deciduous & mixwd	1	1	50-80	60	26	7	4	3	0	20-60%
Dry mixedwood	All	1	1	10-50	50-80	10-25	5-10	1-7	0	0	10-70%
Central mixedwood	Aspen-Jack pine	1	1	20-70	50-80	10-25	5-10	1-7	0	0	10-70%
	Spruce	1	1	50-100	50-80	10-25	5-10	1-7	0	0	10-70%
Central Parkland	All	1	1	2-30	50-80	10-25	5-10	1-7	0	0	10-70%

Notes:

- Landscapes with more than one “Regime No.” can flip back and forth between two significantly different modes over time. The “Probability” column captures the relative proportion of time represented by each regime type on the same landscape. Note that in each case, 80% of the time fires are smaller, more frequent, and have higher survival levels (which is Regime No. 2).
- The “Fire Size Classes” reflect the proportion of the number of fires in each class.

Table 2. Estimated Parameters for the Current Wildfire Regime for the NS, by Landscape Type.

Natural Subregions	Leading Species	Regime No.	Probability	Fire cycle	Fire Size Classes (ha) <10	10-100	100-1,000	1-10,000	10-100,000	>100,000	% Area Residual
Montane	All	1	1	200-400	60	39	0.7	0.3	0	0	0-40%
Subplpine	Other conifer	1	1	300-600	60	39	0.7	0.2	0.1	0	0-40%
	Pine	1	1	300-600	60	39	0.7	0.2	0.1	0	0-40%
Foothills (all)	Pine	1	1	300-600	60	39	0.7	0.2	0.1	0	0-40%
	Other conifer	1	1	300-600	60	39	0.7	0.2	0.1	0	0-40%
	Deciduous & mixwd	1	1	300-600	60	39	0.7	0.2	0.1	0	0-40%
Dry mixedwood	All	1	1	500-700	60	39	0.7	0.2	0.1	0	0-40%
Central mixedwood	Aspen-Jack pine	1	1	500-800	60	39	0.7	0.3	0	0	0-40%
	Spruce	1	1	500-800	60	39	0.7	0.3	0	0	0-40%
Central Parkland	All	1	1	>1,000	60	39	1	0	0	0	0-40%

Notes:

- The “Fire Size Classes” reflect the proportion of the number of fires in each class

Summary

Regional modelling exercises are valuable tools for gathering information about past and likely future landscape dynamics on a general level. The most important dynamics to capture should be the most significant, including both those that have changed the most, and those most likely to change in the future. In my opinion, the modelling exercise should at the very least capture the following, in order of priority:

1) **Climate change**. The point of any scenario modelling exercise is to reflect a realistic version of a future condition, and that is not possible without considering climate change. There is more than enough evidence to suggest that climate change will affect this landscape in significant ways, some of which relate to human health and safety. Current conditions are useful, but not sufficient to capture the many ways in which climate interacts with all natural disturbance agents, and thus critical values, in some way.

2) **MPB dynamics**. The fact that there is no substantial history of MPB on this landscape should not dictate if or how it is included in scenario modelling. MPB is a reality of today and the future, and it will be interacting with other natural disturbance agents (such as wildfire), forest, land, and water conditions, and habitat for valued species. Even on a very general level, all of this should be captured in a scenario modelling exercise.

3) **Land-use conversion**. The loss of historical ecosystem types should become a key indicator of landscape ecosystem health, and tracked during landscape scenarios. This applies particularly to those zones associated with the forest-grassland interface, but also parts of the parkland, ecotone, and montane landscapes. Native grasslands and mixed forest-grassland areas are particularly rare and their locations and conditions should be identified and tracked over time.

4) **Fire cycles.** In forested areas, the most significant regime shift is that of extended fire cycles. Forest harvesting will offset this concern to some degree, but over time the expansion of older forest up to and beyond its natural range is important to capture since it could potentially create significant forest health and biodiversity issues.

5) **Fire severity.** The elimination of low and moderate severity fires from the landscape may seem to be a relatively minor issue, but such fires are responsible for stand-scale structural and compositional complexity. The

elimination of these fires over several decades effectively simplifies the landscape, making it less resilient, and more susceptible to natural disturbance agents such as fire, pests and disease. The modelling exercise should capture disturbance-related stand-scale parameters.

6) **Grassland-Forest ecotone.** Regardless of whether we ever want to restore some part(s) of this interface, capturing the historical dynamics has great value. In general, the more we understand historical relationships between many natural disturbance elements, the greater our capacity for predicting future changes to this highly sensitive part of the landscape. It also may provide valuable information about landscape resilience, which may be particularly relevant to how we might manage landscapes in the face of climate change. Ecotones (of all forms) are likely to become the most important regional-scale elements for management / mitigation targets.

7) **Fire size.** The lack of large, substantial wildfires over the last 50 years is a trend not likely to continue. Scenario modelling should include realistic probabilities of extreme fire events in random locations. This could even provide probabilities of community evacuation and substantial property loss.

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