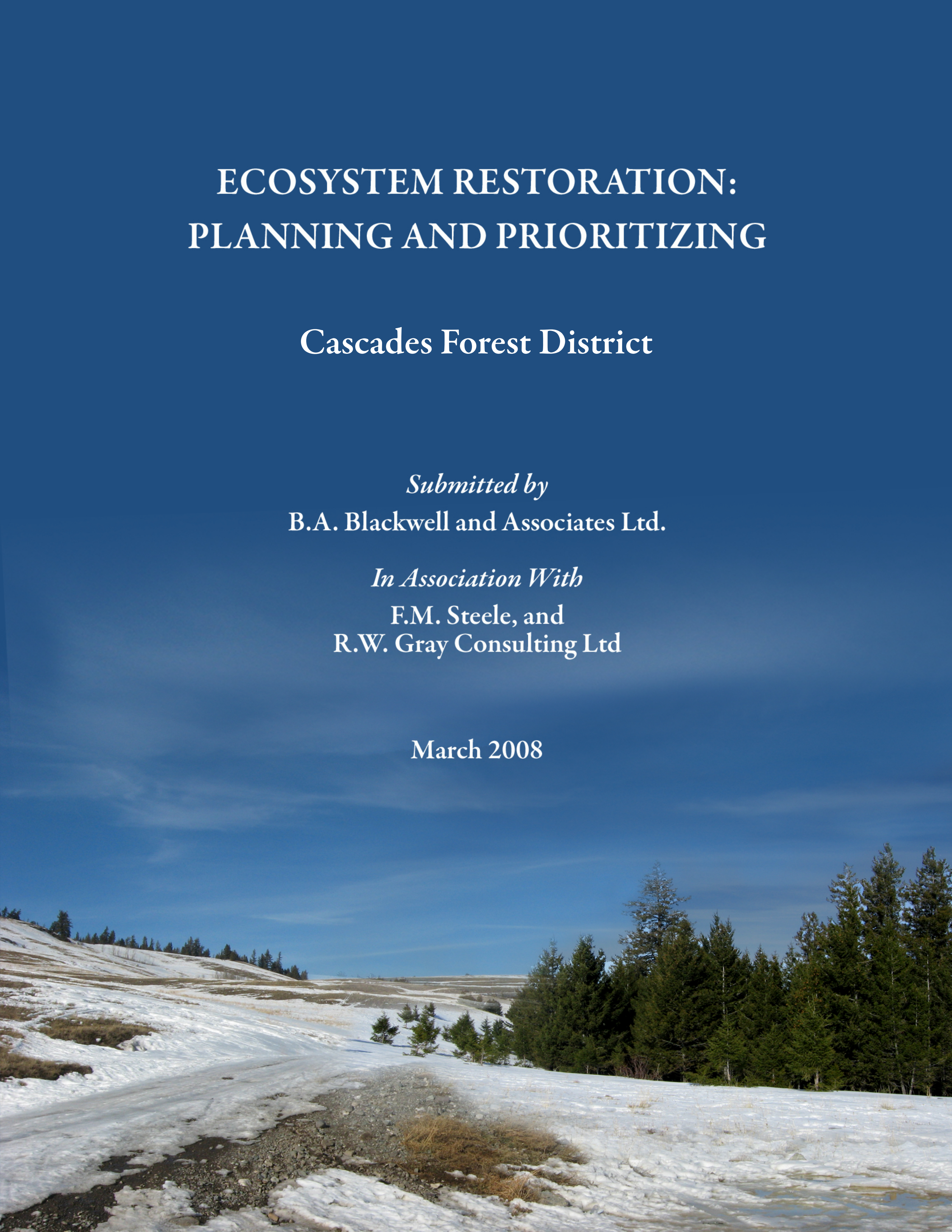
ECOSYSTEM RESTORATION: PLANNING AND PRIORITIZING

Cascades Forest District

Submitted by
B.A. Blackwell and Associates Ltd.

In Association With
F.M. Steele, and
R.W. Gray Consulting Ltd

March 2008



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B.A. Blackwell and Associates Ltd.
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V7J 3B5

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Ecosystem Restoration: Planning and Prioritizing – Cascades Forest District

Prepared By

F.M. Steele[1], B.A. Blackwell[2] and R.W. Gray[3]

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[1] F.M. Steele – 4334 John Street, Vancouver BC, V5V 3W7

[2] B.A. Blackwell and Associates Ltd. (contact consultant) – 3087 Hoskins Road, North Vancouver BC, V7J 3B5

[3] R.W. Gray Consulting Ltd. – 6311 Silverthorne Road, Sardis BC, V2R 2N1

Executive Summary

In high frequency, low and mixed severity fire regimes of the southern interior decades of fire suppression coupled with current and past management practices have resulted in the overall degradation of ecosystem health. Decades of fire suppression have also interrupted the historic cycle of wildfires that previously held tree densities at lower levels when compared to current densities and maintained the quality and quantity of available forage. Fire adapted ecosystems which historically experienced frequent wildfire regimes have been particularly affected. Historically open forests are becoming increasingly ingrown and accumulating increasingly dangerous fuels loads. The extent of grasslands is steadily decreasing due to tree encroachment. This phenomenon has wide ranging biological, social, and economic consequences that will continue to worsen unless effective and appropriate ecosystem restoration measures are undertaken.

The Cascades Forest District is in the preliminary phases of developing an ecosystem restoration program. A critical step in this initial process is to develop a spatial prioritization framework to delineate where ecologically appropriate restoration opportunities exist and to establish a prioritization rationale. This project uses Historic Natural Fire Regime (HNFR) and Fire Regime Condition Class (FRCC) as foundation information to prioritize restoration treatment areas. The project also assesses treatment complexity in the context of the combination of complex objectives, challenging landscapes/sites and high unit treatment cost.

The prioritization framework has identified several areas within the District that should be the focus of restoration efforts over the next three to five years. These areas contain concentrations of FRCC 3 with moderate treatment complexity and represent 4% of the provincially owned land base within the Cascades Forest District. Other opportunities for restoration exist within FRCC 2 with moderate treatment complexity and represent 5% of the Forest District area captured by this study. This analysis represents a coarse scale overview on which to prioritize a District level program, however a substantial amount of work and effort is still required to fully implement the program and this must include some fine scale filtering that addresses key forest and grassland ecosystem values.

The spatial information developed for this project has been translated into map products and displayed in an easy to use Acrobat map viewer that can be maintained on the desktops of operation staff of the Ministry of Forests and the Ministry of Environment and other interested organizations within and outside of government. In addition to developing a spatial prioritization framework, the report provides a synopsis of the history and current state ecosystem restoration programs in BC and recommends further steps to be taken in the development of a District ecosystem restoration program.

Acknowledgements

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1.0 Introduction

1.1 Project Objective

The objective of this project is twofold:

1. To develop map products that will assist managers in the process of prioritizing areas for ecosystem restoration treatments.
2. To recommend further steps to be taken in the development of an ER program.

1.2 Ecosystem Restoration in BC

Historically in British Columbia, ecosystem restoration (ER) has suffered from the lack of a strategic, integrated approach to planning and operations. Part of this is due to a common debate pitting the management of individual species, be they endangered species or commodity species, against the management of "ecosystems" (Weigand and Everett 1994). The scarcity of year-to-year consistency in funding, coupled with insufficient staff resources to run a program, has also led to a scattered approach to restoration. It is also possible that adequate trained and skilled personnel resources to carry out a modest sized ER program are lacking in most regions.

In the not too distant past, ER programs could be described as being "reactive" in nature with treatment units identified by immediate priority and funded out of whatever dollars could be cobbled together. Agency personnel assigned to the task of implementing ER did not have the time or resources for long-range planning, and had become little more than contract administrators for programs carried out largely by outside consultants and contractors.

The one exception to the rule in BC, at least when it came to higher level strategic planning, was the Kootenay-Boundary Land-Use Plan (KBLUP), which took large steps towards developing a strategic ER program. The KBLUP used the assignment of natural disturbance type 4 (NDT4) ecosystems based on biogeoclimatic ecosystem (BEC) zones. This information was used to guide restoration activities within the management area. NDT4 ecosystems include grassland, shrubland and forested communities that generally experience frequent, low severity fire regimes. Unfortunately, this plan suffered from many of the same strategic planning shortfalls experienced in other parts of the province. The KBLUP plan had identified, in a coarse way, the target ecosystems for restoration in the NDT4; this could be referred to as "top-down" direction. The "bottom-up" direction of the plan (the local-level, long-term juxtaposition of objectives) was missing. Individual projects were not explicitly linked but appear to have been reactionary and "single-species" focused, funding was inconsistent, program monitoring was inadequate, and resources were insufficient. These were "strategic" issues with the plan from both a spatial sense and an objective-attainment sense.

The Ministry of Environment (MoE) has not traditionally managed ecosystems. They have managed for specific species and/or attributes within ecosystems but they have not systematically planned for the management of ecosystem health (defined as inherent natural diversity and resilience (Waide 1988, Walker 1994)) across their jurisdiction. Ecosystem management has been characterized by diffuse, single-focus treatments within a general ecological framework. There has been no overarching strategy to manage all ecosystems in a resilient state starting with those in the furthest departed condition.

The MoFR has not traditionally managed ecosystems either. They have managed for a specific objective (*i.e.*, timber and range) within ecosystems but they have not systematically planned for the management of ecosystem diversity and resilience across their jurisdiction. This has resulted in a dominant objective being managed for in a diffuse way. Management focus has been scattered across the landscape in an attempt to answer to social and environmental impacts. Ecosystem health issues abound, attesting to the inadequacy of this approach.

The KBLUP plan could be seen as a compromise strategy between the two. The MoFR emphasis is de-emphasized to a certain degree (reduced stocking standards); ecosystem health can be maintained through repeated disturbance to promote diversity and resilience at the stand level. The MoE single species or habitat attribute emphasis, unfortunately, still prevails as can be seen in how treatments are prioritized. The most ecologically, socially and economically feasible areas are not the first to be treated, instead the prioritization of treatment is determined through the single-species/attribute approach. To make the KBLUP truly successful, the strategy for ecosystem health should shift to a prioritization based on landscape scale forest health factors and treatment funding should compliment and encourage this shift. Although it would be ecologically ideal to treat all areas that are departed from their natural state, social and economic constraints mean that this approach may fail to achieve landscape-level forest health objectives. With limited human and financial resources, it is arguably more efficient to prioritize treatments first in areas that are less severely departed from their natural state. This ensures that these ecosystems are maintained in a healthy state, potentially enables more area to be treated and allows any remaining resources to be directed to treating more departed ecosystems.

Within the past year the province – specifically the Ministry of Forests and Range (MoFR) – has taken a more pro-active and organized approach to ER on lands administered by the MoFR (the Ministry of Environment has always staffed positions linked to ecosystem management but on a scale similar to MoFR). The initial program was established in the Rocky Mountain Forest District in 2007, and has since spread to 10 other forest districts. Thus, a solution to the strategic ER planning issue was the development of regional ER programs focused on managing for ecosystem resilience (Waide 1988, Walker 1994) as opposed to managing for a single species. These programs require long-term direction from strategic plans in order to develop activities that will meet long-term landscape level objectives which are the focus of this document. These programs also require dedicated personnel, resources and operations funding to achieve the scale and effectiveness of treatment that is required to restore the large areas of impacted ecosystems throughout the region.

The approach to strategic planning put forward in this report comes from prior experience in developing comprehensive ER programs in both the US and BC. In the case of the US southwest, strong cultural connections had to be made within the ER program because of long-standing First Nations traditions in land use. In the Squamish Forest District, socio-economic connections had to be made because the primary land-use was timber management. In the case of the Cariboo Chilcotin, conservation was the most important focus of funding opportunities for ER. Regardless of the objectives of the overarching land management agency, there are ways to shape and adapt ER to meet strategic ER planning goals. The steps in this process are as follows:

1. Purpose and Need for Ecosystem Restoration. This may come from pre-existing agency documents that have established goals and objectives for the region. This should include a strong scientific rationale for the program (*i.e.*, why, where, when and how). In the Squamish Forest District, extensive historic fire regime and stand structure studies were conducted to provide direction for the restoration program. These studies were designed to determine the historic or natural range of variation (RONV) and how it compared with current ecosystem structure and composition. Unfortunately, there are few Okanagan, Cascades, or Kamloops region studies of this nature; however, several surrogates do exist. Gray and Riccius (1999) in the Merritt area and Gray (2003) in the Sinlahekin Valley in Washington State provide some applicable data, while the coarse-scale Historic Natural Fire Regime (HNFR) and Fire Regime Condition Class (FRCC) models developed by Blackwell *et al.* (2003) provide further spatial direction. This foundation information is critical to enabling spatial prioritization of areas further along in the process. Defining the restoration program rationale is also critical for public education purposes. Glaring knowledge gaps in disturbance dynamics and ecosystem responses can be identified here and incorporated into program-level adaptive management and monitoring.
2. Data Collection, Collation, and Analysis. In this phase the gross area under management, and past, current and future management activities are investigated. Coarse- and fine-filter analysis systems (GIS-based) that will enable identification of future (5-year window) treatment priorities are built in this phase. The gross management area needs to be reviewed in the context of biogeography (topography, physiography, vegetation characteristics), ownership (public, private), and primary land-use (timber harvesting, wildlife habitat). This becomes one of the key baseline layers for planning the feasibility and costs of various ER strategies. In addition, existing plans for future treatments are reviewed to see how they fit with the new model. There is insufficient funding in the system to discard prior work so every effort must be made to make some use of it. GIS-based filters and queries are used to help delineate operational units once a hierarchical planning approach (agency goals, objectives and prioritization) has been developed. This stage incorporates the necessary environmental, ecological, and social values in a spatial context. Once individual treatment areas have been identified, further analysis is conducted to address treatment strategies, feasibility of success, risk, and cost. Issues such as down-wind smoke sensitive areas,

adjacent area hazards (recent harvest/land clearing slash), and adjacent area land-use conflicts (livestock vs. native ungulates, etc.) are addressed here.

The approach of this plan is to adopt a strategic direction focusing on landscape-scale ecosystem health. While definitions of ecosystem health are prevalent throughout the literature, the central tenets are the creation and maintenance of naturally diverse (meaning "native" species) and resilient (elasticity following disturbance) ecosystems (Cairn 1988, Jordan 1988, Everett 1994, Kolb *et al.* 1994, DellaSala *et al.* 1995, Gayton 2001). This requires the ability to quantify "health" in a GIS platform. In the dry forest and grassland ecosystems of North America, altered fire regimes are at the core of ecosystem health (Everett 1994, Covington 1995, Fiedler *et al.* 1995, Rapport and Yazvenko 1995). Fires have either not occurred frequently enough (*e.g.*, historically open ponderosa pine bunchgrass ecosystems), or have occurred too frequently (*e.g.*, cheatgrass invasion areas). Using fire regime condition as a surrogate for ecosystem health, we can build a base layer from which additional data can be added to culminate in a landscape-scale strategy for ecosystem restoration activities.

1.3 Study Area

This project was carried out for three Forest Districts: Kamloops, Okanagan Shuswap, and Cascades using identical methodologies across Districts. The results described within this report pertain to the Cascades Forest District (2,256,176 ha). Twenty-six percent (587,504 ha) of the District is considered non-contributing to the mapping analysis. This includes lakes, reservoirs, rivers, swamps, marshes, glaciers, alpine tundra, non-productive, urban, developed or otherwise cleared lands.

1.3.1 Ownership

Eighty-nine percent (2,012,229 ha) of the Cascades Forest District is within provincial land (Table 1). Just over 10% (187,953 ha) is privately owned, while the remaining 2% is federally owned. Within the District grazing leases total 443 ha (<1%) and crown grant land totals 40 ha (<1%). There are two community watersheds within the District totaling 38,555 ha (2%).

Table 1. Ownership within the Cascades Forest District.

Owner	Area (ha)	Relative Percent
Provincial	2,012,229	89%
Private	187,992	8%
Federal	55,945	2%
No Data	10	<1%
Total	**2,256,176**	**100%**

2.0 Methodology

2.1 Overview

The overall methodology of the project followed five steps:

1. An ER prioritization framework was developed in consultation with MoFR staff.
2. This framework was translated into GIS on three test mapsheets per forest district.
3. Test sheets were sent for review by MoFR staff and field checked.
4. Modifications and corrections were made to the prioritization framework methodology based on the outcomes of field checking and MoFR review.
5. The prioritization framework was processed in GIS for the entire study area and input into the map viewer.

The final mapping products are contained in the Adobe Acrobat map viewer to facilitate viewing at a 1:50,000 mapsheet scale. The map viewer can be loaded onto any PC and run in Adobe Acrobat. The viewer contains the resultant maps from the prioritization framework as well as an independent map product representing Risk to Public Safety. Every map in the map viewer shows the following information:

- TRIM (water, roads, toponymy, contour lines)
- Open range
- Non productive/developed lands
- Community watershed boundaries
- Municipal boundaries
- Forest District boundaries
- Provincial Park boundaries
- Indian reserves
- Private land
- Grazing leases
- Crown grant land
- Range improvement fence linework (only on Treatment Complexity map)

2.2 Prioritization Framework: Mapping Methodology

There are two mapping components within the prioritization framework: Restoration Treatment Priority and Treatment Complexity. Figure 1 gives an overview of the prioritization framework.

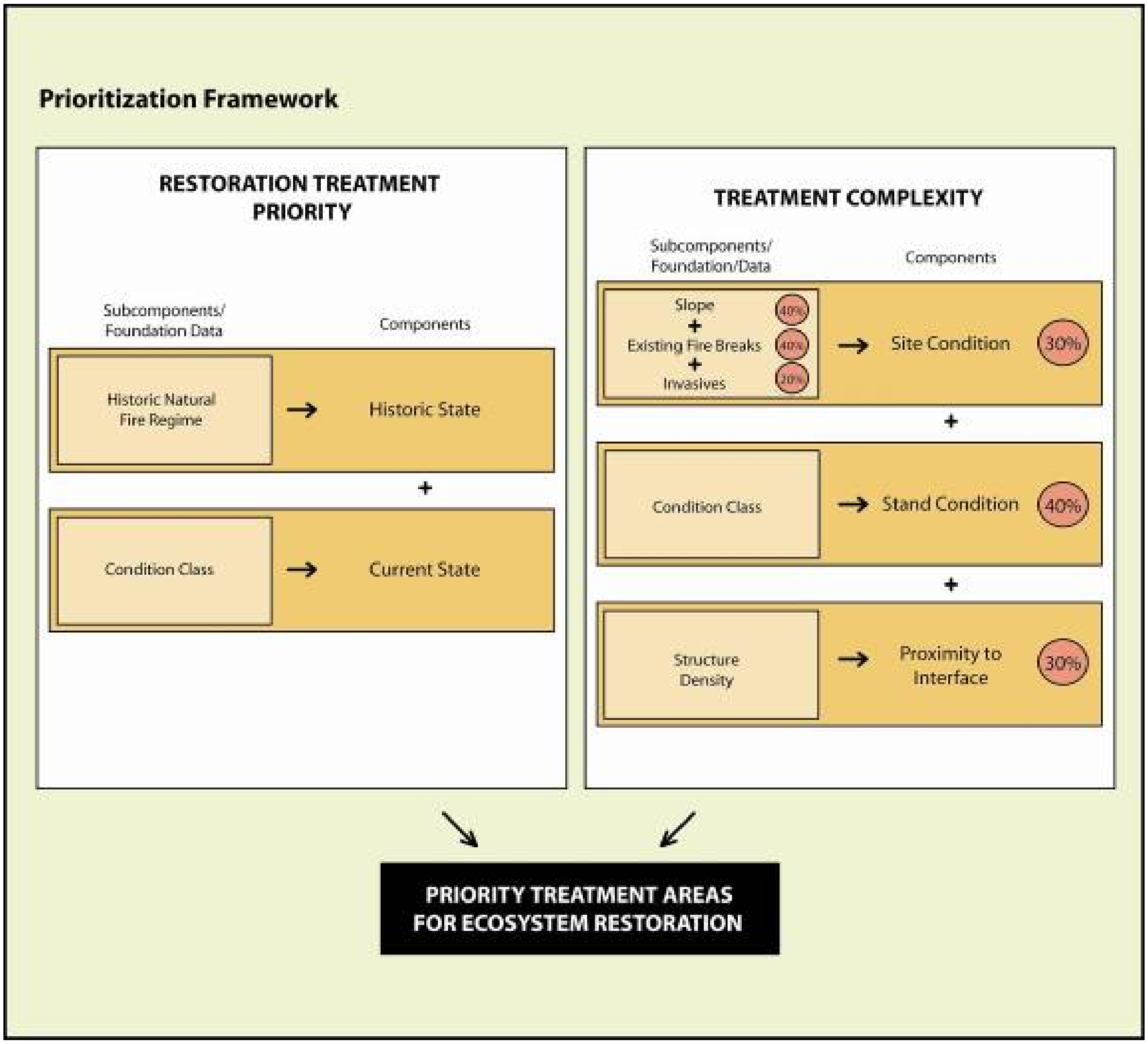

Figure 1. Flow chart illustrating methodology overview.

The subsequent sections will describe how each component within the framework was derived.

2.2.1 *Restoration Treatment Priority*

The Restoration Treatment Priority component is composed of two subcomponents: the **Historic State** of an ecosystem in terms of historic natural fire regime (HNFR) and the **Current State** of an ecosystem in terms of the fire regime condition class (FRCC).

HNFR is a combination of known and predicted fire regime metrics by BEC subzone plus topographic variables that affect fire behaviour. A detailed description of how the HNFRs were constructed can be found in Blackwell *et al.* (2003). For the **Historic State subcomponent,** priority has been assigned to the HNFRs with the most frequent fire regimes. This includes HNFR I, II and III which each experience historic fire regimes of 0 to 35 years. These three HNFRs fall within dry forest types, which include the Ponderosa Pine and Interior Douglas-fir

BEC zones. The most flammable fire regime is HNFR I which includes low elevation, dry ponderosa pine and Douglas-fir forests with grass and/or timber litter as the primary carrier of surface fire. Upslope from HNFR I, the HNFR II fire regimes are found on cool aspects at low elevation. These are characterized by slightly cooler and moister conditions than HNFR I. Fuelbeds in HNFR II range from grass and litter to compacted duff and moss. HNFR III includes primarily grass and shrub types (i.e. open grassland) which have experienced frequent fire that has consumed >90% of dominant overstory vegetation.

FRCC is a quantitative measure of fire regime departure from historic conditions. The more fire is suppressed/removed from a fire regime the more the fire regime changes. This modeling system has as its basis the supposition that fire will eventually return to the fire regime. The more fire is prevented from occurring in a system in which fire previously occurred frequently, the greater the environmental impact. The use of this model holds its value in presenting the range of consequences that could occur once fire returns to the system. Once again, the reader is encouraged to review Blackwell *et al.* (2003) for a detailed description of FRCC.

Applied in a predictive model, FRCC can be used to derive two different metrics: a) time-since-disturbance, or b) complexity of treatment. Time-since-disturbance is a qualitative indicator of structural changes to the ecosystem due to the cessation of fire (*i.e.*, increased fuel loading, increased tree density, increased canopy closure, etc.). In Blackwell *et al.* (2003) FRCC is ranked from furthest departed (longest time-since-disturbance) to least departed. This ranking would identify sites with fuel load, tree density, etc., as the highest priority for treatment. Thus within the **Current State subcomponent,** FRCC 3 (the furthest departed) has been assigned the highest priority for restoration treatment and FRCC 1 (the least departed) the lowest priority.

Table 2 summarizes the subcomponents of the Restoration Treatment Priority component. The final overlay of Historic State and Current State subcomponents produces a Restoration Treatment Priority ranking of FRCC within HNFR I, II and III.

Table 2. Restoration Treatment Priority subcomponents.

Subcomponent	Units	Criteria	Priority Ranking
Historic State	Historic Natural Fire Regime (HNFR)	HNFR I (0-35 year frequency, low severity)	1
		HNFR II (0-35 year frequency, mixed severity)	1
		HNFR III (0-35 year frequency, stand replacement severity)	1
		HNFR IV (35-100 year frequency, mixed severity)	0
		HNFR V (35-100 year frequency, stand replacement severity)	0
		HNFR VI (100-200 year frequency, mixed severity)	0
		HNFR VII (100-200 year frequency, stand replacement severity)	0
		HNFR VIII (200+ year frequency, stand replacement severity)	0
Current State	Fire Regime Condition Class (FRCC)	FRCC 3	1
		FRCC 2	2
		FRCC 1	3

2.2.2 *Treatment Complexity*

The Treatment Complexity component is composed of three subcomponents: **Site Conditions** in terms of slope, existing fire breaks and the presence of invasive plant species, **Stand Conditions** in terms of FRCC, and **Proximity to Interface** in terms of structure density. Treatment complexity is defined here as the combination of complex objectives, challenging landscapes/sites and high unit treatment cost.

The **Site Conditions subcomponent** attempts to quantify treatment complexity in three ways:

1. Slope: steeper slopes may increase complexity.
2. Existing Fire Breaks: greater distance from natural fire breaks (permanent water sources > 1ha and/or roads) may increase complexity.
3. Invasive Plant Species: the presence of invasive plant species may increase complexity.

The **Stand Conditions subcomponent** uses FRCC as a gauge of treatment complexity. Canopy closure from forest cover inventories is an integral component of FRCC determination. FRCC 1 to 3 indicate increasing time-since-disturbance and increasing canopy closure (*i.e.*, increasing stand density). For example, a stand classified as FRCC 3 in an HNFR I fire regime has missed numerous surface fires and has likely experienced an increase in canopy closure. The very issues that make FRCC 3 stands good candidates to place at the top of prioritization make them very complex candidates to restore. High stand density, high fuel load, and high canopy closure make these sites very difficult and expensive to treat with prescribed fire alone. For this reason FRCC 3 stands have been rated as most complex to treat.

The **Proximity to Interface subcomponent** quantifies treatment complexity in terms of distance to and density of interface. Interface is represented by structure density classes (number of structures/km^2). Closer proximity to interface and greater density of interface will increase treatment complexity.

The Site Condition, Stand Condition and Proximity to Interface subcomponents each represent an individual GIS layer covering the study area in which polygons were assigned a rating score from 0 to 10 (10 representing least complexity). The subcomponents were then weighted based on their relative importance as determined in consultation with MoFR staff. Subcomponents were then overlaid spatially in order to calculate the relative score of the Treatment Complexity component. To demonstrate how this scoring system works, refer to the following fictional example:

*The algorithm has determined that a polygon has moderate complexity rating for site conditions and so receives a score of 5 for that value. The stand conditions complexity rating of the polygon is low and receives a score of 10. However, the consultation with the MOFR rationalized that stand condition was more important than site condition and therefore determined that the relative weighting of each value would be 60% and 40% respectively. Therefore, to determine the treatment complexity score out of 10 the calculation was as follows: 5 * .60 + 10 * .40 = 7 out of 10.*

Table 3 summarizes the subcomponents of the Treatment Complexity component.

Table 3. Treatment Complexity subcomponents.

Subcomponent	Units	Criteria	Rating Scale	Relative Weighting	Relative Subcomponent Weighting
Site Conditions	Slope	Slope <35%	10	40%	30%
		Slope 35-50%	4		
		Slope >50%	2		
	Existing Fire Breaks (roads and permanent water >1ha)	0-250m from fire break	10	40%	
		250-500m from fire break	6		
		500-1km from fire break	4		
		>1km from fire break	2		
	Invasive Plant Species	No Invasives	10	20%	
		Invasives present	2		
Stand Conditions	Fire Regime Condition Class (FRCC)	FRCC 1	10	N/A	40%
		FRCC 2	6		
		FRCC 3	2		
Proximity to Interface	Structure Density	No structure density	10	N/A	30%
		500m from any structures	4		
		<1-10 structures/km^2	2		
		>10 structures/km^2	0		

2.2.3 *Final Prioritization Resultant Map*

The final stage involved analyzing the results of the prioritization framework by spatially combining Restoration Treatment Priority with the Treatment Complexity ranking in order to develop a final prioritization map. This final spatial combination maintains the Restoration Treatment Priority and Treatment Complexity values as separate entities such that each polygon shows both values (for example, a polygon may be rated as Restoration Treatment Priority 1 but have a very high Treatment Complexity). In this way, all polygons rated as Restoration Treatment Priority 1 which have a very low Treatment Complexity value would receive the highest treatment priority ranking.

Restoration Treatment Priority and Treatment Complexity are combined to derive an overall Treatment Priority value. The advantage of maintaining subcomponents and components as separate entities lies in the transparency that is achieved in the calculations. In this way, each entity can be presented separately or as a combined result and the way in which each entity has contributed to the combined result is visible. For example, it is possible to see which polygons derive a Restoration Treatment Priority 1 but are also very complex to treat.

2.3 Risk to Public Safety: Mapping Methodology

One additional map product was produced to quantify the risk to public safety posed by wildfire. This product can be used as a public education tool in situations where ecosystem restoration is being carried out in close proximity to the wild land urban interface. This risk assessment map is composed of three subcomponents: **Interface Density**, **Infrastructure** and **Risk of Ignition**.

The **Interface Density subcomponent** uses structure density across the landscape to indicate the relative degree of population density. This allows for a general assessment of the degree of fire risk to humans and structures.

The **Infrastructure subcomponent** accounts for fire risk to infrastructure such as highways and hydro lines.

The **Risk of Ignition subcomponent** uses human and lightning caused fire records to predict the likelihood of fire ignition.

Table summarizes the subcomponents of the Risk to Public Safety Map.

Table. Risk to Public Safety subcomponents.

Component	Subcomponent	Criteria	Rating Scale	Weighting
Risk to Public Safety	Interface density (risk to humans and structures)	> 1000 structures/km^2	10	50%
		100-1000 structures/km^2	8	
		10-100 structures/km^2	6	
		1-10 structures/km^2	4	
		<1 structure/km^2	2	
		None	0	
	Infrastructure (risk to hydro lines, and highways)	< 500 m from infrastructure	10	20%
		> 500 m from infrastructure	0	
	Risk of ignition (# of fires since 1920)	>4 fires	10	30%
		3-4 fires	7	
		1-2 fires	3	
		0 fires	0	

3.0 Results

3.1 Review and Field Checking of Preliminary GIS Output

Once the initial mapping results were completed in GIS, map outputs of three District-selected test mapsheets were produced. These test sheets were reviewed by District staff and selected areas were visited in the field. The following discussion summarizes some of the issues identified during the field checking process and by District staff.

Originally the prioritization framework contained a "Potential Treatment Area" component which attempted to predict the degree of recent tree encroachment on grasslands as well as the degree of forest ingrowth.

- Encroachment prediction criteria incorporated aspect, subzone, and distance to forested edge within current grassland/open range polygons. Although encroachment was generally found within 300 m of forested edges, there was no relation to aspect, nor any way of predicting the density of encroachment. Since mapping was limited to current grassland polygons, there was no way to account for the historic reach of grasslands.

- The degree of forest ingrowth was predicted using a rating scale matrix of FRCC combined with severity classes of insect incidence. The field visit found that the insect incidence data did not consistently represent the severity of outbreak. Combining FRCC with insect incidence masked FRCC, concealing valuable ecosystem restoration planning information. Overall the resulting forest ingrowth map was not found to be useful during field visits.

The "Potential Treatment Area" component was replaced with the "Restoration Treatment Priority" component based solely on HNFR and FRCC. The field visits determined that giving managers the best information available on the historic and current state of an ecosystem would enable them to make ecologically defensible restoration treatment decisions.

The original prioritization framework also contained a third component: an assessment of "Benefit of Treatment". This component combined four subcomponents: community watersheds, public safety, biodiversity and forage potential. After lengthy discussions it was decided that the 'Benefit of Treatment' component should be omitted from the prioritization exercise. All components represented either policy directives (community watersheds and public safety) or values for which there was no appropriate spatial data to accurately represent ecosystems that would 'benefit' from restoration (biodiversity and forage potential).

Some of the language used in the original prioritization framework was revised in an attempt to minimize confusion and make the final map products as user friendly as possible. For example "Treatment Feasibility" was renamed "Treatment Complexity" since this component is a combined assessment of complex/difficult treatment objectives, challenging landscapes/sites and high unit treatment cost, whereas "Feasibility" implies treatment viability or achievability neither of which represents the intent of this assessment.

3.2 Analysis and Mapping Summaries

3.2.1 Restoration Treatment Priority

3.2.1.1 Distribution of the Historic State Subcomponent

Within the Forest District 1,288,366 ha (57%) fall within priority Historic States (HNFR I, II, and III). Table 4 provides an area summary of the priority and non-priority HNFR classes.

Table 4. Area summary of ownership and Historic State subcomponent within the contributing land base.

	Priority 1: HNFR I, II, III		Other HNFR	
	Area (ha)	Relative Percent	Area (ha)	Relative Percent
Cascades District	1,288,366	57%	967,810	43%

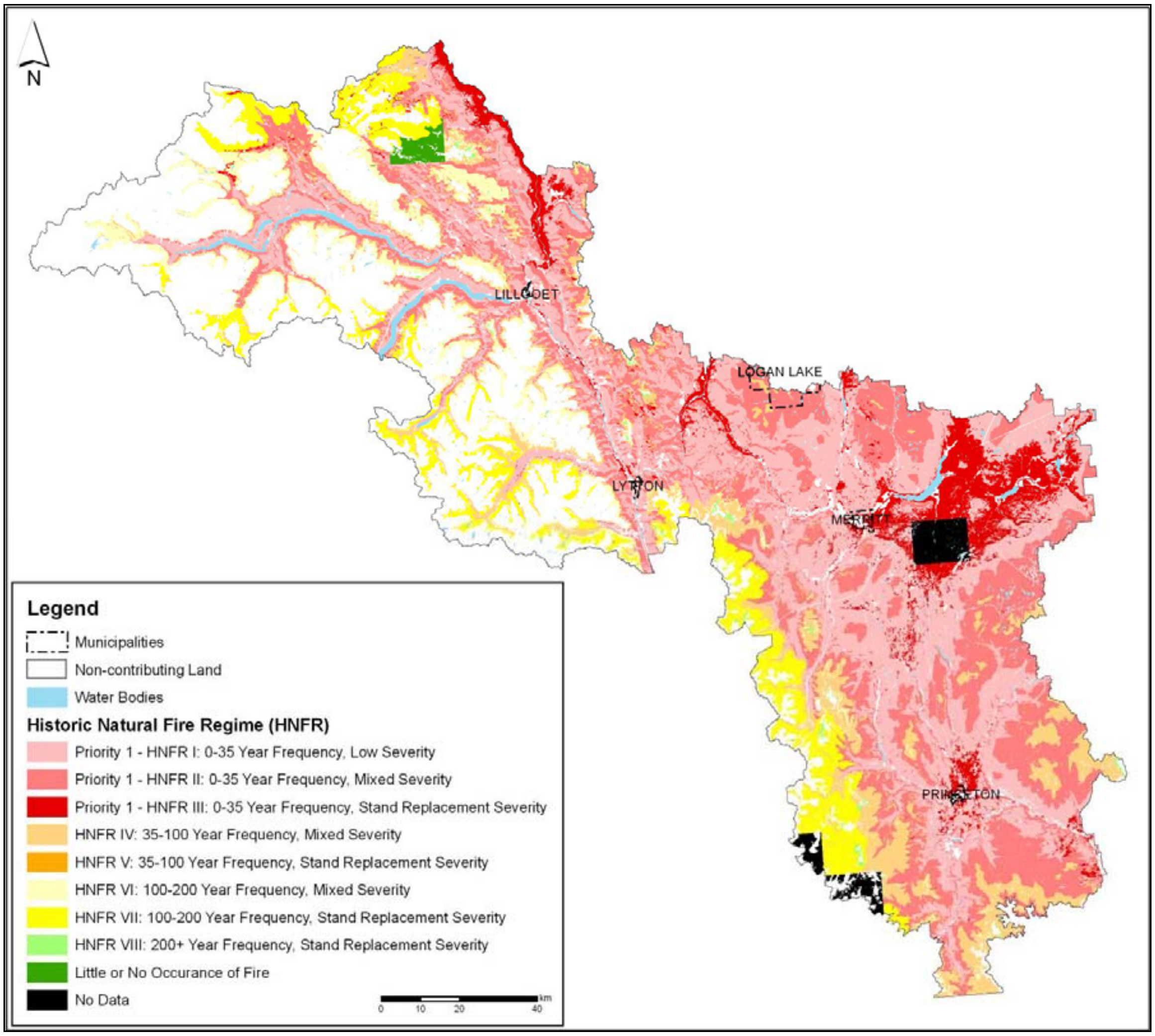

Figure 2. Historic State subcomponent.

3.2.1.2 Distribution of the Current State Subcomponent

Within the contributing land base 637,099 ha (38%) fall within the priority 1 Current States (FRCC 3). Table 5 provides an area summary of priority 1, 2 and 3 FRCC classes.

Table 5. Area summary of ownership and Current State subcomponent within the contributing land base.

	Priority 1 (FRCC 3)		Priority 2 (FRCC 2)		Priority 3 (FRCC 1)	
	Area (ha)	Relative Percent[1]	Area (ha)	Relative Percent	Area (ha)	Relative Percent
Cascades District	637,099	38%	211,502	13%	820,070	49%

[1] portion of contributing land base

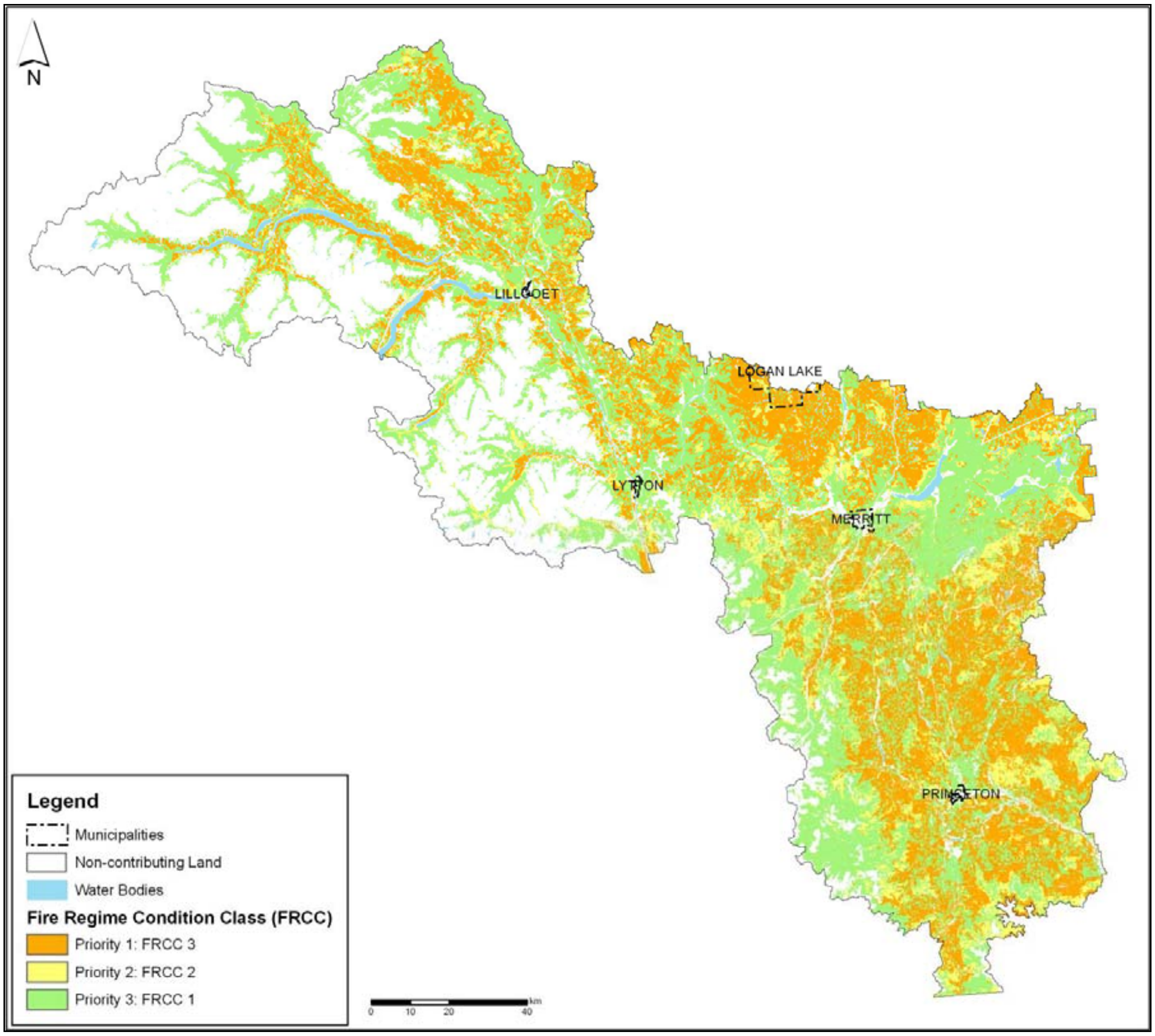

Figure 3. Current State subcomponent.

3.2.1.3 Distribution of Restoration Treatment Priorities

The overlay of Historic State (priority HNFR classes) and Current State (FRCC) created a resultant priority ranking for ecosystem restoration treatment (Table 6 and Figure 4). The ranking system identified 570,655 (34%) priority 1 treatment area (provincially owned) within the contributing land base and 613,318 ha (37%) within the entire contributing land base. This result highlights the high amount of FRCC 3 area within historically high frequency fire regimes. A small portion (7%) of the contributing land base was classified as priority 2.

Table 6. Area summary of ownership and Restoration Treatment Priority component within the contributing land base.

Ownership	**Priority 1**		**Priority 2**		**Priority 3**	
	Area (ha)	**Relative Percent**[1]	**Area (ha)**	**Relative Percent**	**Area (ha)**	**Relative Percent**
Provincial	570,655	34%	101,538	6%	328,718	20%
Private	30,430	2%	10,292	1%	120,698	7%
Federal	12,226	1%	4,323	<1%	32,663	2%
No Data	7	<1%	0	0%	0	0%
Total	**613,318**	**37%**	**116,154**	**7%**	**482,079**	**29%**

[1] portion of contributing land base

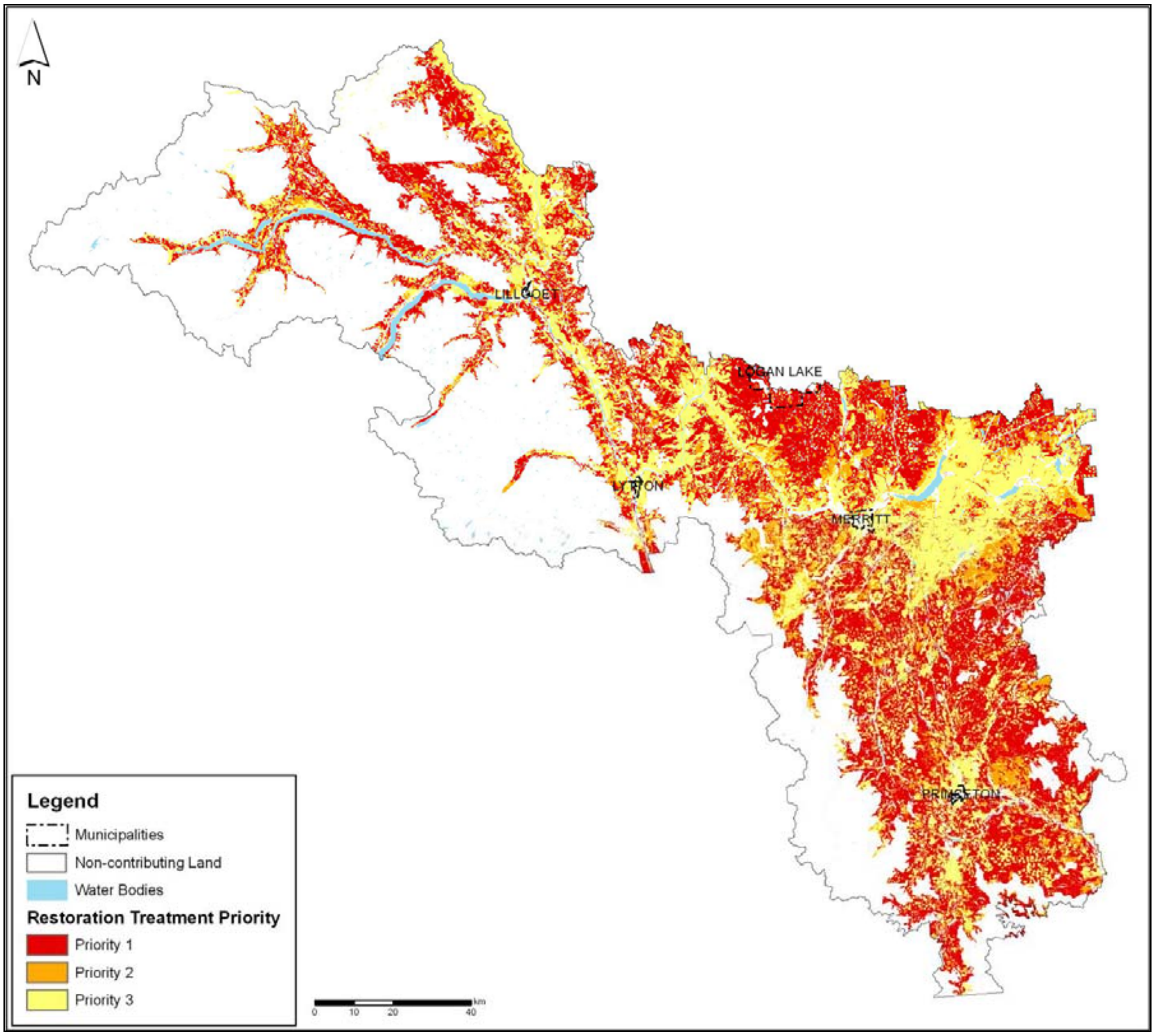

Figure 4. Restoration Treatment Priority component.

3.2.2 Treatment Complexity

3.2.2.1 Distribution of Treatment Complexity Classes

Treatment complexity was classified based on physical site conditions (slope, presence of invasive plant species and proximity to existing fire breaks), stand condition (FRCC) and proximity to the wildland urban interface. Areas that were classified as condition class 1, not in close proximity to interface with favorable site conditions were ranked low for treatment complexity. Within the contributing land base, a total of 424,951 ha (25%) were classified as having a low treatment complexity rating (provincially owned) (Table 7 and Figure 5), while the area classified as moderate was 484,251 ha (29%).

Thirty-three percent of the contributing land base is ranked as high to very high in terms of treatment complexity (provincially owned).

Table 7. Area summary of ownership and Treatment Complexity component within the contributing land base.

Ownership	Low Complexity		Moderate Complexity		High Complexity		Very High Complexity	
	Area (ha)	Relative Percent[1]	Area (ha)	Relative Percent	Area (ha)	Relative Percent	Area (ha)	Relative Percent
Provincial	424,951	25%	484,251	29%	487,810	29%	60,324	4%
Private	74,728	4%	51,771	3%	18,749	1%	16,487	1%
Federal	15,087	1%	18,998	1%	9,708	1%	5,682	<1%
No Data	0	0%	0	0%	6	<1%	1	<1%
Total	**514,767**	**31%**	**555,020**	**33%**	**516,273**	**31%**	**82,494**	**5%**

[1] portion of contributing land base

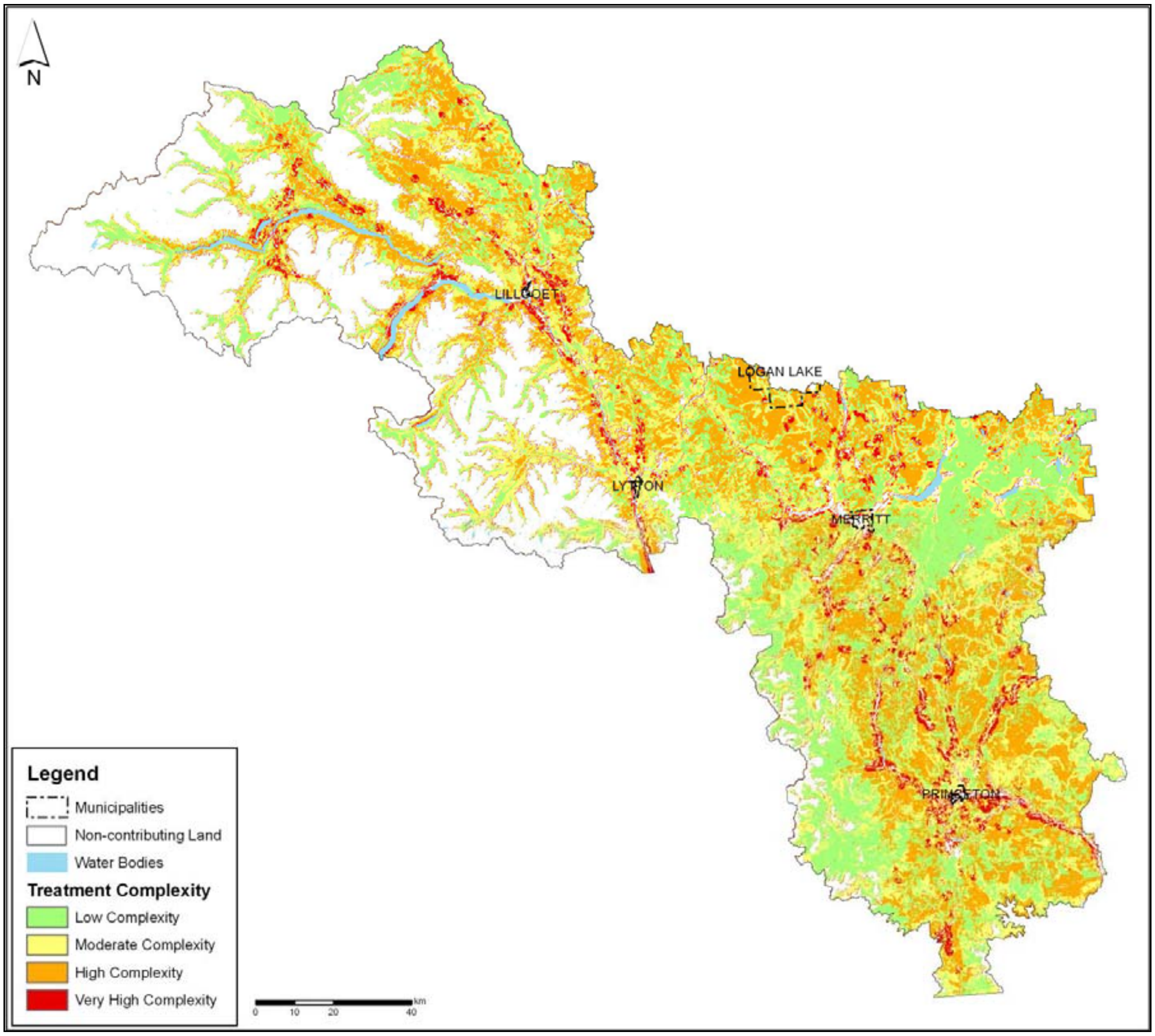

Figure 5. Treatment Complexity component.

3.2.3 *Final Resultant: Restoration Treatment Priority X Treatment Complexity*

The final overlay of Restoration Treatment Priority with Treatment Complexity rating shows there is no priority 1 restoration area rated as low treatment complexity in the Forest District (Table 8). This result highlights the fact that priority 1 restoration areas which are FRCC 3 are also by nature going to be the most complex areas to treat. A total of 71,179 ha (4%) was priority 1 area classified as having a moderate treatment complexity rating (provincially owned) within the contributing land base (red highlight in Table 8). The same result occurred with priority 2 areas (orange highlight in Table 8): no priority 2 restoration areas had low treatment complexity ratings.

Priority 3 areas (FRCC 1) were the only areas to have treatment opportunities rated as low complexity. A total of 211,214 ha (13%) was priority 1 area classified as having a low treatment complexity rating (provincially owned) within the contributing land base (yellow highlight in Table 8).

Table 8. Area summary of ownership and Restoration Treatment Potential X Treatment Complexity resultant within the contributing land base.

Ownership	Restoration Treatment Priority	Low Complexity		Moderate Complexity		High Complexity		Very High Complexity	
		Area (ha)	Relative Percent[1]	Area (ha)	Relative Percent	Area (ha)	Relative Percent	Area (ha)	Relative Percent
Provincial	1		0%	71,179	4%	439,566	26%	59,911	4%
	2		0%	90,311	5%	11,181	1%	47	<1%
	3	211,214	13%	106,245	6%	11,259	1%		0%
Private	1		0%	2,398	<1%	11,591	1%	16,440	1%
	2		0%	6,577	<1%	3,677	<1%	38	<1%
	3	74,640	4%	42,647	3%	3,411	<1%		0%
Federal	1		0%	634	<1%	5,933	<1%	5,658	<1%
	2		0%	2,362	<1%	1,950	<1%	12	<1%
	3	15,062	1%	15,873	1%	1,728	<1%		0%
No Data	1		0%		0%	6	<1%	1	<1%
	2		0%		0%		0%		0%
	3		0%		0%		0%		0%
Total		**300,916**	**18%**	**338,225**	**20%**	**490,303**	**29%**	**82,107**	**5%**

[1] portion of contributing land base

The final result in Table 8 suggests managers explore potential restoration treatment opportunities within the six percent of the contributing land base that contains provincially owned priority 1 areas and moderate treatment complexity ratings. This area (coloured dark red in Figure 6) appears lineal in nature and is somewhat dispersed within large areas of priority 1/high treatment complexity. This can be explained by the fact that these areas contain (or are in close proximity to) potential existing fire breaks (roads or water bodies). For this reason the treatment complexity results in a moderate rating.

Figure 6 highlights recommended restoration focus areas (circled in yellow) to be explored at a finer scale for restoration treatment opportunities. The three focus areas are dominated by priority 1/high treatment complexity inter mixed with smaller portions of priority 1/moderate treatment complexity (potential fire breaks). They also contain scattered patches of priority 2 and 3 areas which will have lower treatment complexity. These focus area are merely coarse scale recommendations. Managers will have the ability to explore the whole District at a finer scale using the Acrobat Map Viewer.

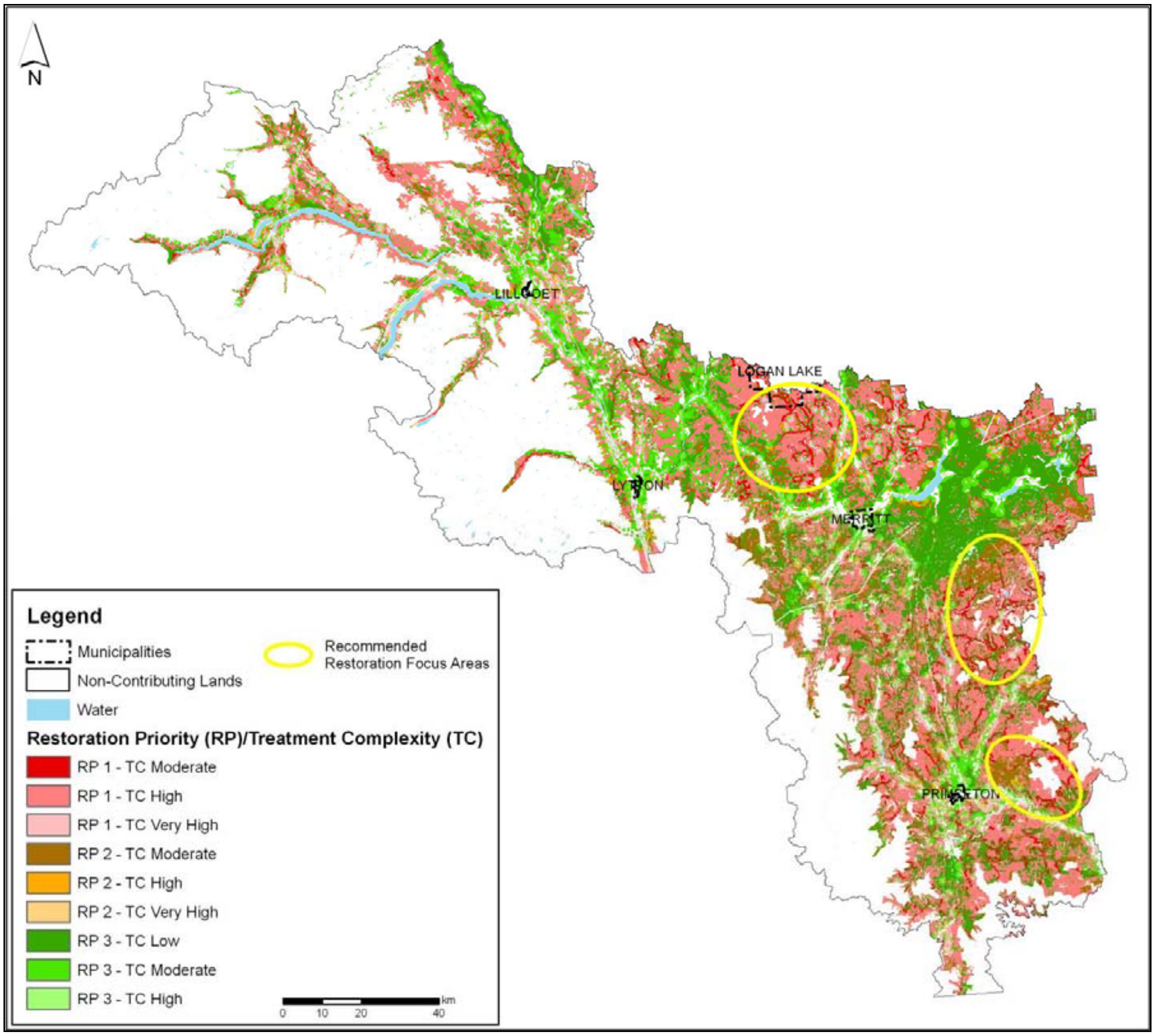

Figure 6. Resultant Restoration Treatment Priority X Treatment Complexity.

It can be argued that with limited human and financial resources, treating priority 2 areas (FRCC 2) which are less severely departed from their natural state is also a viable option. From the perspective of relative complexity of treatment objectives and cost as well as in the context of a small, developing ecosystem restoration program managers may decide to begin by tackling these priority 2 (and even priority 3) areas in the short term, then building on their successes and experience to expand into more complex treatment scenarios (priority 1 areas) in the future. Should this become the short term mandate of the Okanagan Shuswap Forest District ecosystem restoration program, focus would be placed on the dark brown and/or dark green areas in Figure 6.

3.2.4 Risk to Public Safety

3.2.4.1 Distribution of Risk to Public Safety Classes

Risk to public safety was assessed based on the combination of three subcomponents: proximity to interface (structure density), proximity to infrastructure (roads and hydro rights-of-way) and risk of ignition (ignition records). Figure 7 shows the resulting risk map.

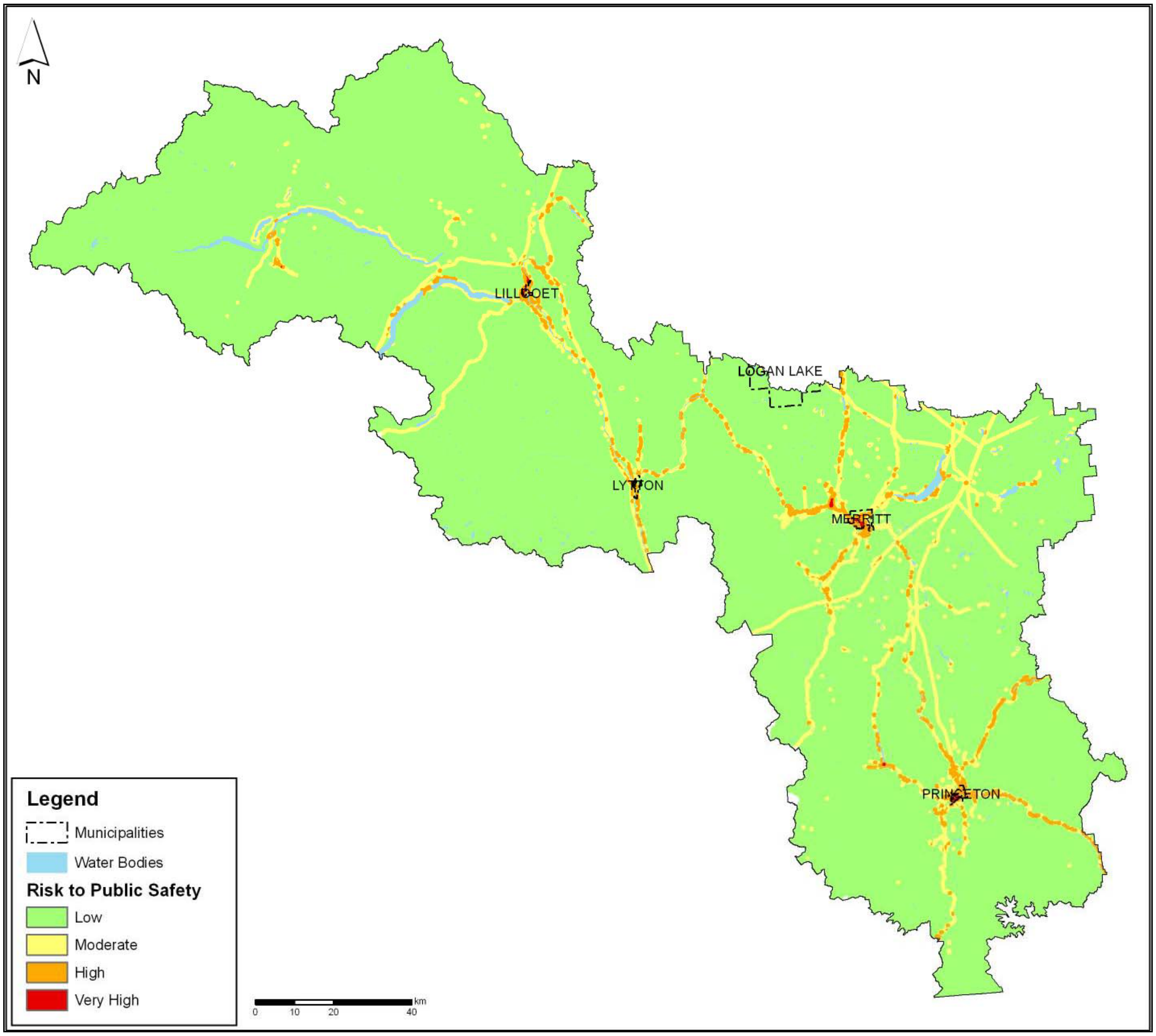

Figure 7. Risk to Public Safety.

4.0 Discussion

4.1 Translating the Results into Treatment Units

With the current social and political acceptability of the Provincial ER Program it is imperative that as much area as possible be treated as quickly as possible. However, this also means that the areas with the highest potential rate of success must be targeted for treatment first. Some of the criteria that can be used to help with this prioritization are FRCC, treatment cost, polygon size, and number of confounding constraints.

We can use Fire Regime Condition Class to help us identify areas that are departed from historic conditions, but that are within a less expensive range of remediation along the departure continuum. Areas categorized as FRCC 3, which are based on time-since-last-fire and canopy closure, can exhibit high fuel load and high tree density. Both of these factors immediately suggest very high treatment costs. Areas identified as FRCC 2 cover a range in departure that is more favourable from an immediate success stand point by having less biomass to deal with. Simply put, the greater the biomass loading at a given site, the greater the treatment cost for that site. This can also be affected by the number of synchronous treatments required. Sites categorized as FRCC 3 may require a treatment regime that includes mechanical thinning, manual thinning followed by chipping or pile burning, followed by broadcast burning. These are all additive costs applied to the same hectares.

Polygon size also affects treatment cost. Some treatment methods such as prescribed fire are substantially cheaper when conducted over larger treatment areas.

The number of confounding constraints is also a critical factor in prioritizing treatment areas. Mitigating the effects of treatment on a number of elements can add time and significant expense not only to treatment planning, but also to operations. Examples of constraints include livestock grazing schedules, endangered species habitat, adjacent high value assets, wildland-urban interface, etc. It is not often that a treatment area can be located that is free of constraints, but efforts could be made to locate areas with as few constraints as possible. This is a strategy to employ early in the program; as the program matures and participants have had some successes, more difficult areas should be tackled.

4.2 Considerations in the Development of Ecosystem Restoration Prescriptions

The process of “restoring” an ecosystem begins with a solid, quantitative understanding of the ecosystem’s component parts – structures, species, and processes. As defined by the Society for Ecological Restoration, *ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed.* This requires an understanding of the elements contributing to degradation, damage, or destruction. In some cases, ER is required *post facto* after a highly destructive or damaging incident such as wildfire of uncharacteristic severity. In other cases, ER is required as a pre-emptive act in order to prevent the effects of a highly destructive or damaging incident.

With Fire Regime Condition Class, as it applies to the high-frequency fire regimes, we are gauging the degree to which an ecosystem has been degraded as a result of fire-exclusion. Stand structure has been changed, as has species composition. A continuum exists between the scale of stand structure and species composition change and the degree of degradation. Part of this continuum is the potential scale of damage/destruction to ecosystems in the event of a wildfire. Therefore, the designation of FRCC is linked to degradation (current departed condition and its impact on ecosystem services), and potential damage/destruction. The less departed the system, the less impact on ecosystem services, and the less potential damage/destruction in the event of a wildfire.

Restoring an ecosystem, using this line of thinking, is contingent upon accurately identifying how far the ecosystem has moved along this continuum, as well as the factors contributing to the departure (Condition Class) and jeopardizing future outputs of ecosystem services. It should be pointed out here that there is not one standard of measure with which to assign Condition Class, or to help build plans for moving an ecosystem from one Condition Class to another. An ecosystem (with a specific HNFR) does not automatically change FRCC just because fire interval reaches a certain number, or stand density or canopy closure reach a certain number. These empirical markers are used to help us predict where the ecosystem is on this continuum; however, there’s much more to consider – especially when planning ER operations.

In this current model we use a combination of time-since-last-fire and canopy closure because they are spatial in nature and we have adequate empirical data. Simply reducing canopy closure and applying a prescribed burn does not constitute ER, even though we would certainly meet the criteria necessary in our coarse model to change FRCC. This is where the fine scale and really critical elements of ER kick in. Based on historic forest reconstruction and fire history, we would focus on the following elements in addition to time-since-last-fire and canopy closure:

- Overstory species composition
- Overstory diameter distribution
- Overstory density
- Understory composition
- Understory density
- Coarse fuel (CWD) characteristics (i.e., piece size, number, decay class, etc.)
- Snag population by species, diameter, and decay class
- Duff/litter characteristics

4.3 Ecosystem Restoration Treatment Strategies

Our model uses a number of data sets to craft a proxy condition for threats to ecosystem resilience and biodiversity – a condition referred to as “ecosystem health.” Most authors list the following as threats to ecosystem health:

- Increased tree density in dry forest types;
- Increased fuel load;
- Increased incidence of insect attack and disease; and
- Decreased biodiversity.

The first three variables can easily be quantified by comparing historic conditions with current conditions. This represents the fundamental premise of the prioritization model applied in this project. Dry forest resilience and biodiversity are threatened by the structural conditions that lead to catastrophic fire and insect and disease epidemics. High-density stand types, high fuel loads, and/or forests attacked by insects or disease are the targets for treatment. The fourth variable, biodiversity, is an “affected” attribute stemming from the influence of density, fuels and forest health that are outside of RONV. This variable is much more difficult to quantify at the coarse-scale, hence its omission in the prioritization model.

For the ER program to be effective, appropriate treatment objectives need to be developed that recognize the relationship between “causal” agents and the “affected” structures. The steps in this secondary process include:

- Identifying fine-scale structural features key to maintaining and enhancing treatment-level biodiversity;
- Identifying key structural targets for treatment;
- Identifying the desired future condition (*i.e.*, what to restore to); and
- Identifying how to attain the desired future condition.

Candidate restoration units will need to undergo a secondary level of analysis prior to moving to operational treatment status. The results of the prioritization modeling reveal some coarse-scale aspects of current condition and geographic location, both important elements in choosing the most appropriate treatment strategy. This coarse level of analysis, however, does not provide enough fine-scale information to set appropriate quantifiable objectives that are necessary to guide operational plans. At this stage in planning, key structural features that could be negatively or positively impacted by the treatment such as live trees, snags, downed logs, or specific plants need to be identified.

The relationship between these structures and fire (or other types of treatment) must also be understood. If the objective is to retain these structures, there must be a solid understanding of the fire ecology of the specific structure. For example, snags are a significant element of biodiversity in dry forest types being highly sought after for habitat for a wide range of organisms. Unfortunately, attempts to “protect” snags from either mechanical/manual thinning or prescribed fire – two commonly employed treatment strategies – are often unsuccessful (Gray and Blackwell 2006). Nonetheless, these structures need to be identified and, if possible, mitigation measures employed in an attempt to minimize their damage or loss (Figure 8).

Figure 8. Large downed log being consumed in a cool, spring prescribed burn. Most attempts to save these structures, through constructed firebreaks or avoidance firing, are unsuccessful (R. Gray photo).

The "target" in restoration treatments is typically trees, understory plants, and/or fuels. If the objectives include killing, top-killing, or consuming any of the above structures, a fairly precise inventory is required followed by an investigation of the fire ecology of the structure. Structural inventory provides key arrangement conditions that help guide the appropriate treatment strategy. The juxtaposition of these structures relative to key biodiversity elements is also critical. For example, attaining a Douglas-fir encroachment reduction objective is possible with the right combination of surface fuels, foliar moisture content, canopy bulk density, and canopy base height (Figure 9). However, if a key element of biodiversity is to protect an old Douglas-fir vet that is situated in the middle of the treatment area, it may be advisable to entertain a different treatment strategy.

Figure 9. Large diameter, old Douglas-fir killed as a byproduct of thinning young Douglas-fir encroachment (K. Iverson photo).

In ecosystem restoration, what condition do we restore to? The notion of ecological restoration rests on the premise that the entire ecosystem will function best under the conditions to which its component organisms have become adapted over evolutionary time (Covington 1995). For large portions of the project area there is little or no stand-level and landscape-level ecosystem structure data to help guide restoration projects. The HNFR and FRCC models provide some coarse-scale direction but suffer at the finer scale of individual treatment units. Certain structural attributes, assemblages of attributes, and records of disturbance regimes provide contemporary clues to historic conditions. Long-lived tree species, such as ponderosa pine and Douglas-fir, are evidence of historic plant community composition, and the arrangement of long-lived species provides clues to past structure (Wong 1999, Gray *et al.* 2004). In addition, the records of disturbance regimes, both biotic (insects) and abiotic (fire, drought), provide clues to the historic characteristics of surface fuel, coarse woody debris, and understory community composition (Gray *et al.* 2004).

Starting with what structures are present today we can work backwards to determine a range of historic conditions. Determining a point to stop at – the desired future condition – has much to do with the resilience of biodiversity attributes when faced with current and future disturbance. For example, if a desired future condition is a moderately stocked stand of ponderosa pine, the test for resilience is the stand's ability to survive the range of probable disturbance agents likely to affect it in the future. Would the structures that are key to biodiversity likely survive either wildfire or bark beetles? If not, this structure or desired condition would not be considered resilient and further planning would be required.

How we attain the desired future condition is the core of operational planning. Once objectives have been set it's time to determine the best way to meet those objectives. While there may be a strong emphasis to use prescribed fire, it should be pointed out that prescribed fire may not always be the most appropriate tool or the only tool to be used on a given project. It is our strong recommendation that agencies conducting ER treatments strive for a very high level of treatment precision.

The potential for post-wild land fire insect infestation in the treatment area and beyond is significant (Figure 10). Bark beetles such as Douglas-fir beetle (*Dendroctonus pseudotsugae Hopkins*), western pine beetle (*D. brevicomis LeConte*), mountain pine beetle (*D. ponderosae Hopkins*), and red turpentine beetle (*D. valens LeConte*), can have a profound impact on the success of the treatment. Excess "collateral" damage, in the form of excess crown scorch, bole scorch, or root damage, can often lead to an infestation of secondary scolytids (bark beetles) (Edmonds *et al.* 2000, Kelsey and Joseph 2003). Once the infestation gets established it is difficult to predict the amount of damage it can do. With current and projected beetle populations in the region insect infestation is a significant consideration.

Figure 10. Pitch tubes resulting from a post-prescribed burn infestation of red turpentine beetles in a ponderosa pine. On this particular unit no crown scorch was recorded yet 20% of the mature pines were killed by bark beetles within two years of the burn (R. Gray photo).

4.4 Research and Monitoring

As pointed out above, ER must be guided by a solid understanding of ecosystem components and their ecological interrelationships. Efforts should be made to identify knowledge gaps by ecosystem type and to fill those knowledge gaps as quickly as possible. This does not mean halting current efforts and waiting until all the answers are in. It means ensuring that as programs become operational there is a system in place that will guide learning from actions back into planning and management. This can take the form of adaptive management – an oft quoted panacea to this problem. However, adaptive management suffers from a long-term commitment to data collection, analysis, extension, storage and funding that is just not there.

A quicker, but less scientifically rigorous method, that will still yield some useful results, is project-level implementation and effectiveness monitoring. Effectiveness monitoring protocols have already been written for the East Kootenay Trench Program, however, these suffer from a lack of connection to implementation monitoring, and from too rigorous a design. Effectiveness monitoring needs to be tied to implementation and must be tailored to the objectives of the project. The project objectives must also be dynamic. As post-treatment data comes in, it is often the case that something unexpected has occurred leading to a new objective to monitor on the next project. Solid record-keeping during the monitoring process is important, and in the long run, it is well worth taking the time and providing the funding for a project monitor who is qualified to collect the data.

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6.0 Appendix I. Historic Natural Fire Regime - Defined

Historic natural fire regime defined (from Blackwell *et al.* 2003):

Fire Regime Code	Description
0	Little or no occurrence of fire
I	0-35 year frequency, low severity
II	0-35 year frequency, mixed severity
III	0-35 year frequency, stand-replacement severity
IV	35-100 year frequency, mixed severity
V	35-100 year frequency, stand-replacement severity
VI	100-200 year frequency, mixed severity
VII	100-200 year frequency, stand-replacement severity
VIII	200+ year frequency, stand-replacement severity

Fire Regime 0 is a non-fire regime where there is little or no occurrence of fire.

Fire Regime I (0- to 35-year frequency, low severity) is found primarily in forest types that experience frequent, low severity, non-lethal surface fires. For example, this fire regime would be found in ponderosa pine and Douglas-fir (*Pseudotsuga menziesii* [Mirb.] Franco) forest types with an herbaceous understory occurring on both subdued terrain and steeper, warm aspects. Fires occurring in HNFR I are generally non-lethal to the dominant vegetation and do not substantially change the structure of this layer. Fire history studies in this regime suggest it has the highest frequency of fire occurrence in B.C. and that it was historically widely spread throughout the study area. To support high frequency fire, sufficient surface fuels must accumulate between fires to carry subsequent fires, in many cases within one or two years, but not enough to result in fire severity sufficient to kill many overstory trees. More productive ecosystems within this type may develop thick regeneration or shrub/herb layers between fires that are killed, thinned, and/or top-killed by subsequent fires. Approximately 80% or more of the aboveground dominant vegetation survives these fires.

Fire Regime II (0 - to 35-year frequency, mixed severity) is closely associated with Fire Regime I. It is found in similar dry forest types but occurs on cooler aspects at lower elevation, and at higher elevations directly upslope of Fire Regime I ecosystems on warm aspects. Depending on the ecosystem affected, mixed severity can be defined spatially, temporally, or both. At low elevation these sites may “miss” one or several fires that occur in the adjacent HNFR I sites due to fuels and topography. Higher productivity sites on cooler aspects also results in more surface fuel, in turn resulting in higher fire intensity and severity than the adjacent HNFR I. Many fires originating in HNFR I have a high probability of affecting upslope, HNFR II ecosystems. On steep, warm aspects where HNFR II ecosystems transition to HNFR I ecosystems, fire severity is regulated by the season of fire, site productivity, and species composition. Historic fires that occurred early in the growing season (some First Nations burning) in HNFR I may not affect adjacent HNFR II ecosystems due to fuel moisture. Higher elevation sites, even on warm aspects, may be more productive than lower elevation warm sites due to precipitation and soil moisture. These sites therefore have the ability to produce more surface fuel over a short period of time. A caveat to site productivity, however, is the shorter growing season. Tree species inhabiting the higher elevation, warm aspects include subalpine fir (*Abies lasiocarpa* (Hook.) Nutt.), Engelmann spruce (*Picea engelmannii* Parry ex Engelm.), and lodgepole pine (*Pinus contorta* Dougl. ex. Loud.), which exhibit a lower fire tolerance (Uchytil 1991a; Uchytil 1991b; Uchytil 1992) than species such as ponderosa pine and Douglas-fir (Howard 2002a; Steinberg 2002). All of these factors produce highly variable levels of fire effects on tree species and structures within a fire regime with a high frequency.

Fire Regime III (0- to 35-year frequency, stand-replacement severity) is found primarily in grass and shrub types where frequent fire consumes or kills >90% of the dominant overstory canopy. It is critical to note the distinction between the terms "consumes," "kills," and "top-kills" in the definition of this fire regime. In many grass- and shrub-dominated ecosystems natural fires "top-kill" the dominant vegetation but do not "kill" the plants outright. Historically, most of the species found in these ecosystems were fire-adapted and persisted through mechanisms such as below-ground epicormic buds and soil stored seed. Landscapes subject to this fire regime likely contained "refugium" patches where less fire adapted species, such as prickly pear cactus (*Opuntia polyacantha*) and Rocky Mountain juniper (*Juniperus scopulorum*) (Johnson 2000; Scher 2002a), lichens, and liverworts, survived the high frequency of fire occurring in the surrounding landscape matrix (Blackwell *et al.* 2001).

Fire Regime IV (35- to 100-year frequency, mixed severity) is associated with forest types and topography where fuel moisture conditions are favorable to fire ignition and spread, and where topography and moisture conditions are more variable than in the more frequent fire regimes. This fire regime often occurs in close proximity to HNFRs I and II, but due to higher elevation, cooler, moister conditions, and/or variable topography may "miss" several fires occurring below or adjacent to it. The season during which burning historically occurred in these ecosystems is critical. Early season fires at low elevation, or on adjacent warm aspects in HNFR I and II ecosystems, did not likely impact HNFR IV ecosystems resulting in the theory of "missed" intervals. First Nations burning to encourage the propagation of subalpine plants such as black huckleberry (*Vaccinium membranaceum*), spring beauty (*Claytonia lanceolata*), and glacier lily (*Erythronium grandiflorum*) (Turner *et al.* 1990; Turner 1991; Turner 1999) was instrumental in HNFR IV fire history, as was summer/fall lightning. With increasing elevation, or more northerly aspects, comes a reduced fire "window" wherein conditions favorable for fire ignition and spread would be limited to late summer and fall. Probabilities of fire starts are decreased compared to HNFR I and II. Tree species found in HNFR IV include a range of fire tolerances from low, {western redcedar (*Thuja plicata* Donn ex D. Don), western hemlock (*Tsuga heterophylla* [Raf.] Sarg.), subalpine fir and Engelmann spruce}, moderate, (lodgepole pine and whitebark pine [*Pinus albicaulis* Engelm.]), to high, (Douglas-fir and western larch [*Larix occidentalis* Nutt.]) (Tesky 1992a; Tesky 1992b; Howard 2002b; Scher 2002b).

Fire Regime V (35- to 100-year frequency, stand-replacement severity) is found on more northerly aspects but within landscapes where fires occurred relatively frequently. In this regime, fires kill the aboveground parts of dominant vegetation, changing the aboveground structure substantially. Approximately 80% or more of the aboveground vegetation is either consumed or dies as a result of fires. The proximity of these ecosystems to high fire frequency ecosystems is instrumental in their fire history, as is the relative frequency of fire-favorable weather and fuel conditions. These ecosystems typically contain tree species with a low fire tolerance such as subalpine fir and Engelmann spruce.

Fire Regime VI (100-200 year frequency, mixed severity) is found in areas where fires occur infrequently, but, due to high fuel accumulations, a mix of species fire tolerances, and highly variable topography, when fires do occur they result in high, but not complete, overstory mortality. This fire regime is driven more by the infrequent occurrence of fire-favorable weather and surface fuel conditions. Weather patterns conducive to fire are variable but typically infrequent. Surface fuels may go through transitions of succession where certain plant communities are very poor carriers of fire (e.g. shrub or deciduous tree) but eventually surface fuel accumulations and plant community succession lead to a more flammable condition. When these two factors interact, relatively high intensity fires occur. Highly bisected topography, which is a characteristic of these ecosystems, produces both spatially, mixed succession stages and fire effects.

Fire Regime VII (100-200 year frequency, stand-replacement severity) is found in areas where fires occur very infrequently but when they do occur the fire kills aboveground parts of dominant vegetation, changing the aboveground structure substantially. Approximately 90% or more of the aboveground vegetation is either consumed or dies as a result of fires. This fire regime contains similar regime characteristics to Fire Regime VI.

Fire Regime VIII (200+ year frequency, stand-replacement severity) is found in areas where fires occur very infrequently. Characteristics of these ecosystems include strong northerly aspects, variable topography, dominant weather patterns of poor fire-favorable weather, and mostly inflammable surface fuel conditions. Following a major fire event these ecosystems may go through a prolonged succession of shrub and deciduous tree plant communities that are very poor carriers of fire. Eventually a conifer community inhabited by species with very low fire tolerance, such as mountain hemlock (*Tsuga mertensiana* [Bong.]) or Pacific silver fir (*Abies amabilis* [Dougl.] ex. Loud.), will dominate (Cope 1992; Tesky 1992c). The conifer community will burn in a stand-replacement fashion once adequate surface fuel and weather conditions are met.

7.0 Appendix II. Fire Regime Condition Class - Defined

Fire regime Condition class defined (from Blackwell *et al.* 2003):

The effect of HNFR on forest and range ecosystems produces a variable, but predictable, range of species and vegetation structures (Brown 2000). Shifts in species composition and vegetation structure have accompanied the interruption of the HNFR across many parts of the study area (Gray *et al.* 2002; Gray *et al.* [in press]). As a result there has been a significant departure from the species and structural elements adapted to the HNFR; were fire to return to these ecosystems in their departed state, extensive environmental damage could occur. Not all ecosystems are departed from their historic state, however, and many fall within a range of departure. The condition class (CC) concept (Hardy *et al.* 2001, Hann and Bunnell 2001, Schmidt *et al.* 2002) was developed as a useful tool for assessing an ecosystem's fire regime change over time. Condition classes (Table 3) are a function of the degree of departure from the HNFR resulting in the alteration of key ecosystem components such as species composition, structural stage, stand age, and canopy closure. One or more of the following activities may have caused this departure: fire exclusion, timber harvesting, grazing, introduction and establishment of exotic plant species, insects and disease (introduced or native), or other past management activities (Hardy *et al.* 2001).

Condition Class descriptions (from Hardy *et al.* 2001, and Hann and Bunnell 2001)

Condition Class	Departure from HRV[1]	Attributes	Example management options
Class 1	Low	- Fire regimes are within or near an historical range - The risk of losing key ecosystem components is low - Fire frequencies have departed from historical frequencies by no more than one return interval - Vegetation attributes (species composition and structure) are intact and functioning within an historical range - Disturbance agents, native species habitats, and hydrologic functions are within the historical range of variability - Smoke production potential is low in volume	Where appropriate, these areas can be maintained within the historical fire regime by treatments such as management ignited prescribed fire or prescribed natural fire
Class 2	Moderate	- Fire regimes have been moderately altered from	Where appropriate, these areas may need

Condition Class	Departure from HRV[1]	Attributes	Example management options
		their historical range - The risk of losing key ecosystem components has increased to moderate - Fire frequencies have departed (either increased or decreased) from historical frequencies by more than one return interval. This results in moderate changes to one or more of the following: fire size, frequency, intensity, severity, or landscape patterns - Disturbance agents, native species habitats, and hydrologic functions are outside the historical range of variability - Smoke production potential has increased moderately in volume and duration	moderate levels of restoration treatments, such as management ignited prescribed fire and hand or mechanical treatments, to be restored to the historical fire regime
Class 3	High	- Fire regimes have been significantly altered from their historical range - Fire frequencies have departed from historical frequencies by multiple return intervals. This results in dramatic changes to one or more of the following: fire size, frequency, intensity, severity, or landscape patterns - Vegetation attributes have been significantly altered from their historical range - Disturbance agents, native species habitats, and hydrologic functions are substantially outside the historical range of variability	Where appropriate, these areas may need high levels of restoration treatments, such as hand or mechanical treatments. These treatments may be necessary before fire is used to restore the historical fire regime

[1] HRV = historic range of variability