West Arm Provincial Park Fire Management Plan

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British Columbia | BC Parks

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Approved by:

May 1, 2017

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John Trewhitt, Regional Director **Date**

BC Parks & Conservation Officer Service Division

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EXECUTIVE SUMMARY

West Arm Park (the Park) is close to the communities of Harrop-Procter and the City of Nelson and protects important ecological and social values, such as mountain caribou and community watersheds. Fire risk in the Park is significant, and a wildfire could have negative effects on the values in the Park. BC Parks is actively managing fire risk in the Park to help protect Park values and working with local and regional governments to reduce wildfire risk to the adjacent communities.

BC Parks retained B.A. Blackwell and Associates Ltd (Blackwell) to develop a Fire Management Plan for West Arm Provincial Park (the Plan) based on new and existing information including previous fire management plans completed for the Park. The objectives of the Plan are to provide an ecosystem based framework for fire management in the Park and recommendations to reduce negative effects of wildfire to the Park's ecological and social values as well as values adjacent to the Park.

The Plan is presented in two parts: Part 1: Background Information and Part 2: Fire Management Planning. Part 1 outlines the features and values considered in fire management planning including: Park ecology, biodiversity values, watershed values, social values, historic fire regimes, climate change, fire environment, fire behaviour, fire consequences, wildland urban interface (WUI), and the implications of fuel management in the Park. Part 2 provides high level recommendations to guide subsequent operational fire management plans or strategies in the context of the values and background management issues identified in Part 1. Additionally, Part 2 outlines the steps required to implement fire management measures in the Park and recommends actions to address information gaps and planning requirements to help guide suppression activities in the event of a wildfire and inform post-fire rehabilitation activities.

Part 1: Background Information

The Park values included in the assessment in Part 1 consider the ecological value of the Park in regards to the contribution to the protected areas system and the biological and social values it provides. Values adjacent to the Park also influence fire management planning within the Park. The values addressed in the Plan include:

- Ecological representation;
- Biodiversity values such as old-growth forests and forest age distribution, and rare and endangered species and communities such as whitebark pine, mountain caribou, grizzly bear, and fish species;
- Community watershed values and the City of Nelson's water supply related infrastructure;
- Social values including archaeological sites, recreation uses, adjacent tenures and land ownership;
- First Nation's interests; and
- Adjacent communities and the wildland urban interface (WUI).

While wildfire can negatively affect values in the Park, it has been one of the primary disturbance agents that has influenced ecosystem development in the Park. Fire history in the Park is complex and fire frequency for the lower elevation forests is likely between 30 to 100 years, while the higher elevation forests experience longer return intervals (of up to 500 years) but higher fire severity due to fuel build-up. In the future, fire frequency and the annual area burned are anticipated to increase due to climate change, which could result in species and structural shifts to Park ecosystems and losses in adjacent communities.

Fire weather, fuels, and topography are key determinants of fire behaviour. Key fire weather parameters, such as Fire Danger Class Days and Drought Code support the characterization of frequent hazardous fire conditions in the Park. The fuel complex in the Park is also capable of supporting high fire behaviour. Provincial Strategic Threat Analysis (PSTA) fuel types were updated to reflect changes associated with mountain pine beetle effects on lodgepole pine stands. There are over 20,000 ha in the Park in PSTA threat classes 7 to 10. Areas in these classes can support high fire behaviour, crown fires with headfire intensities > 10,000 kW/m, and could be affected by spotting.

A significant wildfire in the Park would have effects on biodiversity that would be highly variable and depend upon timing, extent, severity of a wildfire, and the biophysical setting in which it occurs. Species such as grizzly bear would likely experience primarily positive effects related to increased forage availability; whereas effects to species such as whitebark pine and mountain caribou are anticipated to be negative. Other Park values such as community watersheds would also be negatively affected, with potential changes in the hydrologic functions that govern water yields, water quality, and timing and volume of seasonal flows. Other social values such as archaeological sites, First Nations interests, and recreation values could also be negatively affected by a significant wildfire. As the Park is located in an interface area, the threat of fire moving to or from the interface is considerable. Wildfire risk to the adjacent communities is significant and the potential loss of infrastructure and human life is a key consideration when assessing wildfire effects.

Part 2: Fire Management Planning

Fire management and risk reduction are the overarching concerns that have directed this planning document. However, as discussed in Part 1, fire management must be guided by the values that the Park provides and protects. The main objectives identified to guide fire management planning in the Park are protection of 1) watershed values, 2) habitat and biodiversity values, and 3) adjacent communities and the associated values such as recreation.

These three objectives informed the development of Fire Management Zones (FMZ), which were identified to best manage the principle value in each region of the Park. FMZ boundaries were based on natural topographical breaks, mountain caribou habitat, and proximity of the communities. The three FMZ identified are: 1) Watershed FMZ; 2) Mountain Caribou FMZ (reserve area); and 3) Harrop-Procter FMZ. Management objectives and actions specific to each of the FMZs are provided; however, in the event of a fire, all of these FMZ are full suppression zones.

Using the FMZs to guide planning, PSTA analysis, assessments of values at risk within and adjacent to the Park, and the existing and planned fuelbreaks, potential landscape level fuelbreak locations were identified for review in the Park.

However, the implementation of landscape level fuelbreaks in the Park is only one step in addressing wildfire risk and potential effects in the Park. To support wildfire planning in the Park, four principle actions have been identified for BC Park's consideration to support wildfire risk reduction and planning for the Park: 1) Creation of the landscape level fuelbreaks; 2) Development of tactical response plans; 3) Collection of Park inventory data to support planning; and 4) Development of a wildfire rehabilitation plan. These are described in greater detail below:

1) Landscape level fuelbreaks - Based on the supporting information presented in this Plan and field reconnaissance, potential fuelbreak review areas in the Park were identified in the Watershed FMZ and Harrop-Procter FMZ. The selection of these areas considered fire history, fire behavior, values at risk, topographic and logistic constraints in terms of fuelbreak construction, and natural fuelbreaks. This Plan has been developed in conjunction with Community Wildfire Protection Plans (CWPP) for the City of Nelson and adjacent Electoral Areas E and F of the RDCK, and it considers constructed fuelbreaks external to the Park that will enhance the effectiveness of a fuelbreak in the Park.

The recommended landscape level fuelbreaks for the FMZs cross jurisdictional boundaries and require coordination with other agencies including adjacent municipal jurisdictions, stakeholders such as adjacent communities, licensees, and utilities. Establishing landscape level fuelbreaks based on the considerations listed above and irrespective of the Park boundary, allows for optimal placement of the fuelbreaks to protect values at risk within and external to the Park. As part of the review process, consultation on each area will be completed by BC Parks.

2) Tactical response plan – A tactical response plan is a detailed plan about how to respond in case of a fire, and identifies natural fuel breaks, areas that could be used for fire control and areas off limits for suppression activities like retardant drops and cat guard construction. The tactical response plans should be living documents that are updated as new pre- and post-fire planning information becomes available from the studies outlined in steps 3 and 4 below.

3) Collection of Park inventory data to support planning – Collecting Park inventory data to support pre-planning will support the development of comprehensive tactical response plans and post-fire stabilization and rehabilitation to reduce the effects of wildfire and suppression activities. Inventory information should include terrain stability and soil hazard mapping, Terrestrial Ecosystems Mapping, Archaeological Overview Assessments, and surveys to characterize forest health and mountain caribou presence and habitat. Assembling information in advance will subsequently allow for the rapid refinement of planned strategies such as emergency stabilization and short- and long-term rehabilitation methods.

4) Development of a wildfire rehabilitation plan - The focus of the plan should be on information gathering rather than outcome prediction and preparation for all possible events. There are three categories of stabilization/rehabilitation: i) short-term emergency stabilization; ii) rehabilitation of fire suppression related effects; and iii) long-term rehabilitation. Post-fire planning should consider a risk-based approach to assessing potential hazards from fire and post-fire conditions, and the potential consequences of such hazards on key Park values. *Post-wildfire Natural Hazards Risk Analysis* (Hope et al. 2015) provides a risk analysis procedure and standard considerations that should be used to help guide professionals in the assessment of wildfire effects.

These four '*next steps'* are explained in detail in the Plan and supporting recommendations have been identified for each step. Where applicable, the recommendations have been prioritized based on their relative importance.

However, the order in which they are completed will depend upon the funding and resources available. Some lower priority recommendations may be completed before those with higher priority based upon the ability of BC Parks to implement them. While the recommendations have been made to support planning in the Park, many of the recommendations will be best conducted or supported by partnering agencies, the City of Nelson, or the RDCK and by the residents of Svoboda Road and Harrop-Procter.

GLOSSARY AND ABBREVIATIONS

Acronym	Full Name/ Definition
AOA	Archaeological Overview Assessment
BCWS	BC Wildfire Service
BCGW	BC Geographic Warehouse (managed by DataBC)
BEC	Biogeoclimatic Ecosystem Classification
BGC	Biogeoclimatic
CDC	Conservation Data Centre
CMT	Culturally Modified Tree. A tree or a remnant of a tree with evidence of traditional aboriginal forest use.
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CWD	Coarse woody debris. Typically, sound or rotting logs, stumps, or large branches that have fallen or been cut and left in the woods, or trees and branches that have died but remain standing or leaning (estimated for pieces > 12.5 cm in diameter).
CWPP	Community Wildfire Protection Plan
DataBC	DataBC encourages and enables the strategic management and sharing of data across the government enterprise and with the public. It is responsible for the Open Data initiative and the Province's Spatial Data Infrastructure and associated products and services.
DBH	Diameter at Breast Height (1.3 m)
ECA	Equivalent clearcut area (ECA) is defined as the area that has been clearcut, with a reduction factor to account for the hydrologic recovery due to forest regeneration (MFLNRO 1995)
FMPIV	Fire Management Planning Information Viewing
GIS	Geographic Information System
LRDW	Land and Resource Data Warehouse (replaced by the BC Geodata Warehouse)
LU	Landscape Unit
MFLNRO	Ministry of Forests, Lands and Natural Resource Operations
MOE	Ministry of Environment
MPB	Mountain pine beetle
OGMA	Old Growth Management Area. Defined areas that contain, or are managed to attain, specified structural old-growth attributes and that are delineated and mapped as fixed areas.
Polygon	In GIS work, a polygon is a stream of digitized points approximating the delineation (perimeter) of an area on a map.
PSTA	Provincial Strategic Threat Analysis
RDCK	Regional District of Central Kootenay
Riparian habitat	The stream bank and flood plain area adjacent to streams or water bodies.

Acronym	Full Name/ Definition
SRMP	Sustainable Resource Management Plan
TEM	Terrestrial ecosystem mapping
UWR	Ungulate Winter Range - An area containing habitat that is necessary to meet the winter habitat requirements of an ungulate species.
VRI	Vegetation Resource Inventory
Windthrow	Tree or trees felled or broken by the wind.
WIST	West Arm Interface Steering Team
WUI	Wildland Urban Interface

1 INTRODUCTION

BC Parks is actively engaged in developing strategies to manage and mitigate the risks associated with wildfire in West Arm Provincial Park (the Park). In recognition of the ecological and social values provided by the Park and the risk posed by wildfire to the adjacent communities and the Park, B.A. Blackwell and Associates Ltd (Blackwell) was retained to develop a Fire Management Plan for West Arm Provincial Park (the Plan). This Plan includes information compiled from previous plans including: *West Arm Provincial Park Interface Fuel Management Plan* (Blackwell et al. 2008), *West Arm Provincial Park Ecosystem Based Fire Management Plan* (Blackwell et al. 2010), and *West Arm Provincial Park Ecosystem Based Fire Management Plan Update* (Blackwell 2012).

The Plan incorporates more recent wildfire data and information, including the current Provincial Strategic Threat Assessment (PSTA) data and key inputs including fuel types, wildfire urban interface zones, and structure density as well as provincially compiled data relevant to assessing values in and adjacent to the Park. Since 2012, new fuel treatments have been implemented or are planned; these were used in fire behaviour modeling and considered during landscape fuelbreak design. The Plan incorporates current BC Wildfire Service (BCWS) Fire Management Planning Information viewing (FMPIV) system data and meets the relevant mapping standards.

This 2017 Plan includes revisions where information was outdated or new information was identified. No changes were made when the previous plan information was still relevant. This Plan was developed in conjunction with Community Wildfire Protection Plans (CWPP) for the City of Nelson and adjacent Electoral Area E of the Regional District of Central Kootenay (RDCK). Combined, these jurisdictions provide a coordinated, regional approach. The Plan has been guided by the Interface Working Group, which consists of the agencies tasked with wildfire planning and management activities in and adjacent to the Park, including senior staff from BC Parks, the City of Nelson, and the RDCK. During the development of this Plan, public input was sought through a consultation process (Section 4) and further consultation is planned prior to the finalization of the plan.

The Plan is presented in two parts: Part 1: Background Information and Part 2: Fire Management Planning. Part 1 outlines the features and values considered in fire management planning including: Park ecology, biodiversity values, watershed values, social values, historic fire regimes, climate change, fire environment, fire behaviour, fire consequences, wildland urban interface (WUI), and the implications of fuel management in the Park. Part 2 provides high level recommendations to guide subsequent operational fire management plans or strategies in the context of the values and background management issues identified in Part 1. Additionally, Part 2 outlines the steps required to implement fire management measures in the Park and recommends actions to address information gaps and planning requirements to help guide suppression activities in the event of a wildfire and inform post-fire rehabilitation activities.

1.1 Plan Objectives

The objectives of the Plan are to provide an ecosystem based framework for fire management in the Park and provide recommendations to reduce negative effects of wildfire to the Park's ecological and social values as well as values adjacent to the Park. The Plan is intended to function as a guidance document for subsequent operational fire management planning in the Park, provide recommendations on landscape level fuelbreaks to protect values, and identify information gaps and the actions required to support more detailed pre- and post-wildfire planning and consultation.

Part 1: Background Information

2 PART 1 – INTRODUCTION

Part 1 identifies West Arm Provincial Park (the 'Park') features and values considered in fire management planning. It includes discussion of all the significant biological, physical, and social aspects to be considered when developing fire management strategies for the Park.

To develop Part 1 of the Plan, studies provided by BC Parks specific to West Arm Park and the surrounding region and other available data and literature were used to describe the biophysical values in the Park. Available Geographic Information System (GIS) data was used to identify the spatial distribution or location of values at risk in the Park. Spatial data was primarily obtained from the BC Geographic Warehouse (BCGW). GIS maps for the previous reports have been updated to current BCWS FMPIV standards.

3 PLAN AREA

The Park is 26,199 ha based on the Ministry of Environment (MOE) Protected Land Registry. The south-western Park boundary abuts the north eastern municipal boundary of Nelson and extends north along the shore of Kootenay Lake to Harrop-Procter. The boundary extends in the alpine areas above the lake and extends close to Whitewater Ski Resort (Figure 3-1). The Park includes a range of habitats, from lakeshore to alpine. It plays an important role in representing the Southern Columbia Mountains (SCM) Ecosection and includes the Interior Cedar Hemlock (ICH) and Engelmann Spruce-Subalpine Fir (ESSF) Biogeoclimatic zones (BGC). The lowest elevation in the Park is along the Kootenay Lake shoreline at 530 m, and its highest elevation is 2,377 m at the peak of Mount Lasca. The Park includes varied terrain from peaks, high ridges, and rock outcrops to gentle slopes in the lower elevations.

Access to the Park is limited. Whitewater Ski Resort provides some hiking and ski touring access, and the foreshore is primarily boat accessible where stream fans exist. Three gravel roads provide access: Svoboda Road is located parallel to Five Mile Creek; a 1.4 km road extends to Goddard Hill from Harrop; and a forest service road that extends to the confluence of Midge and Kutetl Creek. The Park is largely undeveloped and there are no camping facilities although wilderness camping is permitted. Trails include an unmaintained historic trail that runs along Lasca Creek and another along the water pipeline that extends to the City of Nelson and is primarily used by mountain bikers. Numerous user-built mountain biking trails exist in the Park.

Recreation use in the Park includes mountain biking, hiking, backcountry skiing, hunting, wildlife viewing and water based activities on Kootenay Lake such as boating, fishing, and swimming. Most activity occurs on the lower slopes adjacent to Nelson.

The Park also contains the City of Nelson community watersheds which supply drinking water for the City. Protection of the watersheds is important to maintain the hydrological functions that influence water quality, quantity, and timing of flows.

There are several known First Nations archaeological sites in the Park. Most sites are located along the foreshore; however, surveys have only been conducted within 750 m of Kootenay Lake, according to the Park Management Plan (MOE 2007). There are also archaeological sites related to European settlement along the foreshore.

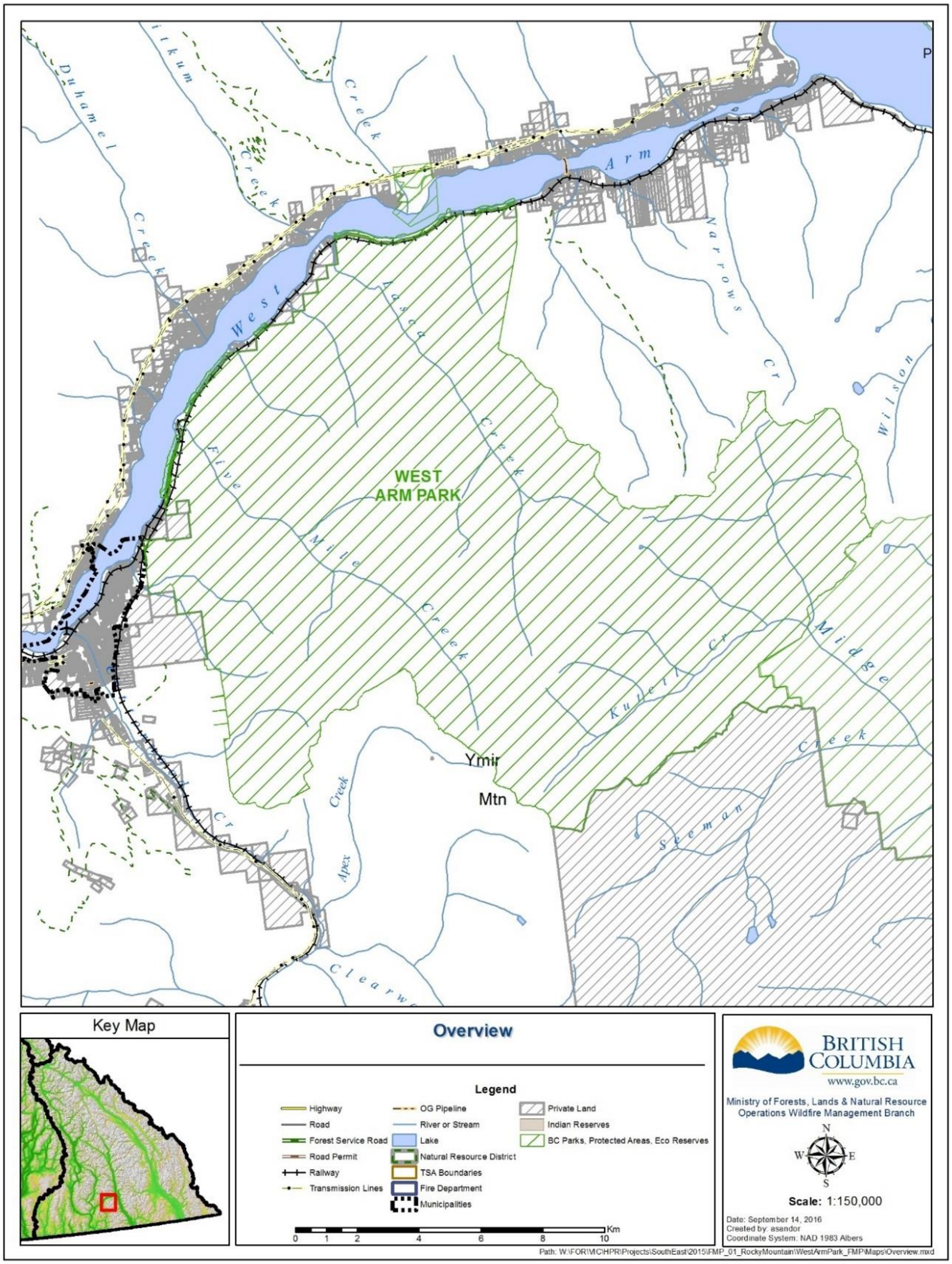

Figure 3-1. Overview of West Arm Provincial Park.

4 PLAN CONSULTATION

Given the significance of the Plan and public and stakeholder interest in the Park, there is a need for broad public and stakeholder consultation prior to the adoption of the plan by BC Parks and implementation of Plan recommendations.

Community engagement played a key role in the development of the Plan and was important in building community awareness and support. Local community members are well informed about the threats posed by wildfire, and there is widespread awareness regarding the need for hazard mitigation measures. The consultation done to date is summarized below (Table 4-1).

A draft of the Plan was posted on the West Arm Park website for further public consultation and consultation with First Nations with asserted traditional territory in West Arm Park, and BC Parks considered comments received in the final Plan.

Table 4-1. Consultations undertaken during the development of this Plan.

Group	Activity	Outcome
Interface Working Group	Quarterly meetings between City of Nelson, RDCK and BC Parks senior staff to provide project oversight	Clear progress updates, issues identified get resolved, external communication is consistent.
Harrop-Procter Community Forest	Several field tours to conduct WUI threat analyses and discuss options for collaboration	Alignment on CWPP and operational considerations
West Kootenay EcoSociety, Conservation Committee	Tuesday May 24 Meeting to review project scope and discuss areas of common interest especially the process going forward to protect biodiversity at the strategic planning, prescription and operational phases	Shared understanding of project scope and agreement to strike a technical review committee comprised of local biologists and ecologists associated with the Nelson EcoSociety
	Technical review committee meeting on Monday July 4 to review preliminary priority areas, discuss treatment options and agree to progress	Agreement to review and comment on the draft Plan
West Arm Interface Steering Team (WIST)	The WIST was established to facilitate communication between groups and agencies responsible for wildfire preparation and response and is comprised of City of Nelson, Regional District of Central Kootenay (RDCK), local fire departments, forest companies, Ministry of Forests, Lands and Natural Resource Operations (MFLNRO), BC Wildfire Service (BCWS), Ministry of Environment (MOE), BC Parks and other local organizations. Wednesday May 25 Meeting at RDCK office to review progress and seek feedback from local licensees, MFLNRO staff, City staff, RDCK staff and local conservation representatives	Shared understanding of project scope and time lines, invitation extended to attend field tours, public meetings or technical sessions when the draft Plan is ready to be reviewed

Group	Activity	Outcome
Licensee Field Tour #1	Thursday May 26 field tour with local licensee to review interface fuel reduction objectives, project timelines and opportunities for collaboration	Agreement to work together on a priority west of Nelson in Area F
First Nations	Information sharing with First Nations	Shared understanding of project scope and time lines, invitation extended to review the draft Plan
Field Tour #1	July 5 field tour to the east shore north of Creston with City of Nelson, City of Creston, BC Parks and RDCK staff and elected officials to discuss the draft Plan, review previous fuel reduction projects and discuss overall Plan implementation	Shared understanding of project scope and time lines, invitation extended to attend field tours, public meetings or technical sessions when the draft Plan is ready to be reviewed
Licensee Field Tour #2	Thursday July 7 field tour with local licensee to review interface fuel reduction objectives, project timelines and opportunities for collaboration	Agreement to work together on a priority area adjacent to the Municipal boundary, once the Plan is complete
Field Tour #2	August 9 field tour to various locations in Nelson with City of Nelson, BC Parks and RDCK staff and elected officials to discuss the draft Plan, review previous fuel reduction projects and discuss overall Plan implement	Shared understanding of project scope and time lines, invitation extended to attend field tours, public meetings or technical sessions when the draft Plan is ready to be reviewed
Public Meeting #1	August 17 open house in Nelson to provide the public, land managers, local elected officials and government staff an opportunity to review the draft Plan and provide feedback	Comments received and incorporated into the final Plan
Public Meeting #2	August 18 open house outside of Nelson (on the North Shore) to provide the public, land managers, local elected officials and government staff an opportunity to review the draft Plan and provide feedback	Comments received and incorporated into the final Plan
General Public	The draft 2017 Plan was posted on BC Parks website from February 15 to March 16, 2017 for public comment	Consideration of public comments and incorporation into the final Plan

5 PARK VALUES

The Park values included in the assessment consider the ecological value of the Park in regards to the contribution to the protected areas system and the biological and social values it provides. Values adjacent to the Park are also characterized as they influence fire management planning within the Park. The values described include:

- Ecological representation;
- Biodiversity values such as old-growth forests and forest age distribution, and rare and endangered species and communities such as whitebark pine, mountain caribou, grizzly bear, and fish species;
- Community watershed values and the City of Nelson’s water supply related infrastructure;

- Social values including archaeological sites, First Nation's interests, recreation uses, adjacent tenures and land ownership; and
- Adjacent communities and the wildland urban interface (WUI).

6 ECOLOGY

The Park is located in the Interior Cedar Hemlock (ICH) and Engelmann Spruce Subalpine Fir (ESSF) biogeoclimatic subzones (MacKillop and Ehman 2016). Within these zones are the: West Kootenay Dry Warm Interior Cedar - Hemlock Variant (ICHdw1); Ymir Moist Warm Interior Cedar - Hemlock Variant (ICHmw4;) (Table 6-1 and Figure 6-1). There are four variants of the Wet Cold Engelmann Spruce Subalpine Fir (ESSFwc): Salmo Wet Hot Engelmann Spruce – Subalpine Fir (ESSFwh3); Ymir Wet Mild Engelmann Spruce – Subalpine Fir Variant (ESSFwm3); Wet Cold Woodland Engelmann Spruce - Subalpine Fir Variant (ESSFwcw); and Wet Cold Parkland Engelmann Spruce - Subalpine Fir Variant (ESSFwcp).

The Park is within the Southern Columbia Mountains (SCM) Ecosection, of which 6.3% is in the protected areas system, and West Arm Provincial Park contains 60% of the SCM Ecosection (MOE 2007). The Park's contributions to protection of the ICHdw1 (14.93 %) is the second greatest in the protected areas system (MOE 2007).

Table 6-1. Summary of BEC subzones and variants in West Arm Provincial Park.

Biogeoclimatic Subzone and Variant	Area (ha)[1]
ESSFwh3	3,557
ESSFwm3	10,306
ESSFwcp	784
ESSFwcw	4,682
ICH dw1	2,593
ICH mw4	3,166

The ICHdw1 has hot to very hot and dry summers and mild winters with little snowfall and shallow snow packs. Compared to the rest of the moist climate region, the ICHdw1 is relatively dry and warm. The ICHmw4 is characterized by wet springs, warm, moist summers and mild to cool winters with deep snowpack. The ESSFwh3

[1] BGC mapping provided courtesy of BC Geographic Data Warehouse

has cool to warm, moist summers and cool, wet winters with heavy snowfall and the ESSFwm3 has cool and moist to wet summers and cool wet winters with heavy snowfall (MacKillop and Ehman 2016).

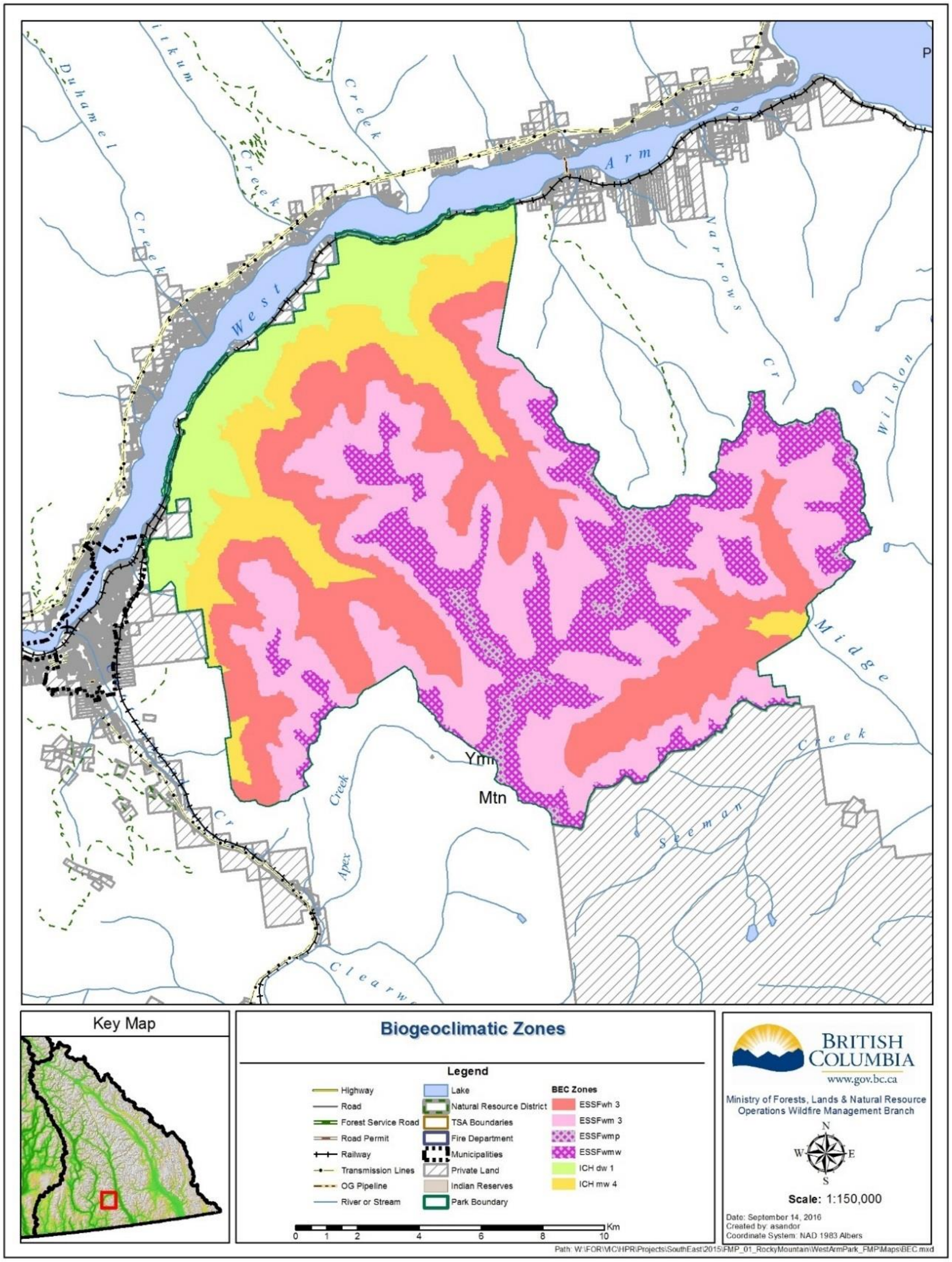

Figure 6-1. Biogeoclimatic subzones and variants in West Arm Provincial Park.

6.1 Biodiversity

The Park is an important movement corridor for wildlife in the southern Selkirks and protects old-growth forests and wildlife habitat for species at risk, including mountain caribou, and grizzly bear (MOE 2007). It is likely that other species and rare or listed plant communities exist in the Park, but inventory information in the Park is limited. A brief summary of forest age classes, species at risk, and potential ecosystems at risk in the Park is provided below.

6.1.1 FOREST AGE CLASSES

The Biodiversity Guidebook (Province of British Columbia 1995) uses forest age class proportions as an important indicator of biodiversity. Part of the rationale behind the use of age class proportions is to emulate the type of structure produced by natural disturbances. In the Park, most of the age classes older than 141 years of age are located in the ESSFwh3 and ESSFwm3 BGC units (Table 6-2 and Figure 6-2). Age class 0 to 20 is also primarily found in these variants along the southern eastern boundary of the Park, where logging occurred prior to Park creation. Much of the 80 to 120-year-old forest is located in the ICHdw1 and ICHmw4, and the origin for some of this area can be traced to the fires of 1896 and 1911. Currently, the age class structure of the Park has good representation of mature and old seral stages; however, much of the old seral stage forest is at higher elevations. There is a lack of older age class forests in the ICH subzones.

A mosaic of seral stages provides for species different seasonal habitat needs. Species needs vary seasonally and may include the use of early seral habitat during portions of the year and late seral habitat during other times. The spatial distribution of habitat types is also important. Generally, stands are defined as early seral stands if they are younger than 40 years of age (MFLNRO 2008). The early seral habitat that does exist in the Park is located primarily where the Kutetl Fire occurred (Figure 6-2. The mountain pine beetle (MPB) infestation has also altered the amount and spatial distribution of seral stages and associated habitat, but this is not reflected in the seral stage map or area summary, as Vegetation Resource Inventory (VRI; accessed September 15, 2016) data has not been updated to reflect MPB effects. However, as the lower elevation forests in the Park experienced the greatest MPB mortality, it is highly likely that these areas (and some areas affected by the Kutetl Fire) are comprised of complex stand structures that are not easily described using only stand age as a characterization criteria.

There are 3,175 ha of non-legal Old-growth Management Areas (OGMA) in the Park located along the upper reaches of Five Mile, Tunstall, Lasca, and Midge creeks. These areas are designated to protect representative amounts of old-growth forests within landscape units. While they are non-legal OGMAs, consideration on them during fuel management development is required.

Table 6-2. Summary of age classes in West Arm Provincial Park.

Age Class	0-20	21-40	41-60	61-80	81-100	101-120	121-140	141-250	>250	Total
Area (ha)	4,574.2	229.3	613.9	1,204.1	2,787.10	5,828.3	7,332.6	3,741.4	11	26,321.9
Percent	17%	1%	2%	5%	11%	22%	28%	14%	<1%	

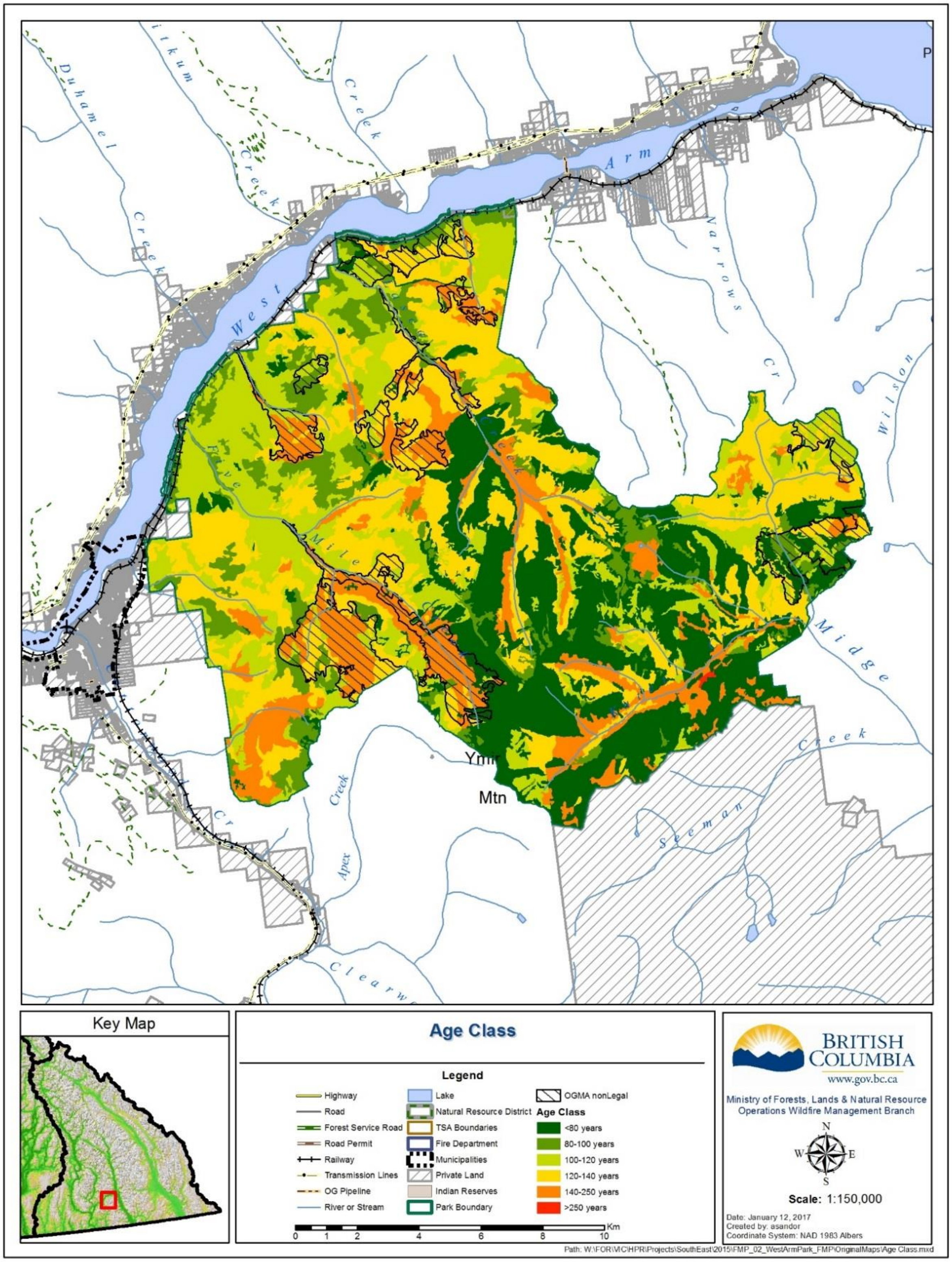

Figure 6-2. Age classes in West Arm Provincial Park based on Provincial VRI data.

6.1.2 SPECIES AND ECOSYSTEMS AT RISK

The Park management plan identifies 33 yellow- blue- and red-listed animal species that occur in the Park and surrounding areas (MOE 2007). These include bird, mammal, amphibian, fish, and reptile species; however, spatial data or habitat mapping does not exist for these species in the Park. A search was conducted in August 2016 of the Conservation Data Centre (CDC) for masked (species of interest not revealed) and non-masked mapped element (species identification provided) occurrences near or in the Park. The search located one fish species, three terrestrial vertebrates, and two plant species at risk (Table 6-3; Figure 6-3). CDC records for blue- or red-listed plant communities indicate that one red-listed community occurs in the ICHdw1/02: *Pseudotsugae menziesii* / *Mahonia aquifolium* / *Cryptogramma acrostichoides* (Douglas-fir / tall Oregon-grape / parsley fern). The Predictive Ecosystem Mapping (PEM) available for the Park was reviewed and two records of this ecosystem (0.5 ha; now the ICHdw/102 in the updated BGC nomenclature) were mapped along the western boundary of the Park but only a small portion of this occurs in the Park (JMJ 2013).

Table 6-3. Conservation Data Centre records for species at risk in or adjacent to West Arm Provincial Park.

English Name	Scientific Name	Status	Last Observed	Site	Habitat
White Sturgeon	Acipenser transmontanus	Red	2002	Kootenay river above Kootenay Lake	Riverine: Big River, low-moderate gradients, pool. Lacustrine: deep water
Western Skink	Plestiodon skiltonianus	Blue	2004	Kootenay Lake – Foster Creek, Donegal, and Grohmen Creek	Terrestrial: rock outcrop, coarse talus/boulders, grassland/herbaceous, forest needleleaf
Mountain Caribou	Rangifer tarandus	Red	2004	Selkirk Mountains	Terrestrial: Forest needleleaf
Monardella	Monardella odoratissima ssp. discolor	Red	1956	Nelson	Dry shrublands in the steppe and montane zones
Western Screech Owl	Megascops kennicottii macfarlanei	Red	1971	Nelson	Noted in urban habitat. Forests and fields
Spurless Touch-me-not	Impatiens ecalcarata	Blue	1973	Kokanee Creek Provincial Park	Terrestrial

The Park provides habitat for red-listed mountain caribou (*Rangifer tarandus)*, a globally unique population that has experienced drastic population declines over the past century (MOE 2016a). The Southern Mountain sub-population is federally listed as endangered (COSEWIC 2016). The decline of mountain caribou has been linked to a number of factors, including loss of critical winter habitat, human disturbance, and predation. The 2003 Kutetl Fire resulted in loss of winter habitat in the Park (Figure 6-2). Mountain caribou are protected to some degree from human disturbance in the Park as motorized activity is restricted. The subpopulation of mountain caribou that resides in the South Selkirk Mountains spends the winter months in higher elevation old spruce-fir forests where arboreal lichens grow (Poole and Mowat 2001). In winter, they feed primarily on arboreal lichens, particularly *Alectoria* and *Bryoria* species (MELP 1999). West Arm Provincial Park plays a critical role in protecting this subpopulation and gentle southwest facing slopes provide high use habitat (Holt and Machmer 2005).

Grizzly bears (*Ursus arctos)* are provincially blue-listed and federally listed as a species of special concern (COSEWIC 2012). While not identified in the CDC records, important grizzly bear habitat exists in the Park. Avalanche slide tracks that support herb dominated vegetation communities are important habitat for the bears. Old forest, riparian areas, and ecosystems that support berry crops are also important. Subalpine ecosystems that support Whitebark pine (WBP; *Pinus albicaulis*) may also provide valuable forage opportunities depending on the tree density and distribution. Of the 56 extant grizzly bear populations in BC, nine are classified as threatened. The bears in the Park are part of the South Selkirk population unit (MOE 2016b). The entire population estimate of this unit is only 58 and is threatened (MOE 2016b) as a result of the physical isolation of this population unit.

Whitebark pine (*Pinus albicaulis*) is blue-listed by the Province and is listed under Schedule 1 of SARA as endangered and a recovery strategy is currently being developed. The four most significant threats facing WBP provincially, and in the Park, include white pine blister rust, climate change, wildfire and fire suppression related stand changes, and MPB (Sadler 2014). WBP is a slow growing, long-lived species that is generally found on harsh, rocky, cold, and exposed sites. It is an important food source for grizzly bears, Clark's Nutcracker, and small mammals. It also has positive hydrological effects and creates favourable microhabitats for other vegetative growth in harsh high elevation habitats. This species grows in isolated pockets within the Park.

Fisheries values are present in and adjacent to the Park and include 27 species of fish in Kootenay Lake and fish species including blue-listed cutthroat trout (*Oncorhynchus clarkii lewisi*) and bull trout (*Salvelinus confluentus* - interior lineage) in larger creeks such as Lasca and Five Mile creeks (MOE 2007). There is no data for the small, high elevation lakes in the Park, but they are unlikely to support fish habitat due to the generally shallow depths (MOE 2007).

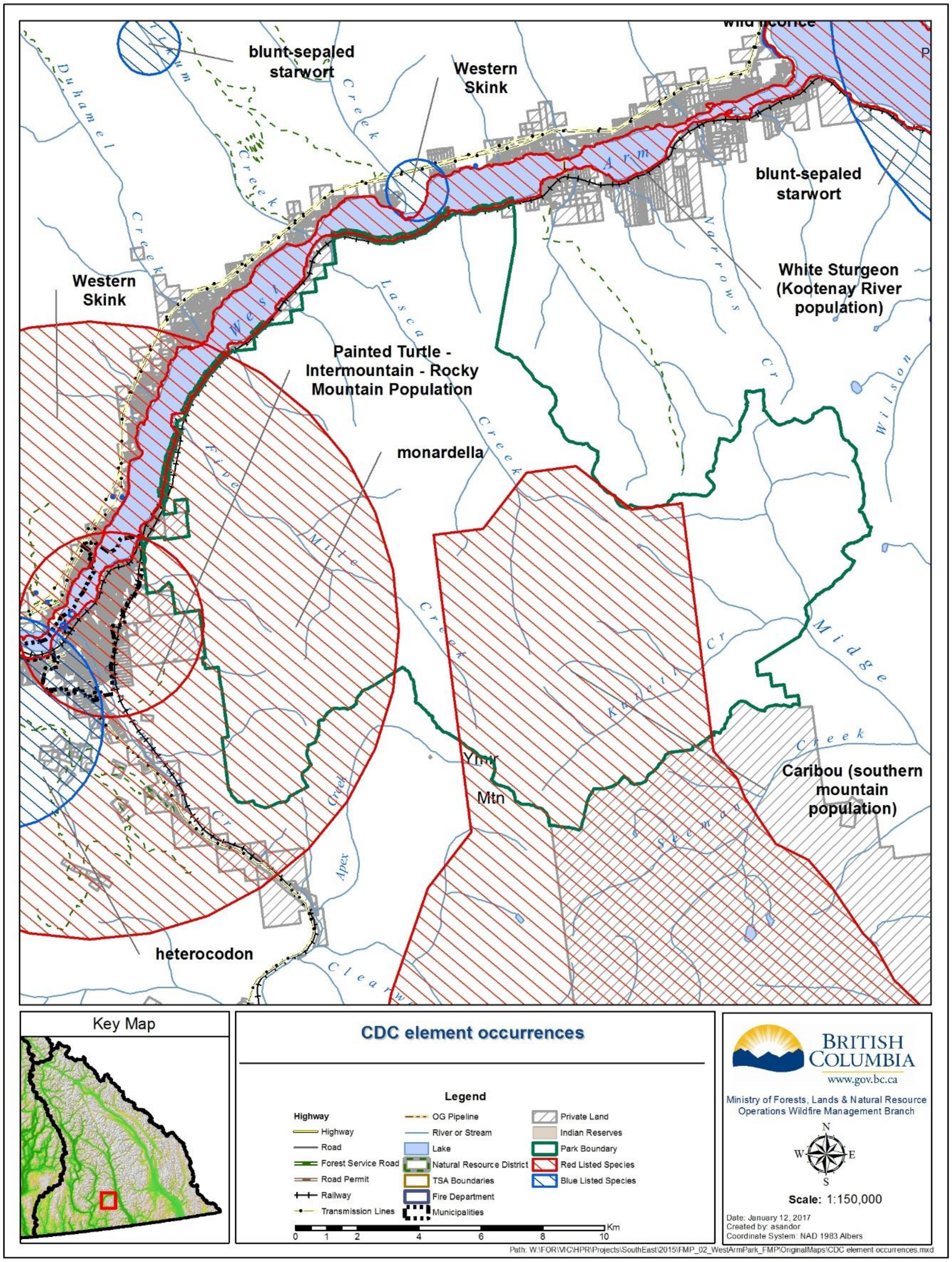

Figure 6-3. Conservation Data Centre records for species at risk in or adjacent to West Arm Provincial Park.

6.2 Watershed Values

The community watersheds within the Park are important infrastructure for the City of Nelson (Nelson; Figure 6-4). Most of Nelson's watersheds (80%) lie within the Park and include infrastructure such as roads, pipelines, a small dam, spillway, and an intake house. There are also domestic water licenses in the Park that provide water to local residents (MELP 2000). The community watershed infrastructure and domestic water licenses are authorized under Park Use Permits.

The watersheds include Five Mile Creek, Anderson Creek, Fell Creek, and Selous Creek. Five Mile Creek produces high quality water due to the protected catchment area. It was built in 1925 and has a catchment of 47.5 km^2. The water is collected by a small intake structure and conveyed to Mountain Station reservoir through a 6.7 km pipeline. The Diversion License is 16.8 million litres per day (M/d). Anderson and Fell Creek are supplementary water sources with a combined catchment area of 13.5 km^2. Fell Creek has a small intake that routes water to the Anderson Creek intake. The Anderson Creek intake was built in 1899 and has a combined diversion license of 13.6 M/d. This system produces good quality water but is prone to turbidity issues during spring freshet. Selous Creek is a supplementary source for the City. It was built in the 1970s and has a catchment of 14.5 km^2 and a Diversion License of 4.5 M/d.

These watersheds are important in maintaining hydrological functions that determine water quality, quantity and timing of flows, critical to public health and the sustainability of the City of Nelson. Forty-four percent of the watershed area that intersects the Park is located on slopes greater than 41%, making the watersheds vulnerable to surface erosion, especially post wildfire.

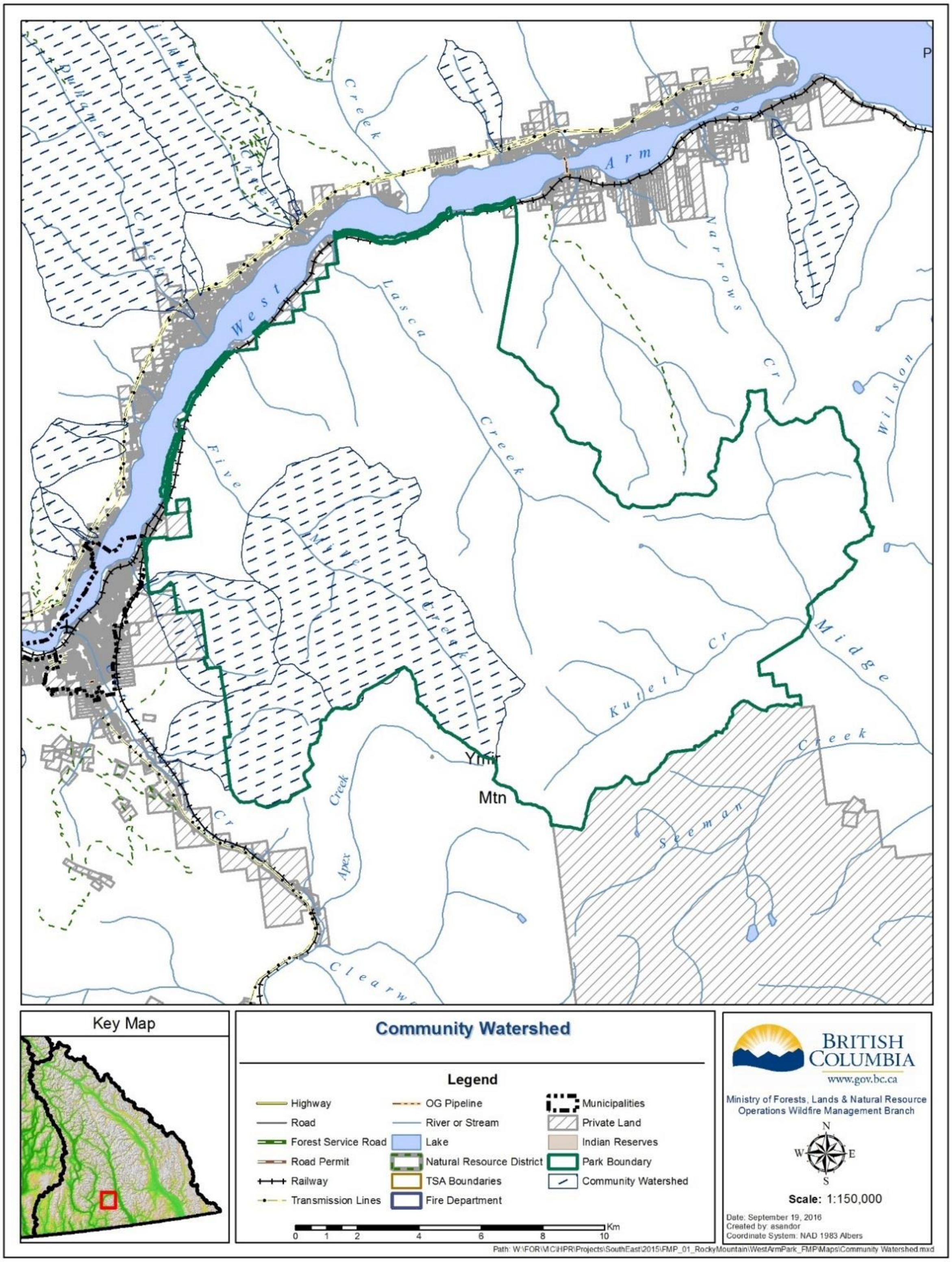

Figure 6-4. Nelson and Harrop-Procter community watersheds in and adjacent to West Arm Provincial Park.

6.3 Social Values

6.3.1 ARCHAEOLOGICAL SITES

An archaeological survey conducted in 1992 identified high archaeological values within the Park along the Park shoreline. Most known archaeological sites are located along the foreshore of Kootenay Lake, but only the area within 750 m the Lake has been surveyed (MOE 2007). There are archaeological sites related to European settlement that are also located primarily along the foreshore.

6.3.2 RECREATION VALUES

The Park is primarily undeveloped and considering its close proximity to developed areas, access into the Park is fairly limited. Boat access exists from Kootenay Lake along the northern boundary of the Park. Recreation activities along the lakeshore include swimming, boating, and fishing. All camping and day use is undeveloped and no facilities are provided. Though improvised rock fire rings exist, these are discouraged in the Park.

Road access to the Park includes Svoboda Road, which is parallel to Five Mile Creek, and the road from Harrop to Goddard Hill. Svoboda Road provides access to user-built mountain biking trails that are part of a greater trail-system in and around Nelson. There are approximately 17 mountain bike trails in the Park. These trails are located near Hermitage, Fell, and Anderson creeks. Mountain bikers are thought to be the most prominent users of the Park and have an organized club (Nelson Cycling Club). There is also a forest service road which goes up to the confluence of Midge and Kutetl Creeks, where backcountry backpacking opportunities exist. Backcountry opportunities extend along the ridge tops that that run east to west in the Park.

There is trail access to the Park along the 13 km Lasca Creek trail and along the water pipeline that extends to Nelson. Hiking and backcountry skiing is also accessible from Whitewater Ski Resort located on Ymir Peak, through Hummingbird Pass. In 2007, use of the Park for backcountry skiing was estimated between 50 to 100 users per week from December to April (MOE 2007). Skiers in the Park are thought to primarily use the bowls at the headwaters of Kutetl, Lasca, and Five Mile creeks.

There is walk-in access to rock climbing along the Burlington Northern Rail right-of-way to the “Kootenay Crag” between Fell and Five Mile Creeks. There are 25 to 30 bolted routes at these sites, which is one of the only places near Nelson for rock climbing. There is also climbing near the Park on Ymir Peak.

All of the above access routes can be used for wildlife viewing. In keeping with Section 29 of the Park, Conservancy and Recreation Area Regulation of the *Park Act*, the Park is open to hunting September 1 to June 20 during the appropriate game hunting season (MOE 2016c).

Recreational activity is more frequent along the lower slopes of the Park near Nelson. High recreational use has also been recorded around Whitewater Ski Resort in the bowl of Five Mile Creek and along Kootenay Lake foreshore. The Recreation Opportunity Spectrum (ROS) is a classification used by MFLNRO to characterize probable experience opportunities based on the qualities of a place as they relate to recreational use. The ROS of the Park is mostly classified as being “Primitive” or “Semi-Primitive Non-Motorized”.

6.4 First Nations Interests

The Park is included in the asserted traditional territory of multiple First Nations[2]. The Park is in the asserted traditional territory of the Ktunaxa Nation, which covers the Kootenay region extending into the United States. The Ktunaxa Nation Council represents the interests of the four Indian Band members: St Mary’s Band, Tobacco Plains Band, Akisqunuk First Nation (Columbia Lake Band), and Lower Kootenay Band. The Park is also within the asserted traditional territory of the Secwepemc (Secwepemc Reconciliation Framework Agreement), and the Okanagan Nation Alliance (including the Okanagan Indian Band, Shuswap Indian Band, Lower Similkameen Indian Band, Upper Nicola Indian Band, and Penticton Indian Band). The Park management plan (MOE 2007) identifies the need for management of the Park to consider First Nations’ interests including protecting important features and archaeological sites; completing an inventory and assessment of all archaeological features; and managing heritage resources within the Park.

6.5 Adjacent Land Ownership and Tenure Values

There are four forest licensees that share boundaries with the Park, including Kalesnikof Lumber Co Ltd., Atco Lumber Ltd., JH Huscroft Ltd., and the Harrop-Procter Community Forest License. There are also BC Timber Sales (BCTS) tenures across Kootenay Lake from the Park. There is private land along the northern and western boundaries of the Park near Nelson, and along the lakeshore, and the southern half of the Park and the adjacent area is classified as Provincial Crown Land. No ownership data is available for the northern and eastern portions of the Park. The Nature Conservancy of Canada holds private land adjacent to the Park.

The Midge Creek Wildlife Management Area extends from the southeastern Park boundary to Kootenay Lake, and the Harrop-Procter Community Forest extends from the northeastern boundary to the Lake. The Canadian Pacific Railway follows the northern boundary of the Park. Additionally, there are five traplines that overlap the Park; however only one trapline owner has a valid Park Use Permit (TR0407T010, TR0407T009, TR0407T006, TR3407T008, and TR0407T007). There is one non-acquisitioned mineral reserve that overlaps with the Park near Nelson, and three mineral tenures which overlap the Park.

Adjacent and nearby communities include the City of Nelson to the southwest and the small rural community of Harrop-Procter to the northeast along the West Arm of Kootenay Lake. Nelson serves as a regional hub to many surrounding communities and had a population of approximately 10,230 in 2011 (Statistics Canada, 2016). Private lands are located along the Park Boundary, particularly along the south-western edge of the Park. Most of the wildland urban interface is located in Harrop-Procter and Nelson. Isolated and mixed interface classes occur along

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[2] http://maps.gov.bc.ca/ess/sv/cadb/

the lakeshore and at Whitewater Ski Resort and are within the Regional District of Central Kootenay, Electoral Area E. The concept of the WUI is described in more detail in the next section.

6.6 Wildland Urban Interface

To characterize WUI values, density classes are used based on the number of structures found in a specified area (1 km^2). The interface zone density classes found adjacent to the Park range from none to urban; however, the majority of the Park area is classed as none. Most of the interface is located in Harrop-Procter and Nelson, although isolated and mixed interface classes exist along the lakeshore and at Whitewater Ski Resort (Figure 6-5.

Table 6-4. Descriptions of interface density classes.

Class	Density (structures/km^2)
Urban	250+
Developed	100 to 249.9
Mixed	25 to 99.9
Isolated	6 to 24.9
Undeveloped	.01 to 5.9
None	0

The WUI is defined as the place where the forest meets the community. There are two classes of WUI: interface and intermix (Figure 6-6). Interface occurs where urbanized or areas that are largely developed abut lands with natural fuel types, typically forests. Intermixed areas include smaller, more isolated developments that are embedded within the forest. In each of these cases, fire has the ability to spread from the forest into the community or from the community out into the forest. Although the scenarios of a fire spreading to or from a community are quite different, they are of equal importance when considering interface fire risk. Much of the interface adjacent to the Park could be classified as wildland urban interface and intermixed. Within the study area, the probability of a fire moving out of the adjacent communities and into the forest is equal or greater to the probability of fire moving from the forest into the communities due to the higher ignition probability.

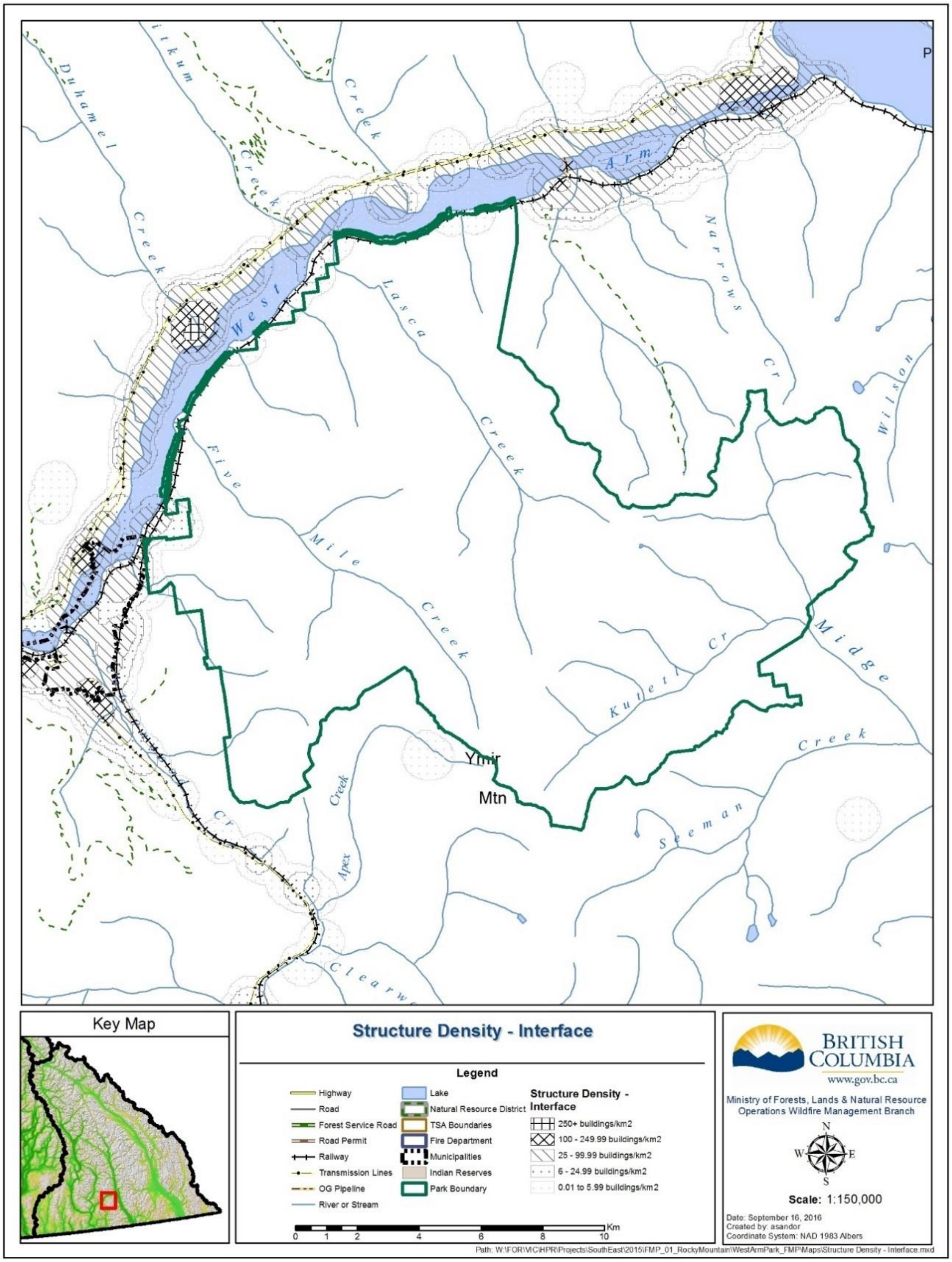

Figure 6-5. Wildland urban interface adjacent to West Arm Provincial Park.

Figure 6-6. Types of Wildland Urban Interface Zones.

7 HISTORIC FIRE REGIMES AND STAND STRUCTURE

Understanding of the historic fire regimes in West Arm Park is an important foundation of fire management and suppression planning in the Park. Historic fire regimes may be inferred based on three recognized methods discussed below: natural disturbance types, predictive modeling of Historic Natural Fire regimes, and empirical fire history studies. Recent fire history, between 1950 and 2015, is described separately in Section 9.3.

7.1 Historic Natural Fire Regimes[3]

A number of lines of evidence are available that can be used to gain a more accurate picture of the fire ecology history of the Park, including: age structure data, point-source fire chronologies, historic photographs, empirical data from adjacent sites, and predictive models. A predictive model of Historic Natural Fire Regimes (HNFR) was developed for the southern third of the province, including the Park (Blackwell et al. 2003; Figure 7-1.). This model incorporated up-to-date empirical historic fire regime data from BC, AB, and the adjacent states in the United States of America. It also included terrain factors affecting fire behaviour and professional judgment. Another significant difference of the model is the recognition and delineation of mixed-severity fire regimes. The model resulted in 10 potential fire regimes compared to four NDT classes. For the Park the primary difference is the classification of the landscape into six fire regimes instead of two natural disturbance types (Figure 7-1).

[3] Adapted from original text by Robert W. Gray – R.W. Gray Consulting

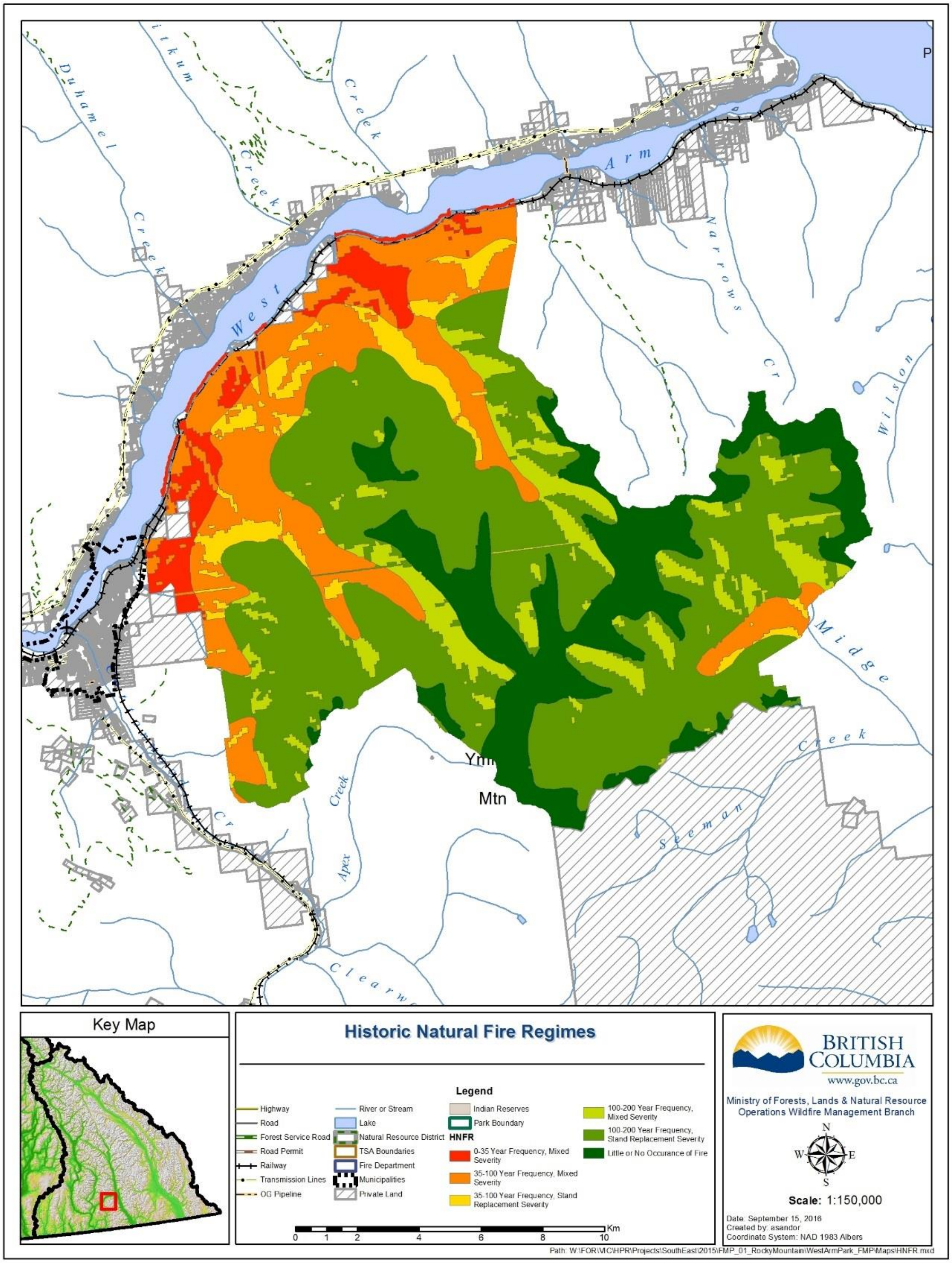

Figure 7-1. Historic natural fire regimes in West Arm Provincial Park.

Using the HNFR model, the lower slopes of the Park are characterized by frequent mixed-severity fire. These areas are comprised of Douglas-fir (*Pseudotsuga menziesii*), ponderosa pine (*Pinus ponderosa*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), western white pine (*Pinus monticola*), western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), and grand fir (*Abies grandis*). A number of deciduous species can also be found here. This area is characterized as high frequency due to the regional climate being conducive to fire start and spread. The mixed-severity characterization comes from the greater fire intensity associated with higher between-fire fuel loads on productive sites in the West Kootenays, and the high number of fire-intolerant species.

Fire frequency decreases with elevation, leading to greater between-fire fuel accumulations and greater fire severity. Fire intensity is also affected by increasing slope angle and slope uniformity. With increasing elevation comes decreasing fire tolerance, and higher general fire vulnerability due to slower growth rates (shorter trees with small diameters). The complex terrain of the Park aids in fire regime heterogeneity. Under this model the maximum fire-free interval would be in the 150 to 200-year range, not the 500-year figure as suggested by the Biodiversity Guidebook (BC Ministry of Forests and BC Environment 1995) and Holt and Machmer (2005). The higher frequency is the result of a number of factors including: the proximity of the Park to higher frequency fire regimes, the lack of significant barriers to fire spread both within and outside the Park, the latitude of the Park, and the lack of terrain features that would ameliorate local fuel characteristics.

This picture of historic fire regimes and forest structure in the Park is still a predictive model, not unlike the model of NDT's proposed in the Biodiversity Guidebook. It does, however, include the interpretation of empirical studies from adjacent areas. An example of this is the small fire history analysis conducted by Quesnel and Pinnell (2000) for the West Arm Demonstration Forest immediately across the lake from the Park. The authors found a very frequent fire regime that maintained open forests comprising ponderosa pine and Douglas-fir. However, because fire has been absent on this site for the past 100 to 120 years, forest density has increased with much of the density comprised of fire-intolerant grand fir, lodgepole pine, and western redcedar. While the study describes conditions on a warm aspect, these conditions should also apply to the cool aspect across the lake in the Park due to proximity. This would suggest that the NDT designation proposed by Holt and Machmer (2005) is too conservative regarding fire frequency. The study results obtained by Quesnel and Pinnell (2000) were used in the development of the HNFR predictive model.

7.2 Empirical Fire History Study[4]

Gaining an understanding of historic fire regimes and forest structure is best accomplished using empirical data derived through disturbance chronologies. Disturbance chronologies document historical disturbance frequency and severity via fire scar interpretation and cross dating (Dietrich and Swetnam 1984, Agee 1993). However, as a stand-alone analytical tool, they often yield only crude inferences about associated vegetation community structure (Hessburg et al. 1999). Historic stand reconstructions, through tree ring and cohort analysis and stem mapping

[4] Adapted from original text by Robert W. Gray – R.W. Gray Consulting

(Habeck 1990, Covington and Moore 1994, Arno et al. 1995), provide spatially and temporally precise information about composition and structure (Hessburg et al. 1999) at one point in time.

In order to gain a better understanding of the historic fire regimes in the Park, empirical data was derived through disturbance chronologies in the fall of 2007. Both fire scar analysis and tree ring and cohort analysis were applied to the Park. However, fires that occurred near the turn-of-the-century as well as the preceding timber harvest, made the collection of disturbance and forest structure evidence difficult. Although several wildfires burned through the Park in the late 1890's and early 1900's, exact dates had not been established. Early photographs and oral histories point to a probable fire in 1896 and a number of subsequent fires in 1911 (www.city.nelson.bc.ca/html/founding.html). From a landscape perspective, the result was heavily denuded hill slopes (Figure 7-2).

Field data collected in 2007, included: a number of increment cores, fire scar samples, and cross-sections. Core samples were collected in the area that was later treated in 2008 to create a fuel break; this area is located along Svoboda Road in the northwest corner of the Park. The samples were used to develop a number of lines of evidence in order to piece together historic disturbance and forest structure.

Some of the findings from this study included the following observations:

- Samples collected on the steep northeast aspect overlooking Five Mile Creek had fires scars that were dated at 1894 and 1917;
- Estimated germination dates of a significant portion of samples collected in the Five Mile creek area correlated with the 1894 fire;
- No estimated germination dates collected in the Five Mile creek area correlated with the 1917 fire, indicating that this was a smaller fire that did not reach the Five Mile creek area;
- Samples collected in the Five Mile Creek area indicate a fire "period" between 1775 and 1805 where germination of western larch and Douglas-fir occurred after each fire event; and
- Cedar and larch samples collected near the end of Svoboda Road indicated three fire "periods": 1620-1655, 1775-1805, and 1835-1860.

Fire "periods" indicated by the results, are date ranges where a number of lines of evidence converge to suggest that a wildfire occurred within the "period".

Although the collected data does not provide a conclusive picture of the historic fire regime, the data provides some clues to better characterize fire history. For example, the two fires dated 1894 and 1917 were likely human-caused and likely burned through an abnormal fuel complex of timber harvest slash. It is thought that the 1894 fire resulted in much of the young cohort seen in the forests immediately adjacent to Nelson today, including the large proportion of lodgepole pine being attacked by the MPB. The three fire "periods" suggest that historically, fires were not uncommon in this area of the Park, occurring on average every 60 to 150 years. Some were high-severity, creating good germination and growth conditions for Douglas-fir, western larch, and western redcedar, and some were low-severity, scarring but not killing western redcedar (Figure 7-3). With this relatively frequent, mixed-severity fire regime, fire-tolerant species would be favoured over intolerant species. Fire tolerant species would also be favoured over species that require longer periods of time to reach reproductive age or species that require germination conditions resulting from longer disturbance intervals.

Details on the methodology and more specific results of this study can be found in the West Arm Provincial Park Interface Fuel Management Plan (Blackwell et al. 2008).

Figure 7-2. Photograph of the City of Nelson in 1898. The mountainsides surrounding Nelson have all been heavily impacted by logging and wildfire.

Figure 7-3. Partially consumed western redcedar snag in West Arm Provincial Park.

8 CLIMATE CHANGE CONSIDERATIONS

8.1 Climate Change

Climate change is an important consideration for Park management. The International Panel on Climate Change (IPCC) has established that climate change is occurring and research in BC confirms climatic shifts are occurring here (Spittlehouse 2008). In BC, the changes in temperature and precipitation regimes are predicted to be greater than the global average increase (Spittlehouse 2006), and changes in temperature across BC will result in increased mean annual temperature of 3 to 5°C. Precipitation changes are predicted to result in drier summers in southern BC and reduced snow packs, as winter precipitation will have reduced snowfall and more rain (Spittlehouse 2006).

Climate (temperature, precipitation, and topography) combines with other variables to influence the vegetation that can grow in a given place. It also influences the timing, severity, and extent of fires (the natural fire regime; Wells 2007). As climate changes, species growth, regeneration, and dominance will shift. For example, in much of the Pacific Northwest, lodgepole pine shares dominance with Douglas-fir at low/mid elevations and with subalpine fir at higher elevations. At low elevations, warmer, drier summers may translate into more favourable growing conditions for lodgepole pine than Douglas-fir (Hermann and Lavender 1990; Case and Peterson 2005), and at higher elevations increased temperatures and reduced snowpack may favour Douglas-fir growth and regeneration.

Recent studies in the West Kootenays used downscaled global climate models (GCMs) to project climate change. The model projections indicate the potential changes in annual temperatures, precipitation, snowpack levels, and increases in annual and interannual climate variability (Utzig et al, 2012; Holt et al. 2012).

The models projected climate for three periods 2020's, 2050's, and 2080's. Projections for all three periods indicate an increase in seasonal temperatures. By the 2080's, projections indicate summers will be 2 to 7°C warmer with similar with a 0 to 30% decrease in precipitation and winters, springs and falls will be warmer 1 to 5°C and 10 to 25% wetter (Utzig 2012). It should be noted that the models slightly under-estimate seasonal temperatures, except summer, and while precipitation is reasonably projected, winter precipitation was poorly estimated by all GCM models (Utzig 2012).

These potential changes could have dramatic effects on ecosystems, including altering plant community composition and health, natural disturbance agent types and frequencies, and ecosystem distribution on the landscape. To provide insight on potential changes, Bioclimatic Envelope Modeling was completed for the West Kootenays. The modelling used three climate type scenarios and projected changes in the distribution of ecosystem types (Holt et al. 2012). The study identified three regional landscapes based on homogenous climatic elements. The Park is in the South Regional Landscape Unit (South subregion). Holt et al. (2012) describe the potential changes:

> *At the lowest elevations in the South subregion, all of the scenarios project shifts from interior cedar hemlock (ICH) bioclimate envelopes to grassland-steppe envelopes. At the upper elevations, the results are more variable, with one scenario projecting an upward shift of existing ICH climate envelopes, another tending to more coastal transition ICH/CWH (coastal western hemlock), and the third showing a shift to*

semi-arid Ponderosa pine savanna envelopes, with very limited moist and coastal transition ICH/CWH envelopes at the highest elevations. All of the scenarios project very large decreases in Engelmann Spruce-Subalpine Fir (ESSF) and parkland/woodland bioclimate envelopes – approaching complete elimination in most cases.

As bioclimatic envelopes shift, tree species will also change in these locations depending on each species silvics. In general, trees able to tolerate drought and fire will have expanded ranges and species intolerant of drier conditions and more frequent fire regimes will have reduced ranges (Holt et al. 2012). The projections and use of ecosystems descriptions to describe the bioclimatic envelopes were employed to help convey potential changes; however, the resultant ecosystems should be assumed to be analogs not identical to currently existing ecosystems (Holt et al. 2012).

8.2 Future Fire Regimes

Climate warming is expected to increase the frequency of fires (decrease the fire return interval or fire interval) (Running 2006; Swetnam and Westerling 2007; Westerling et al. 2006).

Of particular concern to fire scientists is the potential confluence of warming temperatures, high fuel loads, and impending drought in some areas. Some of these scientists predict that the area burned in wildfires will double or even triple over the next 50 years (Bartuska 2007; Wells 2007). Recent research on climate changes in the West Kootenays supports the concept of increasing fire extent in the region. Projected increases in area burned in the South region (West Arm Provincial Park) indicate an increase of 15 times the average annual percentage of area burned by the 2050's could occur (Figure 8-1; Utzig et al. 2011). Increases in the annual area burned were positively correlated with high mean maximum temperatures in July or August and water deficits (Utzig et al. 2011). A shift is also projected from NDT types 3 and 4 as the most prevalent disturbance regimes in the low elevation regions to NDT 4, which could result in a grassland / savanna type bioclimate envelope (Utzig et al. 2011; Holt et al. 2012).

High fuel loads are problematic in the Park where recent disturbances have resulted in large-scale tree mortality. The 2003 Kutetl Fire was not salvage logged, meaning all dead trees will eventually fall creating high fuel loads into the future. The 2016 helicopter reconnaissance of this area showed relatively low to moderate surface fuel loadings, with variable snag retention throughout the burned areas (Figure 8-2). The fuel loading caused by the MPB epidemic is also resulting in unnaturally high fuel loads and an increase in potential fire severity and intensity. A re-burn of the Kutetl Fire area or an initial burn through the beetle affected areas could result in significant damage to soil productivity and local hydrologic functions.

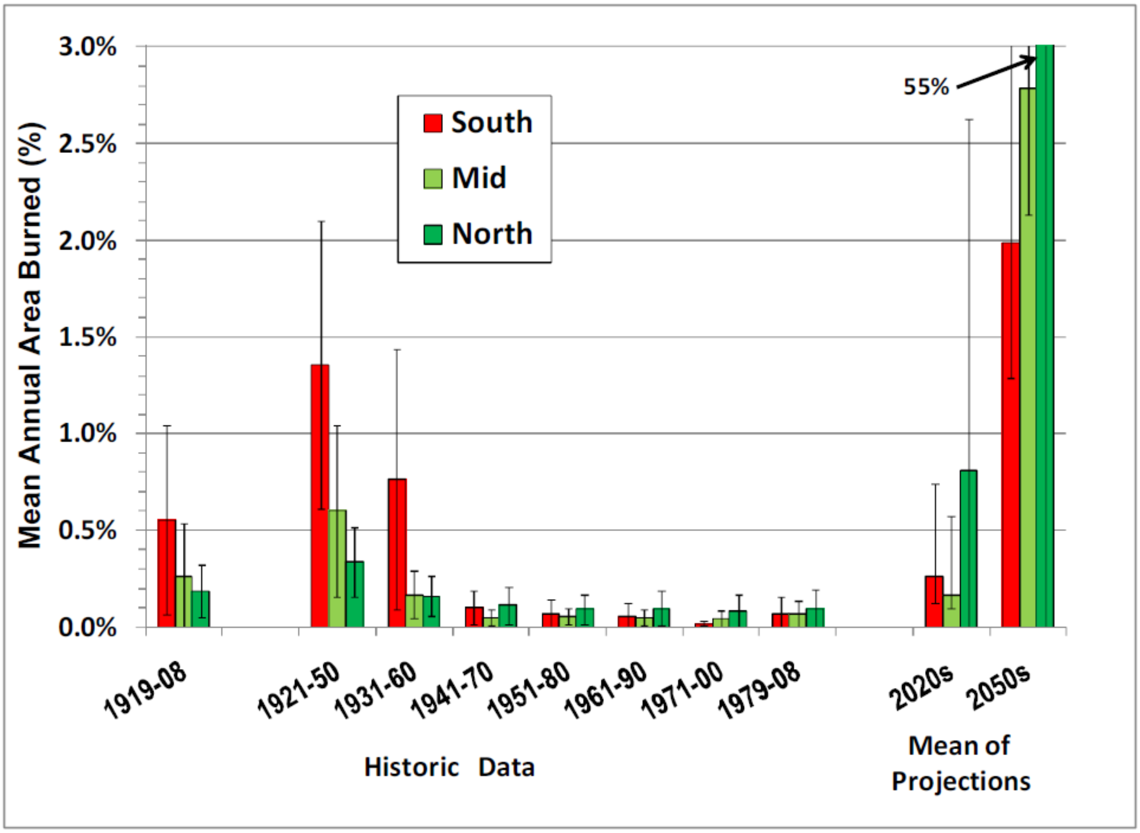

Figure 8-1. Mean area burned projection as a percentage of total area in comparison to area burned in historic 30-year periods (2020's = 2011-2040 and 2050's = 2041-2070; Utzig et al. 2012).

Figure 8-2. Surface and crown fuel loading in 2016 from the 2003 Kutetl Fire.

8.3 Tree Species Distribution

One scenario linked to a warming climate in the West Kootenays involves the distribution and productivity of lodgepole pine, and the consequences for other native species. The effect of a warmer climate on disturbances may have a greater effect on lodgepole pine distribution and productivity than direct climatic impacts on tree growth. Warmer, drier summers will increase the likelihood of fires (McKenzie et al. 2004), which could lead to changes in the distribution and abundance of plant species. While lodgepole pine is relatively intolerant to intense fires, regeneration immediately following fire is typically dominated by lodgepole pine, because it can disperse large quantities of seeds from nearby trees and has serotinous cones that open due to heating from fire (Lotan and Perry 1983). Warmer, drier summers may also lead to increased outbreaks of insects such as the MPB (Logan and Powell 2001). Because it is likely that the current trend of warming temperatures will continue into the future (IPCC 2001), many forested ecosystems, especially drier systems, may experience reduced soil moisture, increased water stress and altered disturbance regimes. Extended summer drought over decades could significantly affect which tree species are the most productive and abundant (Case and Peterson 2007).

Potential future forest succession dynamics in the West Kootenays under a warming climate/increased disturbance scenario is graphically represented in Figure 8-3. Vital attributes theory postulates that a small number of life history attributes termed “vital attributes”, can help us predict the behaviour of plants in disturbed environments (Roberts 1999). Vital attributes pertain to the potentially dominant species in a particular community. Three main groups of vital attributes are recognized relating to the methods of persistence of species during a disturbance, and to their subsequent arrival, to their ability to establish and grow to maturity following the disturbance, and to the time taken for them to reach critical stages in their life history (Noble and Slatyer 1980). In Figure 8-3, most dominant tree species would be able to persist on site with a historically median fire interval of 100 years. Some would be able to survive a disturbance, take advantage of less competitive germination and growing conditions, and start to produce large quantities of viable seed at a young age. This would certainly be the case for Douglas-fir, lodgepole pine, trembling aspen (*Populus tremuloides*), western larch, and paper birch (*Betula papyrifera)*. Other species would be more disadvantaged by being killed by the disturbance, and having to seed in from outside the burn area. Species such as western hemlock, western redcedar, Engelmann spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and grand fir, would also grow slower and take longer to produce large quantities of viable seed. Even with these disadvantages a historic fire interval of 100 years would still enable them to persist on the site.

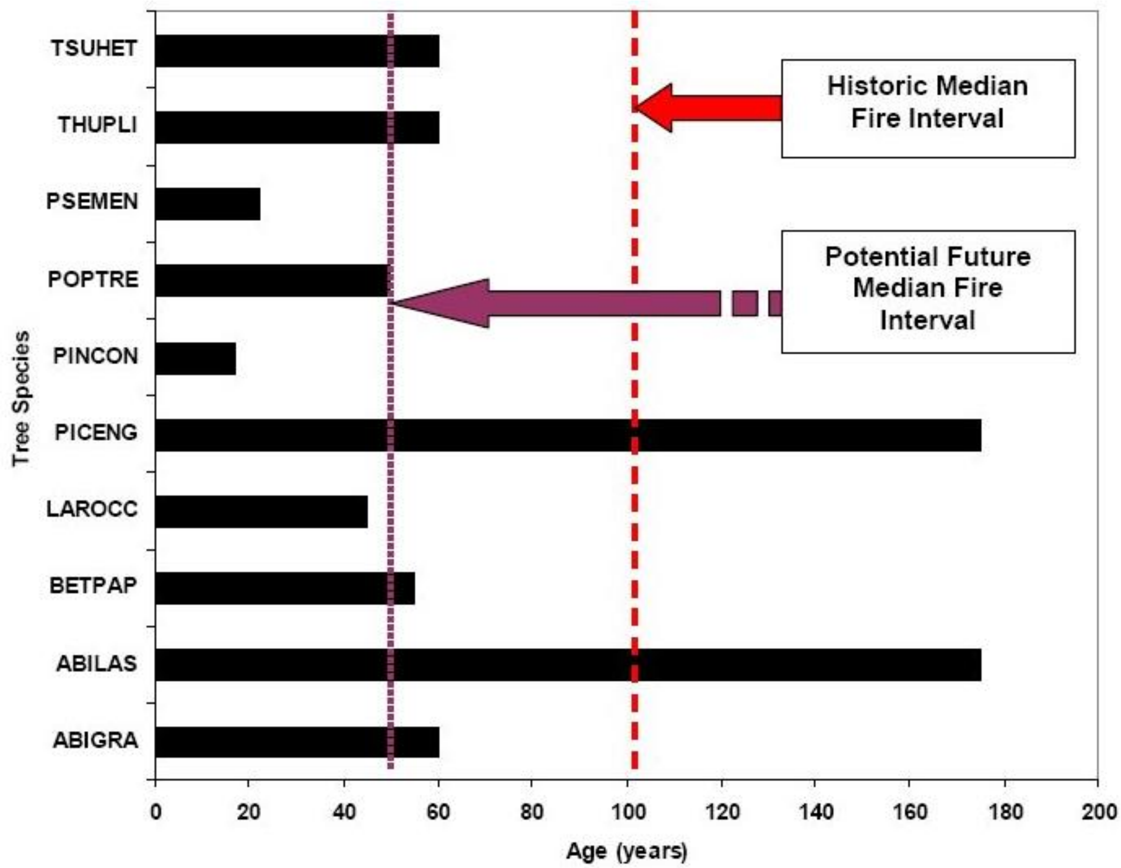

Figure 8-3. Critical life stage ages for a number of West Kootenay tree species are graphed relative to the historic fire interval and a potential future fire interval under a warming climate.

Under a warming climate scenario, and a significant decrease in the fire interval, a large number of tree species would potentially be displaced by species more adapted to a higher frequency of disturbance. The vital attributes of Douglas-fir, western larch, trembling aspen, paper birch, and lodgepole pine would leave these species more adapted to an increased disturbance frequency scenario. Lodgepole pine, with its habit of producing large quantities of viable seed at a very young age, and sealed in serotinous cones, could dramatically increase its distribution and stand proportion under this scenario.

8.4 Insects and Pathogens

Climate change, and in particular warmer winters and summers, has the potential to increase populations of forest health agents that cause tree mortality – in particular, insects. Summer droughts, especially over successive years, have the potential to increase stresses on trees and susceptibility to forest health agents.

Bark beetles are responsive to weather and climatic conditions as seen in the MBP outbreak in BC. The continued spread of MPB is expected in northern areas of Canada (Carroll et al. 2006) due to warming climate in these regions. Other beetle species, including Douglas-fir beetle (*Dendroctonus pseudotsugae*); spruce beetle (*Dendroctonus* *rufipennis*); spruce weevil (*Pissodes strobe*); western spruce budworm (*Choristoneura occidentalis*); and western hemlock looper (*Lambdina fiscellaria lugubrosa*) are increasing in prevalence and distribution due to climate change (Woods et al. 2010). The combination of drought, increased downed trees because of extreme weather events, improved overwinter survival for insects, and summer conditions that allow shorter life cycles are creating better conditions for the increase in insect populations.

Pathogens may also be positively affected by climate change; however, climate models are less accurate in predicting precipitation than temperature changes. Stem rusts such as whitepine blister rust (WPBR; *Cromartie ribicola*) and western gall rust (*Endocronartium harknessii*) have increased over the past decade. However, conditions that facilitate spread are cool moist mid- to late-summer (Woods et al. 2010), so the predicted warming trend reported by Holt et al. (2012) might indicate a decrease in rust species requiring these conditions. Dothistroma needle blight *(Dothistroma septosporum)* is another pathogen that requires increased summer precipitation, and in regions where summer precipitation increases, these conditions could favour Dothistroma needle blight. Increased effects of root diseases such as Armillaria (*Armillaria spp)* and Phellinus (*Phellinus sulphurascens)* are more relevant to the Park due to their common occurrence. Drying climate and the associated drought stress in trees has been shown to increase the prevalence of root diseases (Klopfenstein et al. 2009).

9 FIRE ENVIRONMENT

The fire environment is described in the following section and includes fire weather, fire causes and frequency, fuel types, and forest health factors which are currently influencing fuel types in and adjacent to the Park.

9.1 Natural Disturbance Types

To date there have been no comprehensive empirically-based fire regime and forest structure studies conducted in or adjacent to the Park. The current understanding of historic fire regimes has come from an interpretation of disturbance dynamics as they relate to the biogeoclimatic classification system. The Biodiversity Guidebook (Province of British Columbia 1995) describes disturbance agents and their effects on ecosystem structure by biogeoclimatic subzone and variant and uses a numerical classification system of Natural Disturbance Types (NDT). The predominant disturbance agent in the classification system is fire, although other critical disturbance agents are factored into the system. Ecosystems with historically frequent fire regimes are classified as NDT4, while ecosystems with increasingly long fire intervals are classified as either NDT3 or NDT2. Using this classification system, Holt and Machmer (2005) suggest that the Park's ecosystems be classified as either NDT3 or NDT2. The ICHmw4, ESSFwh3, and ESSFwm3 variants are all classified as NDT2 – very infrequent, stand-replacing disturbance events (Figure 6-1).

The mid-elevation ICHmw4, ESSFwh3, ESSFwm3 BGC units are classified as NDT2, but are considered to vary in historic frequency by site (BC Ministry of Forests and BC Environment 1995). Warm aspects and dry sites are thought to be characterized by a fire frequency of 100 years, while adjacent cool aspects and cool sites are thought have frequencies in excess of 500 years (Holt and Machmer 2005). Lower elevation ecosystems, ICHdw1, in the Park are classified as NDT3, which is characterized by stand-replacing disturbance events with a frequency of 150 to 200 years. Holt and Machmer (2005) suggest that warmer, westerly and south-westerly aspects likely include a mixed-severity fire regime with a frequency range of 30 to 100 years.

These long fire intervals suggest that the natural disturbance regime in the Park is likely dominated by moderate to long intervals of low intensity gap-replacement stand dynamics attributable to agents such as insects, fungi, and wind that operate on a continual basis. These dynamics would be interrupted by infrequent stand-replacing disturbances such as wildfires of various sizes, outbreaks of bark beetles, defoliating insects, and root diseases (Holt and Machmer 2005). Stand structure under this natural disturbance regime would include areas of even-aged forest where shorter interval, stand-replacing fires are common, and structurally-complex forest where very long fire intervals prevail. There is enough evidence, however, to suggest that another interpretation of fire history and historic forest structure is possible. The interpretations of Holt and Machmer (2005) are based entirely on the Biodiversity Guidebook and local opinion (BC Ministry of Forests and BC Environment 1995). The Biodiversity Guidebook natural disturbance classifications are not based on empirical data in most cases, but on professional judgment. However, determining the historic disturbance regimes and resultant forest structures in the Park is complicated by the large-scale fires that occurred in the late 1800's and early 1900's.

9.2 Fire Weather

The Canadian Forest Fire Danger Rating System (CFFDRS), developed by the Canadian Forestry Service, is used to assess fire danger and potential fire behaviour. The BCWS maintains a network of fire weather stations during the fire season that is used to determine fire danger on forested lands within the province. The information is commonly used by land managers, including municipalities and regional districts, to monitor fire weather to determine hazard ratings and associated fire bans and closures within their respective jurisdictions. The key fire weather parameters analyzed and summarized for the Park are Fire Danger Class and Drought Code.

Fire Danger Classes[5] provide a relative index of how easy it is to ignite a fire and how difficult control is likely to be. The five Fire Danger Classes in BC include: Class I (very low), Class II (low), Class III (moderate), Class IV (high), and Class V (extreme). It is important to understand the likelihood of exposure to periods of high fire danger, defined as Danger Class IV (high) and V (extreme), to determine appropriate prevention programs, levels of response, and management strategies.

Fire danger was compiled using representative weather stations in the Fire Weather Zones that the Park is located in (Figure 9-1). Fire weather can vary significantly from season to season as illustrated in Figure 9-2 and Figure 9-3. In the past five decades, there has been a slight shift to increasing percentage of Danger Class IV and V days during the fire season (May through August) in the Interior Wet – West Kootenay Fire Weather Zone. Danger Class V days have increased from 9% in the 1970s and 1980s to 11% and 12% in the 2000s and 2010s (Table 9-1). The 1990s had unusually low numbers of Danger Class IV days. The Interior Subalpine – Columbia Mountains Fire Weather Zone

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[5] Defined by the BC *Wildfire Act* [BC 2004] and *Wildfire Regulation* [BC Reg. 38/2005])

Danger Class III days have increased in the last two decades but Danger Class IV days have decreased compared to the 1980s. No trend in Danger Class V days is evident. Fewer Danger Class IV and V days for the Subalpine Zone, as compared to the Interior Wet Zone, is explained by the higher elevation of this zone (Table 9-2). Typically, the most extreme fire weather occurs between late July and the third week of August.

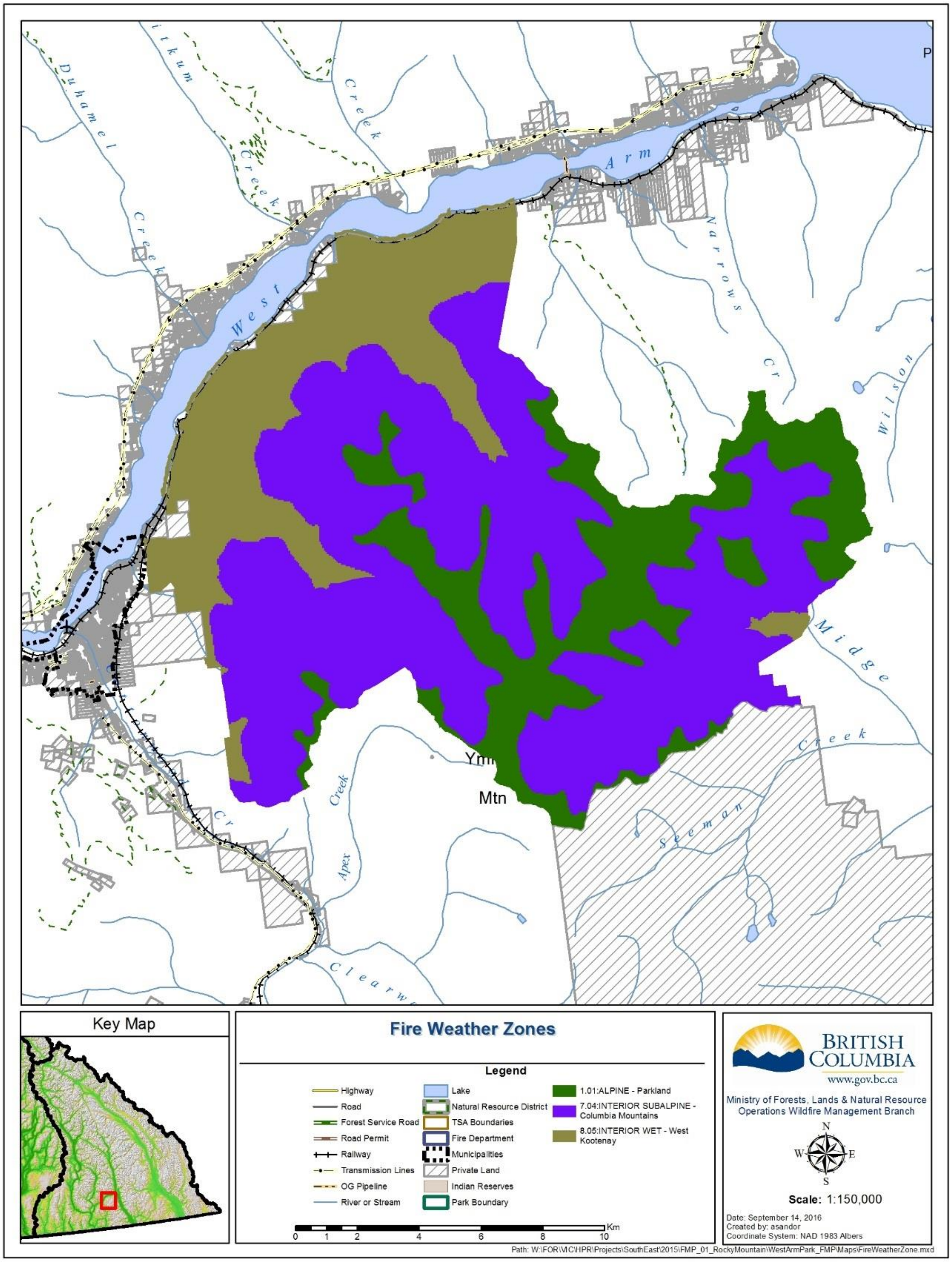

Figure 9-1. Fire Weather Zones in West Arm Provincial Park.

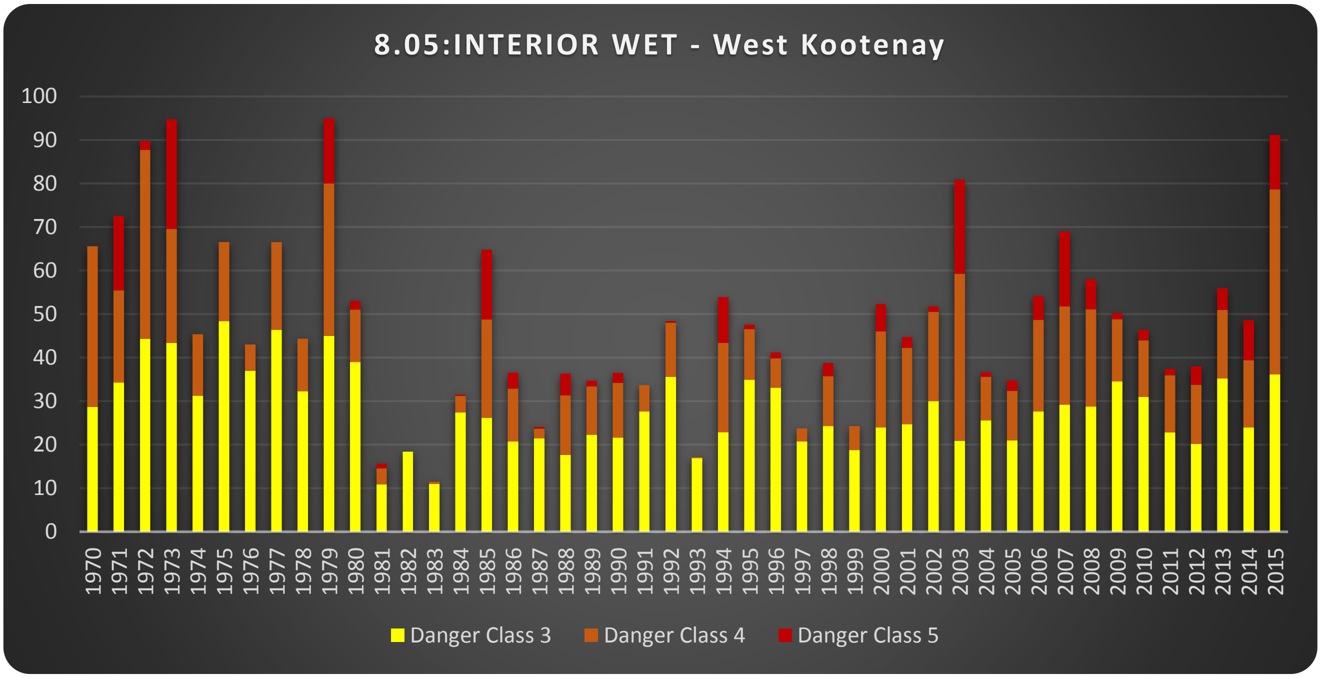

Figure 9-2. Seasonal Averages (May to August) in the number of Danger Class III, IV, and V days in the Interior Wet – West Kootenay Fire Weather Zone.

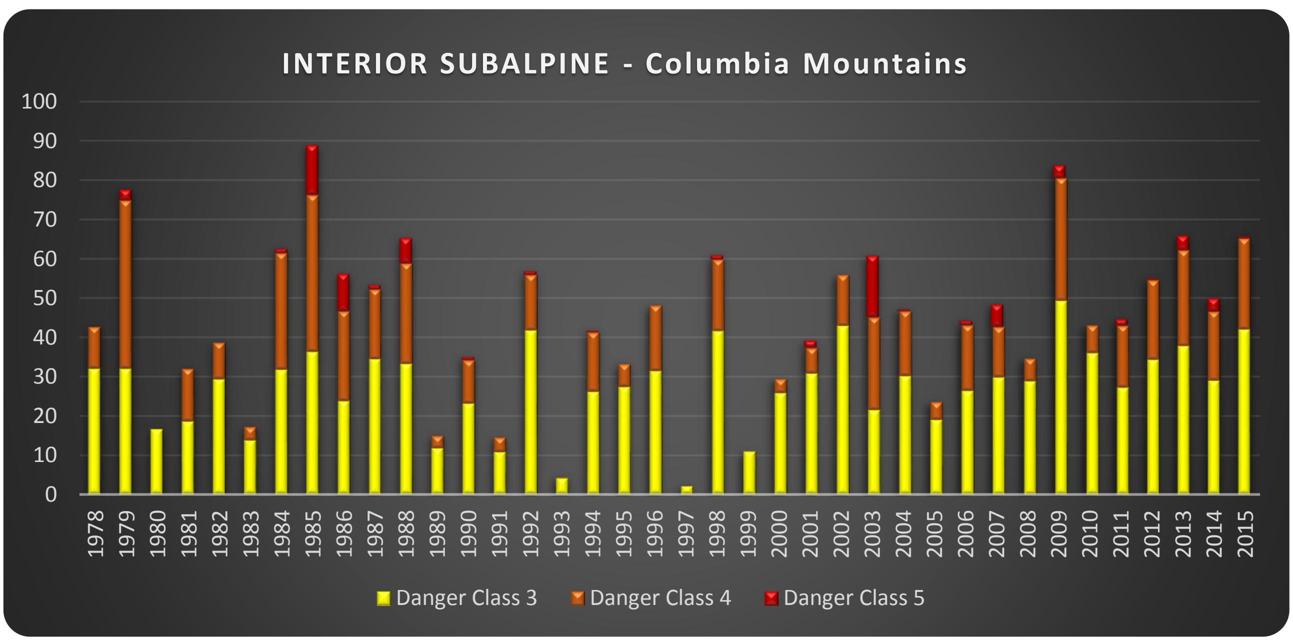

Figure 9-3. Seasonal Averages (May to August) in the number of Danger Class III, IV, and V days in the Interior Subalpine – Columbia Mountains Fire Weather Zone.

Table 9-1. Sum of Danger Class Days by decade for the Interior Wet – West Kootenay Fire Weather Zone.

Decade	Danger Class III		Danger Class IV		Danger Class V		Total
1970-1979	391	57%	233	34%	59	9%	684
1980-1989	215	66%	82	25%	30	9%	326
1990-1999	256	70%	90	25%	19	5%	365
2000-2009	266	50%	200	38%	66	12%	532
2010-2015	169	53%	113	36%	35	11%	318

Table 9-2. Sum of Danger Class Days by decade for the Interior Subalpine – Columbia Mountains Fire Weather Zone.

Decade	Danger Class III		Danger Class IV		Danger Class V		Total
1970-1979	391	57%	233	34%	59	9%	684
1980-1989	250	56%	165	37%	31	9%	446
1990-1999	220	97%	3	1%	3	1%	226
2000-2009	306	69%	134	31%	0	0%	440
2010-2015	207	64%	108	33%	9	3%	324

Drought Code (DC) is a key fire weather parameter that measures long-term drought as it relates to fire behaviour. It is as numeric rating of the average moisture content of deep, compact organic layers. A summary of historic drought codes provides an indication of the fire severity and suppression difficulty (Figure 9-4; Figure 9-5). A DC that exceeds 350 is considered high and is associated with high fire behaviour, and a DC exceeding 500 is considered extreme. Based on annual averages, DC values commonly exceed 350 in the Interior Wet – West Kootenay and Interior Subalpine – Columbia Mountains. A comparison of maximum, rather than seasonal means, indicates that the low values in May and June reduce the seasonal average. During the months of July and August, maximum DC values commonly exceed 500 in the Interior Wet – West Kootenay and, in the Interior Subalpine – Columbia Mountains, DC values have only exceeded 500 six times since DC has been recorded for the Interior Subalpine – Columbia Mountains, indicating more moderate fire behaviour than in the Interior Wet Zone.

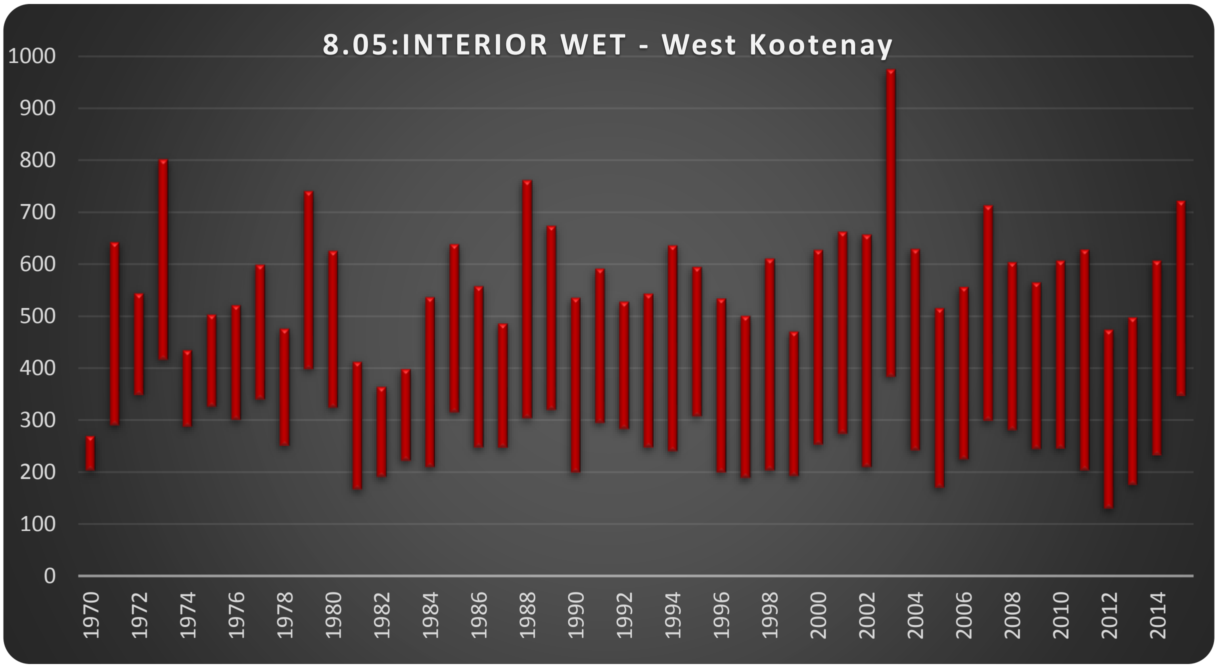

Figure 9-4. Annual variability (May-August) in the number of Drought Codes in the Interior Wet – West Kootenay Fire Weather Zone.

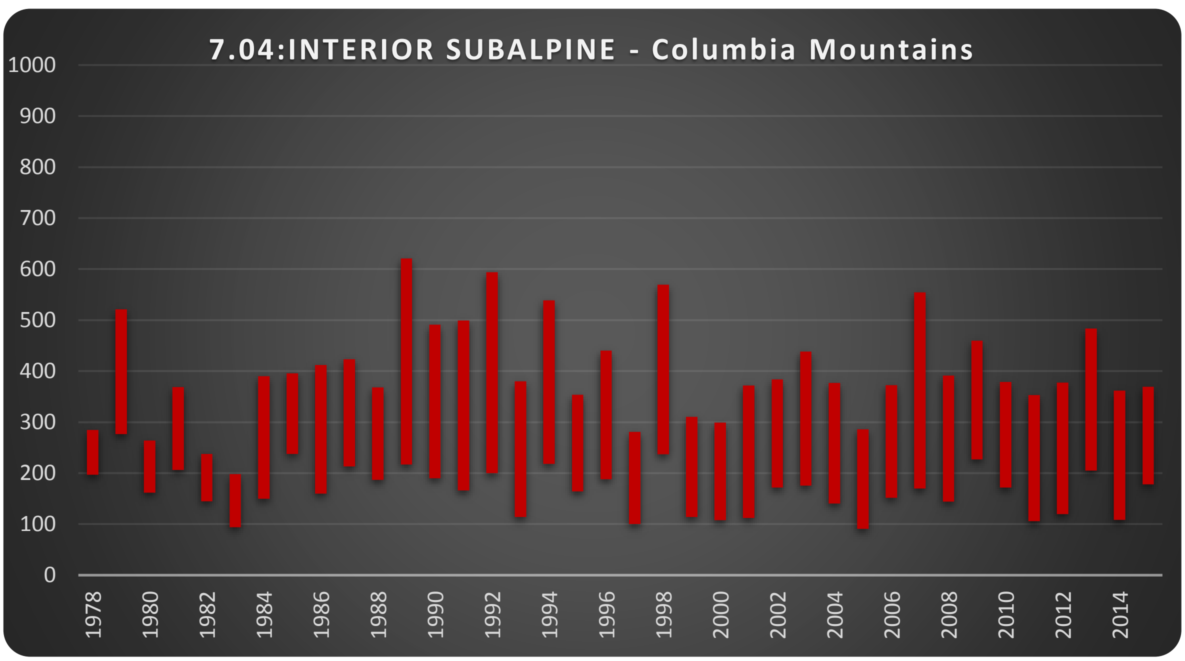

Figure 9-5. Annual variability (May-August) in the number of Drought Codes in the Interior Subalpine – Columbia Mountains Fire Weather Zone.

The wind rose data, which is compiled hourly by the MFLNRO at selected fire weather stations, provides an estimate of prevailing wind directions and wind speed in the area of the weather station. For the Smallwood weather station, the most representative for the Park, the prevailing wind direction is from the south and southwest, indicating movement of a fire from Nelson to the Park is a likely scenario (Figure 9-6). The wind rose indicates that the majority of winds are less than 14 km/hr., with a small percentage of the prevailing winds that are between 14 and 19.9 km/hr.

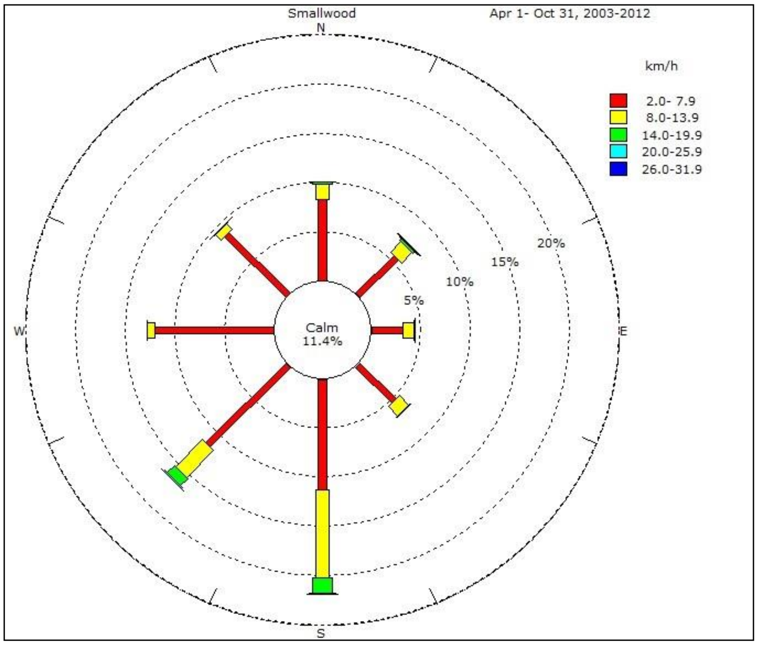

Figure 9-6. Wind rose data for Smallwood weather station, hourly data from 2003 to 2012.

9.3 Recorded Fire History

The MFLNRO fire reporting system was used to compile a database of fires that occurred within the Park. This database provides an indication of fire history for the area, but should not be considered comprehensive. Recent fire history, between 1950 to 2015, in the Park is dominated by lightning caused fires (Table 9-3). No human caused fire was over 4 ha in size, while the largest lightning caused fire was the 7,916 ha Kutetl Fire in 2003. A marked decline in human caused fires has occurred over the last 3 decades (Table 9-4).

Figure 9-7 shows the ignitions in the Park. Most of the human ignitions have occurred a short distance northeast of Nelson. Human caused fires start at the beginning of the record in 1950, and the most recent human caused fire was November 2001 in Selous Creek. It was caused by open burning, and because of the time of year it posed a negligible risk. No human caused fire was greater than 4 ha. Most of the lightning caused fires have occurred between Five Mile Creek and Lasca Creek. Several of these exceeded 4 ha, the largest fire being the Kutetl Fire. In July 2015, a lightning initiated fire was detected by air patrol and actioned in the Park. The total fire size was 0.5 ha. Generally, in B.C lightning is the cause of the largest wildfires. This is often due to the remote location and longer detection time associated with these fire starts.

Table 9-3. The number of fires by cause and size in West Arm Provincial Park. Data courtesy BCWS.

Fire Cause	Fires Smaller than 4 ha	Area (ha)	Fires Larger than 4 ha	Area (ha)	Total Area	Number of Fires
Burning building	2	0.3			0.3	2
Campfire escape	4	0.5			0.5	4
Campfire escape, non-compliance	1	< 0.1			< 0.1	1
Discarded match/cigarette/smoking substance	8	0.9			0.9	8
Friction logging	1	0.2			0.2	1
Hot metal fragment	1	0.1			0.1	1
Open burning	6	1.6			1.6	6
Open burning, compliance, category 7	1	0.5			0.5	1
Spark from metal/metal or metal/rock	1	0.1			0.1	1
Undetermined	6	2.4			2.4	6
Lightning	42	6.2	3.0	8,091.2	8,097.4	45
Grand Total	73	12.8	3.0	8,091.2	8,104.0	76

Table 9-4. Summary of human and lightning caused fires by decade in West Arm Provincial Park. Data courtesy BCWS.

Decade	Human	Lightning	Undetermined	Total
1950-1959	10	4	3	17
1960-1969	5	4	2	11
1970-1979	4	4	2	10
1980-1989	2	9	0	11
1990-1999	1	7	0	8
2000-2003	1	11	0	12
2010-2015	0	1	1	2
Total	23	40	8	71

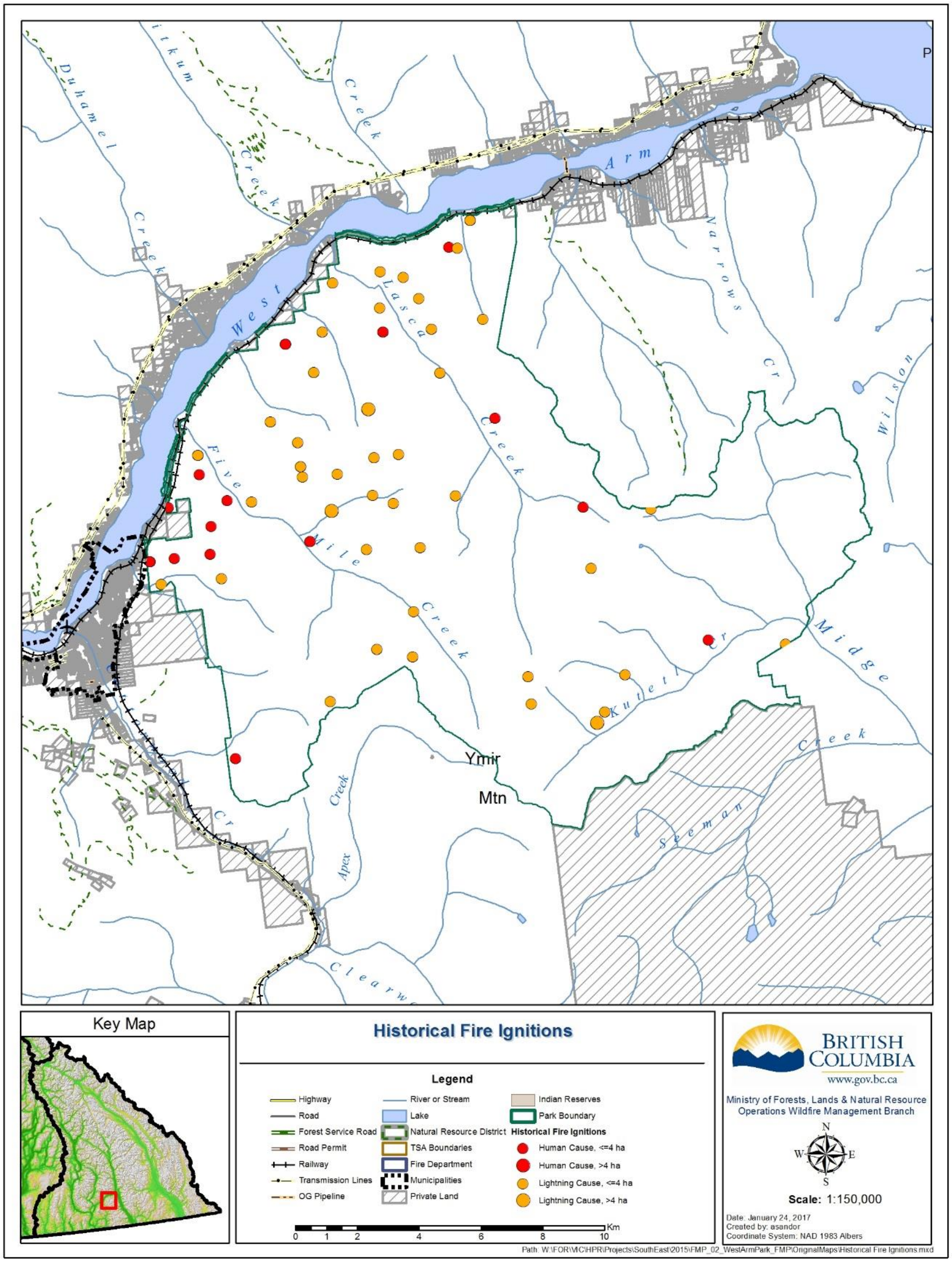

Figure 9-7. Fire history between 1950 to 2015 shown by cause and size in West Arm Provincial Park. Data courtesy BCWS.

9.4 Fuel Types

Predicting fire behaviour requires information on the types of forest fuels distributed across the landscape. The Canadian Fire Behaviour Prediction (FBP) System, used for fire modelling, utilizes a fuel type classification that recognizes 16 national benchmark fuel types. The fuel types are based on attributes such as amount of forest cover, tree species composition, forest age and understory vegetation. For this project, the fuel types used in the Provincial Strategic Threat Analysis (PSTA) were used with some modifications to incorporate changes to fuels due to MPB. Table 9-5 summarizes fuel types recognized for the study area. These represent the best fit to the FBP classes based on current knowledge of potential fire behaviour characteristics of ICH and ESSF forests.

Tree species in the Park are primarily coniferous, although a small component of deciduous exists. Of the 18-tree species in the Park, 16 of these are coniferous. The most commonly found species recorded in the Vegetation Resource Inventory (VRI) spatial data for the Park include (in order of abundance): *Picea spp* (Spruce), *Abies spp* (True fir), *Pinus contorta* (lodgepole pine), *Pseudotsuga menziesii* (Douglas-fir), *Pinus monticola* (western white pine), *Populus tremuloides* (trembling aspen), and *Thuja plicata* (redcedar).

The PSTA fuel types were used to identify fuels in the Park (Figure 9-8). The fuel types have been updated based on mortality that has occurred in lodgepole pine dominated stands since 2008 (Figure 9-9). Stands with a high component of lodgepole pine that have more than 30% mortality have been re-classified as C2 fuel types to account for the increased fire behaviour. Section 9.4.1 provides background on fire behaviour in beetle killed stands and provides an overview of the change in mortality in lodgepole pine since 2008. C3 is the most abundant fuel type (7,241 ha), followed by 01a/b (6,002 ha), C2 (5,151 ha), and M1/2 (2,697 ha) (Table 9-5). The scarcity of D1/2 can be attributed to the scarcity of deciduous tree species in the Park.

Figure 9-9 shows the spatial distribution of fuel types within the Park. The dominant disturbance in the study area was a stand replacing fire that occurred in 1894. The C2 type associated with MPB caused mortality is shown on the figure. Descriptions and photos of fuel types are included in Appendix 1 – Fuel Type Descriptions.

Table 9-5. Fuel type classes in West Arm Provincial Park based on the Canadian Fire Behaviour Prediction System fuel types (Forestry Canada 1992) and British Columbia wildfire fuel typing (Perrakis and Eade 2015).

Code	Area (ha)	Description
C2	5,151	Coniferous, pole sapling to young forest stands with common ladder fuels, high stem density and high crown closure (>80%)
C3	7,241	Coniferous, young forests to mature with moderate crown closure
C5	1,752	Coniferous, mature and old stands with moderate crown closure and none to gappy ladder fuels
C7	2,484	Coniferous, pole sapling and young forest stands with open canopies
D1/2	143	Deciduous tree species stands
M1/2	2,697	Moderately well-stocked mixed stand of conifer and deciduous species, low to moderate dead, down woody fuels, crowns nearly to ground (M1 – leafless, M2 – in leaf)
O1a/b	6,002	Grass or shrub dominated with little tree cover / Low grass or low flammability herb dominated cover
Non-fuel	852	Any significant areas with non-flammable materials (i.e. rock or pavement) or water bodies

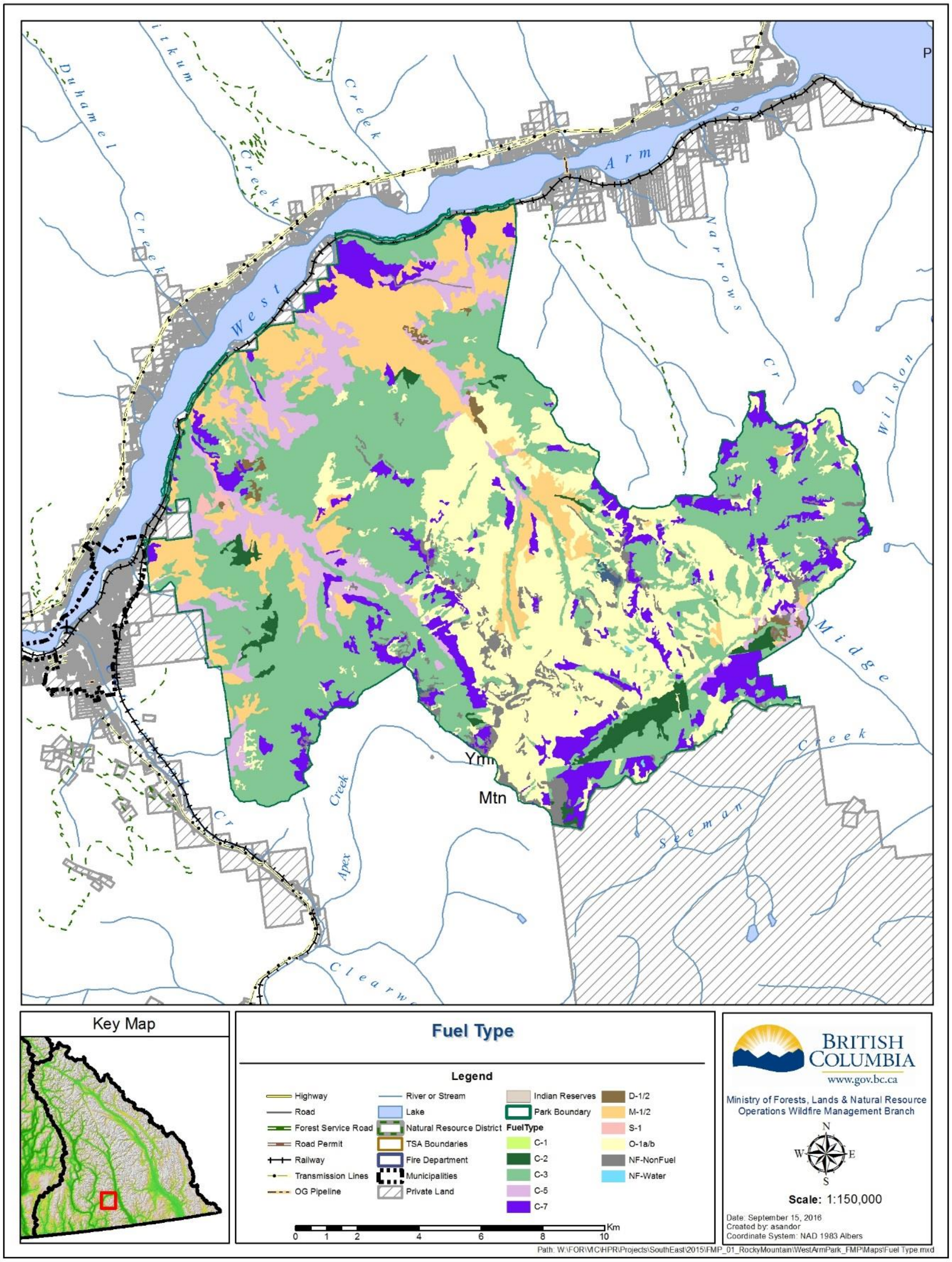

Figure 9-8. Provincial Strategic Threat Analysis fuel types in West Arm Provincial Park.

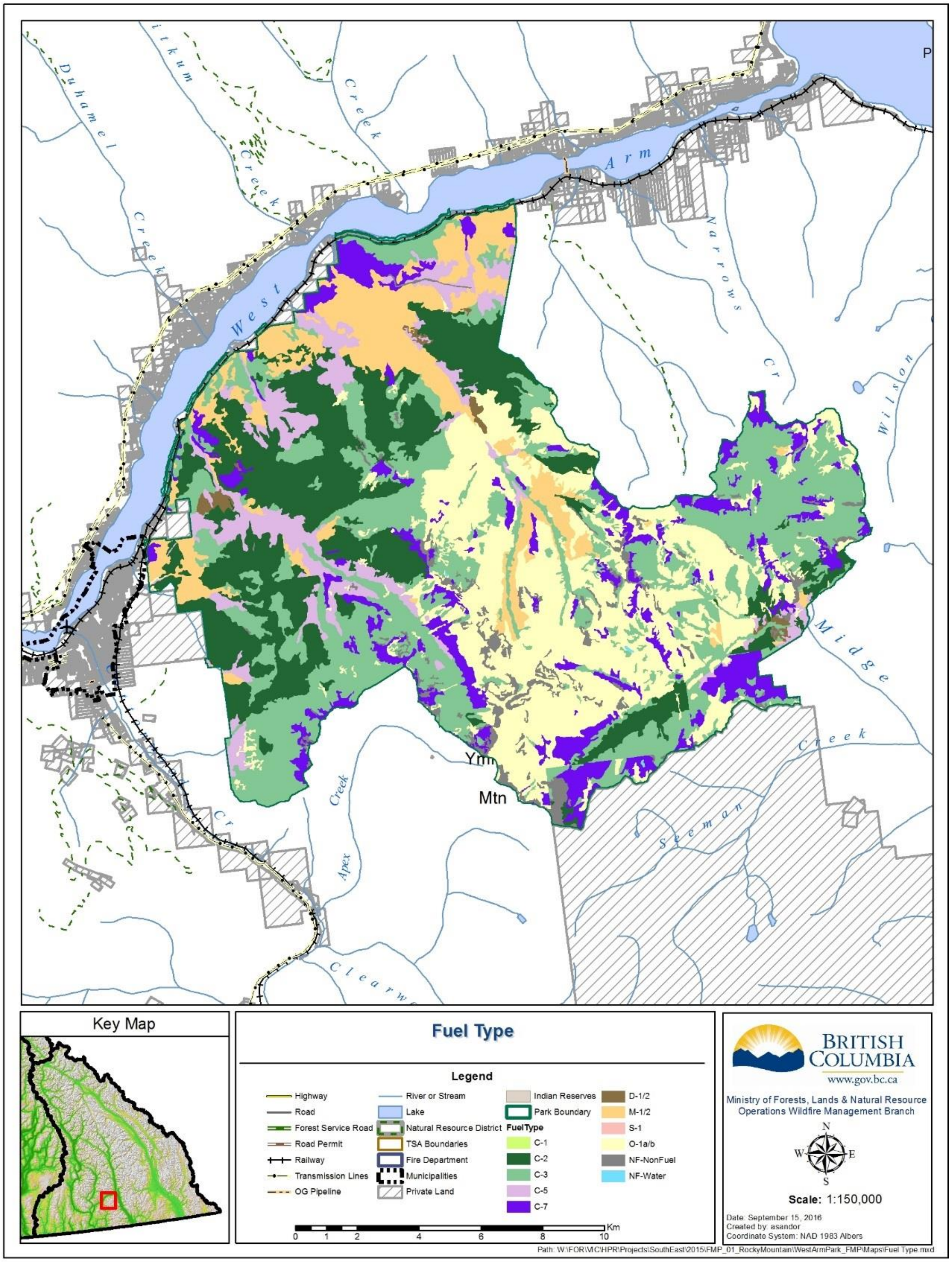

Figure 9-9. Provincial Strategic Threat Analysis fuel types updated to include changes caused by mountain pine beetle in West Arm Provincial Park.

9.4.1 FOREST HEALTH

The outbreak of MPB in BC started in the early 1990s. From 1986 to 1994, only 72 ha of MPB attack were recorded in the Park, according to provincial forest health data (MFLNRO 2015). By 2004, there were 2,362 ha of light to severe incidents of MPB reported for the Park, this increased 2.3 times to 5,426 ha as reported in the 2006 Provincial Forest Health Aerial Survey data (MFLNRO 2015). As forecasted in the 2008 West Arm plan (Blackwell 2008), the trend of increasing mortality due to MPB continued and most of the remaining lodgepole pine dominated stands have been affected. The last mapped polygon of MBP by Provincial Aerial Forest Health Surveys was in 2011.

Over the last 30 years, 11,658 ha of light to very severe MBP attack have been recorded in the Park (Table 9-6; Figure 9-10; MFLNRO 2015). Severe and Very Severe attacks account for 7,300 ha (61%) of this area. This has resulted in a significant change in the seral stage structure of the Park in areas dominated by pine and has increased the fuel hazard. Pine mortality has occurred over multiple years and the accumulation of fuels represents this continuum (Figure 9-11; Figure 9-12). Older dead pine has fallen and is contributing to surface fuel loads and more recently deceased pine is still standing and provides aerial fuels for fire spread. The loose, dead bark on these trees increases spotting potential, as it easily becomes airborne in fire created thermal winds.

Table 9-6. Area affected by MPB since 1986 in West Arm Park (MFLNRO 2015).

Intensity Class	Area (ha)	Severity Code Description
Trace (T)	239	< 1% of trees in the polygon recently killed
Light (L)	2,381	1-10% of trees in the polygon recently killed
Moderate(M)	1,953	11-29% of trees in the polygon recently killed
Severe (S)	1,408	30-49% of trees in the polygon recently killed
Very Severe (V)	5,906	>50% of trees in the polygon recently killed
Total	11,888	

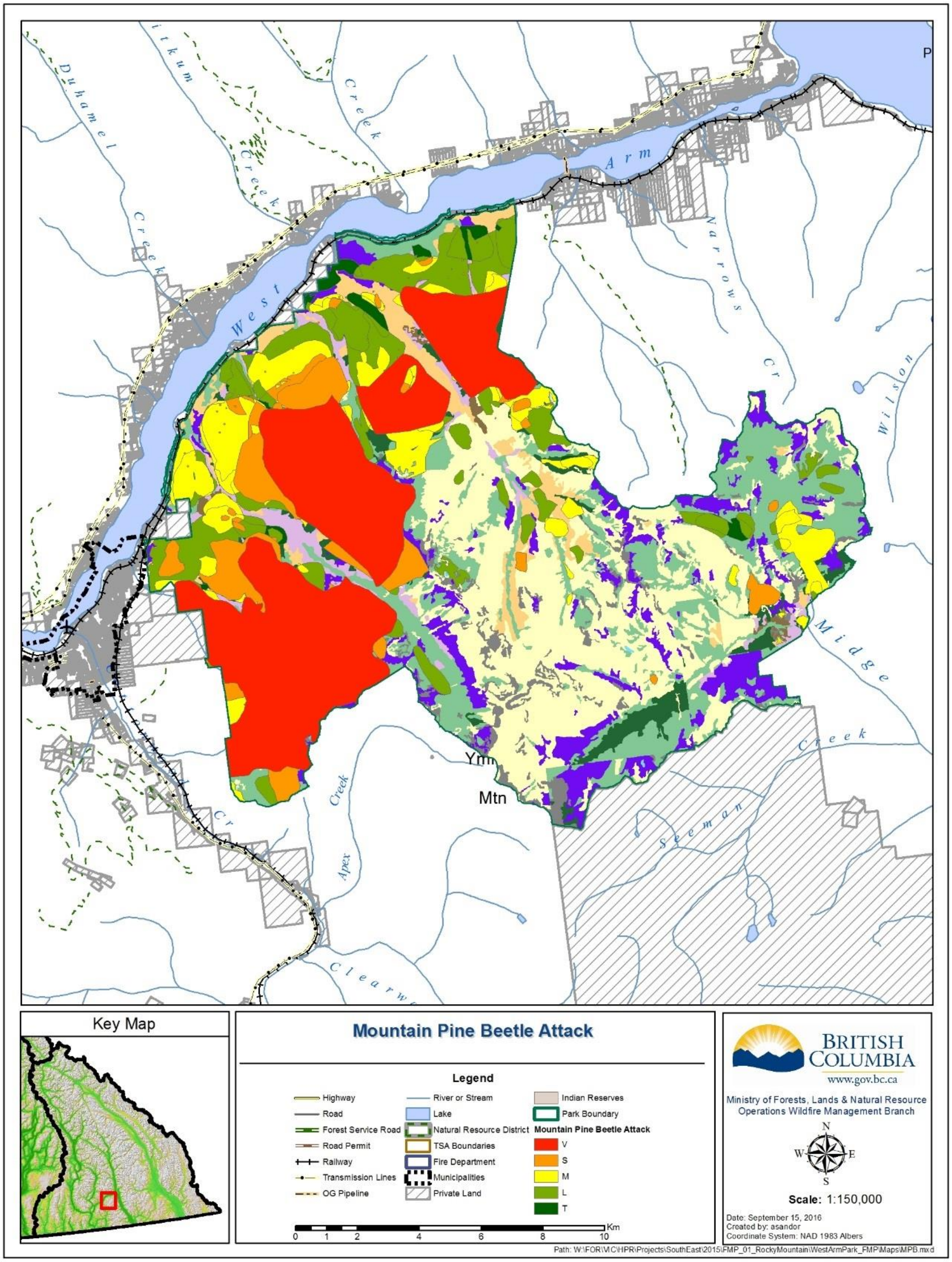

Figure 9-10. MPB attack from 1986 to 2015 in West Arm Provincial Park (MFLNRO 2015).

Figure 9-11. Fuel accumulations in a mountain pine beetle infected lodgepole pine stand in 2008.

Figure 9-12. Fuel accumulations due to mountain pine beetle infected lodgepole pine in 2016.

Mountain pine beetle mortality results in an initial short-term increase in stand level fire hazard as fine fuels are still present in the canopy during the red-attack stage and for some time into the grey-attack stage. Trees enter the red-attack stage approximately one year following infestation and turn grey approximately three years following infestation (Figure 9-13). As needles and small branches fall from the canopy and decompose, stand level fire hazard decreases. After approximately ten years, the fire hazard begins to increase as bark begins to slough off the standing dead trees. Hazard levels remain lower until the beetle killed trees begin to fall (approximately 15 to 20 years), at which point the fire hazard rises to high or extreme depending on the quantity and arrangement of fuel that results from the falling trees (Manning et al. 1982).

Fire hazard (Figure 9-13) refers to the potential fire behaviour, regardless of weather-influenced fuel moisture content. Assessment of fire hazard is based on physical fuel characteristics, such as fuel arrangement, fuel load, and condition of herbaceous vegetation. Fire hazard ratings of high, moderate, and low imply approximations for rate of spread, headfire intensity, and crown fraction burned. Fire Severity refers to the effect of fire on plants, humus layers, and soils. It is dependent on intensity and residence time of the burn. An intense fire may not necessarily be severe.

The healthy stand shown in Figure 9-13 is represented with 35 to 45% crown closure and low fire hazard. The initial phase of pine beetle attack results in the death of overstory trees, which retained needles and small branches (Red-Attack Stand and early grey-attack stages). In this phase, the standing dead trees input fine fuels to the forest floor (attacked stand) and the fire hazard is high to extreme. The loss of overstory tree foliage increases light levels to the forest floor and causes a flush of understory vegetation, including new seedlings that regenerate naturally (understory release). This flush depends on a number of factors but is primarily a function of available light, nutrients, moisture, and the existing seed bank and plant community. In general, fire hazard is lower during this phase. Over time, seedlings begin to dominate the understory forming a contiguous sapling layer (Seedling Dominance) and bark begins to slough off the standing dead trees (Seedling Dominance and Bark Sloughing). During this period, hazard increases again due to the input of fine fuels to the forest floor. After this phase, there may be a period of reduced fire hazard before the standing dead timber begins to fall on a large scale. However, once the dead trees fall in large numbers, they create high surface fuel loading (represented by the Young Pine Stand with Snags Falling). At this time, hazard is often highest due to the combination of a high, contiguous surface fuel loading and overstory, aerial fuels. These characteristics create a stand that is highly susceptible to stand replacing crown fires.

The fuels complex created by MPB in the Park has less discrete stages, as lodgepole mortality has occurred over a 30-year period. As a result, the fuel characteristics created by beetle attack are not well represented by a continuum. Figure 9-13 is still useful, as it shows a representation of the succession of fire hazard status following beetle attack in a healthy stand. The current beetle created fuels in the Park are represented primarily by grey attack phases, including grey attack trees, standing snags, high surface fuel accumulations, and understory re-initiation (Jenkins et al. 2012). The complexity and continuity of fuels, could result in higher fire behaviour, supported by the abundant surface fuels (Klutch et al. 2007). Another compounding factor is the change in canopy density and the effect on wind speeds. The more open canopies allow higher wind speeds, which result in higher fireline intensities than typical mature stands. The increased surface fuels, especially the large diameter woody debris that increase fire duration (Page and Jenkins 2007), can affect soil properties and erosion rates (Wells et al. 1979). The increase in fire severity may affect watershed hydrologic functions that determine water quality and quantity and can increase restoration activities and costs required post-wildfire. Watershed considerations and planning are discussed further in Section 11.2.

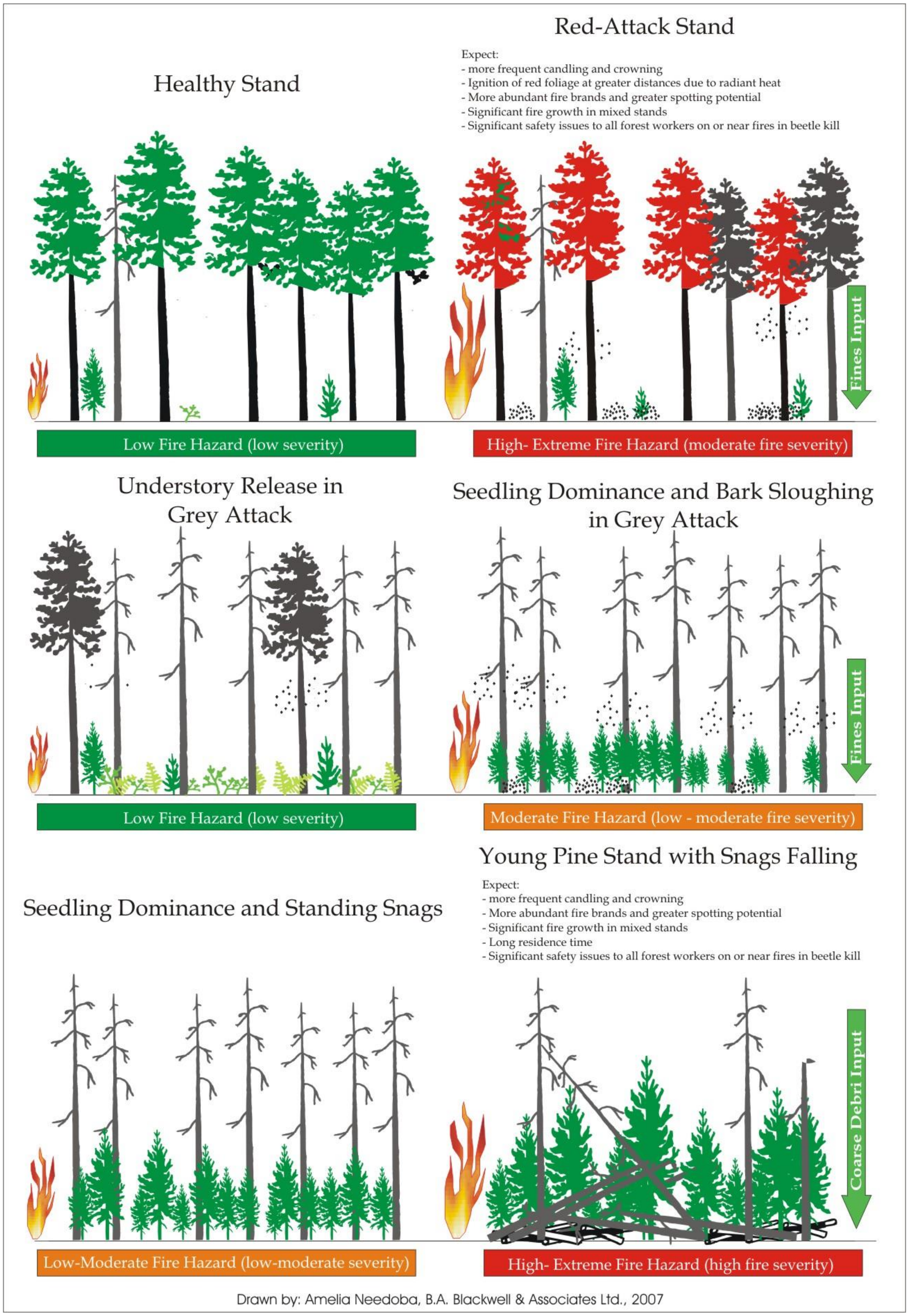

Figure 9-13. Changes in fuel loading and fire hazard over time in mountain pine beetle infected lodgepole pine.

10 FIRE BEHAVIOUR

Fire behaviour (the way a fire ignites, flame develops, and fire spreads) is determined by the fire environment, which is consists of fuels, topography, and weather. Once a fire starts, it will continue burning only if heat, oxygen, and fuel are present. The type of fuel present, size, quantity, and physical distribution affect fire behaviour.

To assess fire behaviour, a worst-case fire was modelled using a realistic weather scenario (90 percentile fire weather conditions), assigned fuel types, and topographic features to determine the potential fire behaviour of individual forest cover polygons located within the Park boundary. The resultant fire behaviour combined with suppression capability and consequences (values at risk) facilitate probability and consequence analysis, which is useful in deciding whether mitigation measures are required or not. As part of this fire behaviour analysis, a 9 km/hr windspeed scenario was modelled to determine potential spotting distance into the communities adjacent to the Park. The risk of fire starts in the community spotting into the Park as influenced by the prevailing wind directions from the south and southwest are discussed in Section 9.1 (fire weather). A fire starting in the Park would tend to move towards Kootenay Lake and Harrop-Procter, but diurnal winds would also affect the direction of fire spread direction as would topography.

The following describes the key components of the analysis and the approach taken to model the different scenarios.

10.1 Provincial Strategic Threat Analysis – Inputs

To assess fire behaviour in the Park, the Provincial Strategic Threat Analysis was used to identify areas with high threat related to values at risk. A complete description of the PSTA methods can be found in Provincial Strategic Threat Analysis 2015 - Wildfire Threat Analysis Component (MFLNRO 2015a).

The PSTA is used to identify areas with high threat based on three factors that help determine fire behaviour: fire density, spotting impact, and head fire intensity as represented by the following key inputs to the PSTA:

- Fire history and density;
- Fire intensity;
- Rate of spread; and
- Crown fraction burned.

These PSTA inputs are described in Appendix 2. As the PSTA only assesses fire behaviour not values at risk, the values at risk and consequences of a wildfire are discussed in Section 11.

10.2 Provincial Strategic Threat Analysis - Wildfire Behaviour

The PSTA shows high to extreme fire behaviour in most areas of the Park and in forests near the adjacent communities (Table 10-1 and Figure 10-1). The 10 fire threat classes indicate increasing fire threat. Areas in class 7 to 10 are at high risk of fire behaviour with crown fires with headfire intensities > 10,000 kW/m and could be affected by spotting (MFLNRO 2015a). Fires in these areas could result in catastrophic losses to values at risk. There are 20,149 ha in classes 7 to 10, which represents 77% of the Park (Table 10-1). Mitigation of these areas is considered a high priority based on fuel types and logistics (MFLNRO 2015a).

Table 10-1. Provincial Strategic Threat classes in West Arm Park.

PSTA Class	Area (ha)	%
No Data	4.7	<1%
Water	112.2	<1%
No Threat	0	0%
1	0	0%
2	259.1	1%
3	1,899.6	7%
4	1,241.9	5%
5	700.7	3%
6	1,954.2	7%
7	2,584.6	10%
8	6,310.9	24%
9	10,687.5	41%
10	566.1	2%

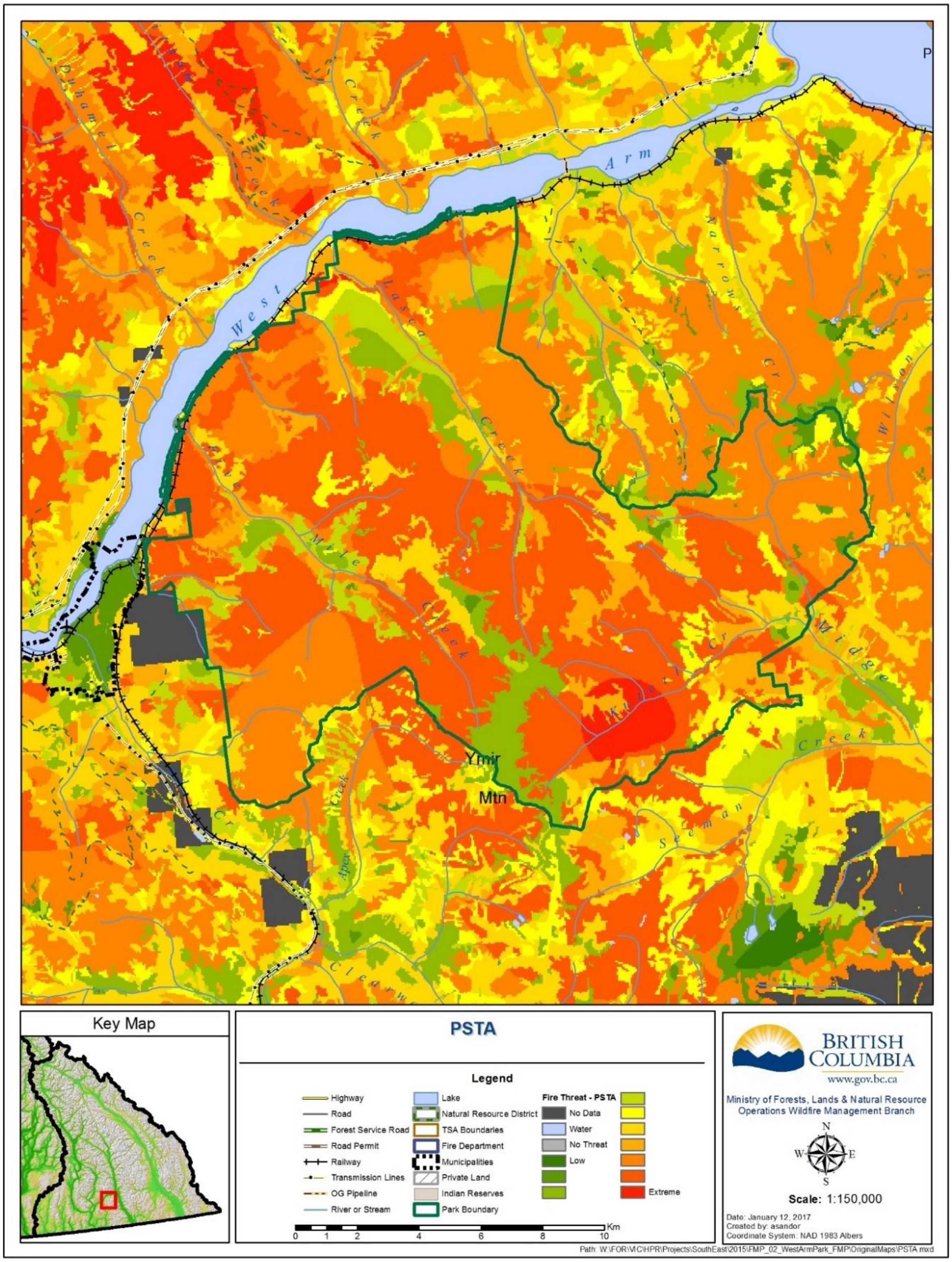

Figure 10-1. Provincial Strategic Threat Analysis – Fire Threat in West Arm Provincial Park.

10.3 Suppression Planning

When a significant natural event such as a catastrophic wildfire occurs, lack of sound planning and preparation can lead to poor decision making. This potentially increases the risk to Park values, human lives, and properties. Therefore, preparation is critical to the successful control of all fires within the Park.

10.3.1 DETECTION AND REPORTING

The BCWS is the agency responsible for fire detection. The BCWS employs the Provincial lightning locator system, aerial observation, and public observation. The proximity of nearby interface communities means public observation is important during the fire season. The occasional presence of Park staff and permanent signage at major entrances in the Park during dangerous fire weather conditions is also desirable in terms of educating the public about the risks during these periods and providing information on how to report wildfires.

10.3.2 FIRE SUPPRESSION CONSTRAINTS

Figure 10-2 shows the suppression response capability in the Park. Much of the Park has steep terrain, which exists from Kootenay Lake to the high elevation boundary of the Park. This severely hinders suppression efforts by ground crews, as does the lack of roads or trails in a significant portion of the Park. In the event of a catastrophic wildfire, the primary suppression tool will likely be aerial attack (air tanker and/or helicopter bucketing). Figure 10-2 suppression constraints considered include:

- Constraints to Detection;
- Proximity to Water Sources;
- Proximity to Roads (and Helipads);
- Helicopter arrival time;
- Air Tanker Arrival Time; and
- Terrain Steepness.

Conventional suppression tactics will be limited to some extent in order to minimize the impacts on the Park and community watersheds. Line construction of fuelbreaks should be minimized and existing natural and manmade fuelbreaks should be used whenever possible. Preferred techniques that minimize impacts on the Park include backfiring or burning out techniques from these firebreaks, and the use of wetlines whenever possible. Additionally, the use of water should be favoured over fire retardant (in particular in the community watersheds) and retardant should not be used on watercourses if possible. Ecological values are discussed in greater length in Section 11– Fire Consequences.

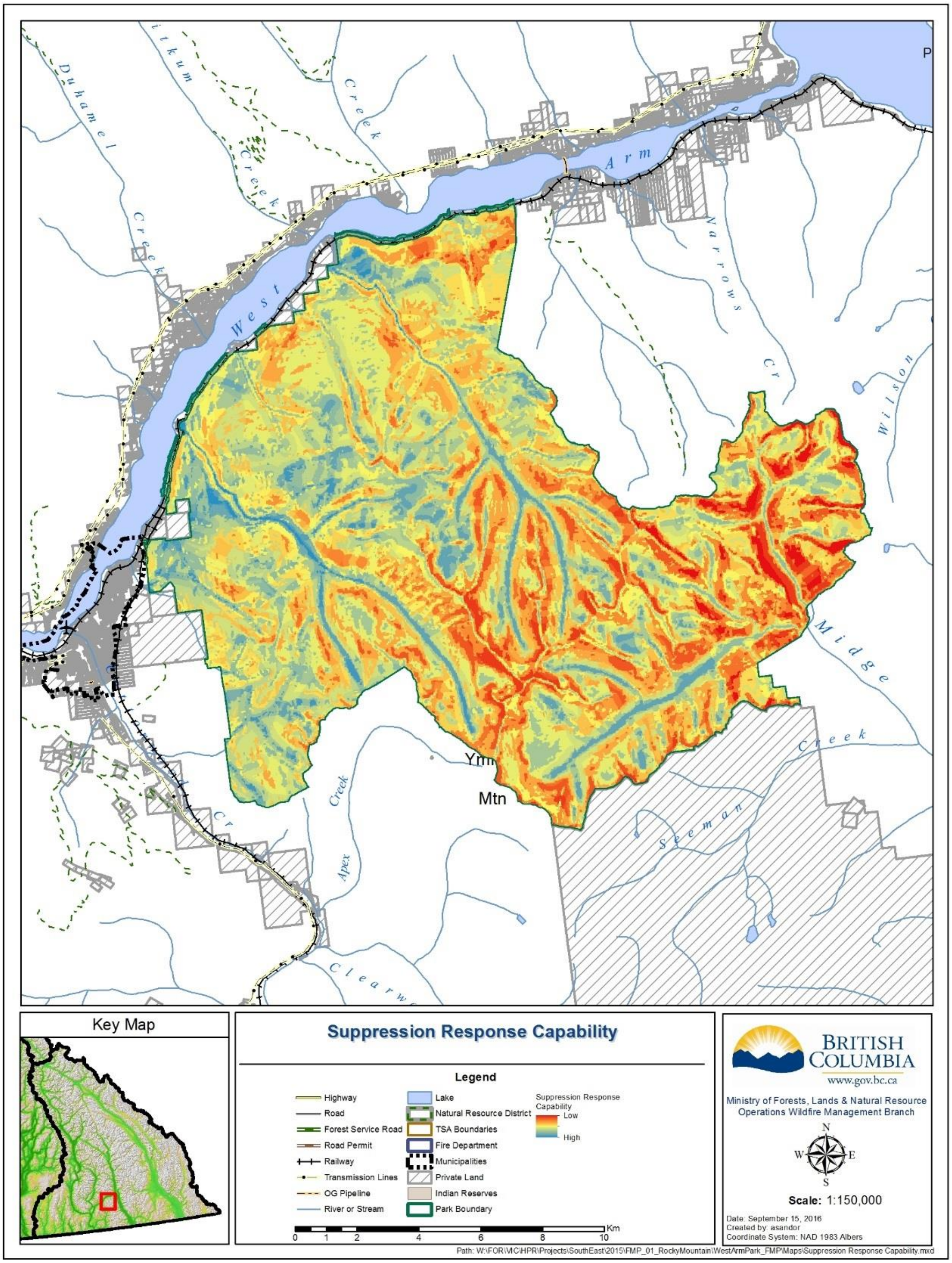

Figure 10-2. Fire suppression capabilities in and adjacent to West Arm Provincial Park as dictated by access and topography.

11 FIRE CONSEQUENCES

This section explores some of the consequences of wildfire and values at risk including biodiversity, species at risk, community watersheds, and the wildland urban interface.

11.1 Fire Effects on Biodiversity Values

Wildfire effects on biodiversity are highly variable and depend upon timing, extent, severity of a wildfire, and the biophysical setting in which it occurs. Effects to forest age distribution and species and ecosystems at risk are discussed below.

11.1.1 FOREST AGE CLASSES

Wildfire could result in a shift in the age class distribution in the Park. The scale of the fire would have different implications on post-fire regeneration and the resulting vegetation complexes (Donato et al. 2009). A low or mixed severity fire would create heterogeneity and structural diversity in the Park and could increase some measures of biodiversity. Conversely, a large stand replacing fire would create a more homogeneous seral distribution in the Park, and could initially negatively affect many indicators of biodiversity such as species richness, genetic diversity, and structural diversity. The potential negative effects of the Kutetl fire on mountain caribou in the Park (US Fish and Wildlife Service 2008; Holt and Machmer 2005) and positive benefits for grizzly bear exemplify how effects may be species specific.

Conifer regeneration post-fire is generally abundant although there may be long recovery periods and a great deal of variation across the landscape (Shatford et al. 2007). Mixed severity fires are likely to result in more post-fire regeneration due to an increase in seed sources within close proximity (<200 m) of openings (Donato et al. 2009). Post-fire regeneration will determine the future stand structure. Typically, fire favours certain species over others (Agee 1993). For example, changes in stand structure could promote the presence or establishment of shade intolerant species, or serotinous species (Parsons and DeBenedetti 1979). In the Park, more frequent fires could cause a shift in species composition, favouring species such as lodgepole pine that are better adapted to fire. Cedar, Douglas-fir, and larch have a high regeneration capacity on burnt or exposed mineral soils and also likely to be favoured in the event of a large fire, provided seed source is present from adjacent trees.

Fire suppression and the associated activities can also influence vegetation structure. Activities involving roads, fire guards, helicopter landings, and staging can significantly disturb vegetation structure through compaction of soil or clearing and result in the introduction and establishment of invasive plant species. Various studies have suggested that roads can fragment a landscape, altering community composition (Lugo and Gucinski 2000; Black 2004). As a result of these activities, soil erosion and changes in runoff patterns can have negative effects on vegetation, particularly in areas of steep terrain. These effects can be compounded if roads are developed without planning in an emergency scenario during a large wildfire.

11.1.2 SPECIES AND ECOSYSTEMS AT RISK

Of all the species at risk identified in the Park (refer to Section 6.1), the threat of habitat loss due to fire is greatest to the mountain caribou. Mountain caribou live primarily in higher elevation ESSF forests but do seasonally migrate to ICH forests. While Ungulate Winter Ranges (UWR) have been created along sections of the Park boundary to preserve habitat from harvesting, large stand replacing fires would create lower quality habitat for the caribou. The Kutetl fire has already had an effect on the caribou population. Approximately 41% of their high elevation winter habitat in the Park was impacted by the fire (Holt and Machmer 2005). This value does not indicate to what degree these areas were affected. Recent surveys have not been conducted to determine where this loss of habitat has had significant effects on the local caribou population.

The Park contains important grizzly bear habitat. A wildfire is likely to have a positive influence on the quantity and quality of forage for bears as early seral habitat with greater availability of herbs and shrubs would be created. A number of studies have found that grizzly bears preferentially use burn sites as feeding habitat. It has even been shown that bears prefer burned sites over other open sites where trees have been mechanically removed (Zager et al. 1983). However, access roads resulting from suppression efforts would need to be restricted and rehabilitated to reduce bear and human encounters, one of the largest sources of mortality to bears (Mattson 1996).

Whitebark pine is a high elevation species with a limited population size and a limited range within BC. It has significant barriers to dispersal, as it needs to migrate across mountain tops through a fragmented habitat range. The continued viability of this species is already greatly threatened by forest health factors and changing climate. Increasing wildfire behaviour and changes in stand composition due to historic fire suppression activities are major threats to the species (Sadler 2014). It is probable that the Kutetl Fire resulted in the loss of some WBP stands. On dry wind-exposed sites, regeneration of this species may require several decades after a severe fire (Tomback, 1986). Whitebark pine generally has low regeneration success due to low germination rates and adverse growing conditions (Klinka et al. 1996). However, the Clark's Nutcracker, the primary seed disperser of WBP, preferentially caches seeds in openings such as those created by fire (Tomback and Linhart 1990). After fire-free periods, WBP is often replaced by mature spruce and fir, although under a frequent low intensity fire regime WBP may be promoted over less fire-resistant species (Arno, 1986).

Only a small area has been identified in the PEM as red-listed Douglas-fir / tall Oregon-grape / parsley fern (ICHdw/102), and the majority of this is outside the Park boundary. No field verification of this location has been conducted.

Wildfire and suppression activities can also create conditions and habitat suitable for the introduction and spread of invasive plant species. Known locations of invasive plant species occur primarily in proximity to the railroad tracks along Kootenay Lake and Svoboda Road[6]. Invasive plant species include species that are highly invasive and capable

[6] iMapBC. Accessed December 17, 2016

of displacing some native plant species and include: purple loosestrife, spotted knapweed, common tansy, yellow and orange hawkweed, scotch broom, Canada thistle, and rush skeletonweed (Holt and Machmer 2005).

11.2 Fire Effects on Watershed Values

Considering the City of Nelson's dependence on the community watersheds in the Park, maintaining watershed integrity is very important for City. Five Mile Creek is the primary water source for Nelson and impacts from wildfire in this watershed, in particular, could have significant consequences.

Deverney Engineering Services conducted a watershed hydrologic assessment for Five Mile Creek watershed (2007) that provided guidance on the condition of the watershed and management direction in response to potential wildfire and MPB effects on watershed values. Both of these disturbance agents may result in widespread removal of tree canopy and hydrological effects. Changes in tree canopy and site water balance are expressed as the equivalent clearcut area (ECA) of the stand or watershed (Lewis and Huggard 2010). ECA is defined as the area that has been clearcut (or cleared of forest cover by other disturbances) with a reduction factor to account for the hydrologic recovery due to forest regeneration (MFLNRO 1995). Both the Kutetl Fire and MPB have had significant effects on watershed hydrology. The watershed report card (Table 11-1) shows the ECA for each sub-basin of the community watershed. The ECA for the total Five Mile Creek watershed in 2007 was already 30%, which is within or near the ECA at which an increase in peak runoff may occur.

Table 11-1. Watershed Report Card (Deverney Engineering Services 2007).

Indictor	Five Mile (West Sub-basin)	Five Mile (East Sub-basin)	Five Mile (Residual)	Total Five Mile Creek Watershed
Total Watershed / Sub-Basin Area (ha)	1,012	2,133	1,576	4,701
Present Weighted Equivalent Clearcut Area (%), including burns and Lodgepole Pine stands under attack from Mountain Pine Beetle	19%	41%	24%	30%
Projected ECA following mortality of Stands at Risk from Mountain Pine Beetle	27%	50%	40%	42%
Total Road / Trail Density (km/km^2) (total kilometres)	0.02 to 0.2 km	0.13 to 2.8 km	0.15 to 8.2 km	0.2 to 11.2 km
Length of Road / Trail as High Sediment Source	0	0	0	0
Number of Stream Crossings	1	1	3	5
Total number of landslides entering streams.	0	1	1	2

The recent outbreak of MPB in the Park has the potential to cause effects such as: increases in water yields; increases in late summer and fall flows; variable responses in peak flows; and possible earlier timing of flows (Uunila et al. 2006). The 2007 hydrological assessment projected an increase in ECA to 42% for the entire watershed because of mortality of pine stands due to MPB (Deverney Engineering Services 2007). This amount of disturbance could result in altered peak runoff flows. An increase in peak flows could result in damage to culverts and bridges, affect water intake conditions, and could increase debris flows and flooding at the mouth of Five Mile Creek (Deverney Engineering Services 2007). The areas affected by MPB are also more susceptible to wildfire due to the dead and downed woody material. Increased fire severity is also likely given the amount of downed woody debris in these areas, which can increase soil hydrophobicity and overland runoff flows post-fire.

In 2003, the Kutetl fire affected 7,916 ha of land in the Kutetl, Five Mile Creek, Lasca and Midge drainages. The combination of MPB and fire related reductions in forested cover could increase peak flows. Access built for fire suppression can also have detrimental effects of watershed hydrological functions; however, access trails and roads built for the Kutetl Fire were rehabilitated, reducing the potential for channeling water and erosion on these surfaces (Deverney Engineering Services 2007).

Wildfire can increase peak runoff rates, as discussed above, and alter the timing of flows due to increased snow pack and changes in solar insolation and albedo. The sum of these changes can result in reductions in water quality and changes in quantity (Deverney Engineering Services 2007) and timing of flows which can result in elevated water treatment costs. As well, watershed rehabilitation to ameliorate post-fire effects can be extremely costly.

Post-wildfire erosion and landslides are a significant concern. Extensive research by MFLNRO has found that the likelihood of debris flows and other landslides in susceptible terrain is significantly increased following severe wildfire in the snow-dominated environment of the southern interior of BC (Jordan 2015). Specifically, numerous debris flow incidents have occurred in the West Kootenays following 2003 and 2007 wildfires including Sitkum Creek, across the lake from the Park (Jordan 2015). Wildfire can have a dramatic influence on watershed functioning depending on fire severity, size, and the terrain of the watershed. The consumption of the tree overstory, understory vegetation, and duff layers leaves soils exposed to precipitation, which can cause elevated rates of soil erosion. Fire may cause chemical changes in the soil that can increase soil hydrophobicity. Increased hydrophobicity reduces infiltration rates and can result in increased overland flow and associated soil erosion.

Slope gradient is an important factor to consider, as it is directly related to sediment erosion and transportation. Forty-four percent of the area in the watersheds is located on slopes greater than 41%, making them vulnerable to surface erosion especially post-wildfire (Table 11-2; Figure 11-1). The slopes greater than 60% are also more susceptible to landslides or other mass wasting events, especially post-fire due to the loss of tree cover and the stability provided by tree roots. Deverney Engineering (2007) indicated that extensive burned areas on steep gullied slopes to the east of Five Mile Creek could result in increased frequency of landslides. Coarse textured soils with granitic origins, which occur in Five Mile Creek, are also believed to be more sensitive to debris slides associated with extreme runoff events. Table 11-2 gives a summary of the slope classes in the community watersheds and indicates the general vulnerability to surface erosion and mass wasting.

Table 11-2. Summary of slopes by class within Nelson Community Watersheds that intersect West Arm Provincial Park.

Slope Class (%)	Area (ha)	Percent
0-20	1,063	14
21-40	3,208	43
41-60	2,546	34
>60	716	10
Total	7,533	100

In the event of a fire and damage to the Nelson water source, restoration would be essential and could be extremely costly. Fire in the watershed could result in closure and damage or destruction of water supply facilities and infrastructure. The potential post-fire increases in erosion, debris flows, and landslides can degrade water quality, affect intake structures, and reduce reservoir capacity. However, water quality is not likely to be significantly impacted by a wildfire in the Five Mile Creek watershed (Peter Jordan, *pers. comm.*). Based on a watershed-scale study of three post-wildfire study sites in southeastern BC near Nelson, Slocan and Trail, effects on water quality were found to be minimal (Jordan 2012).

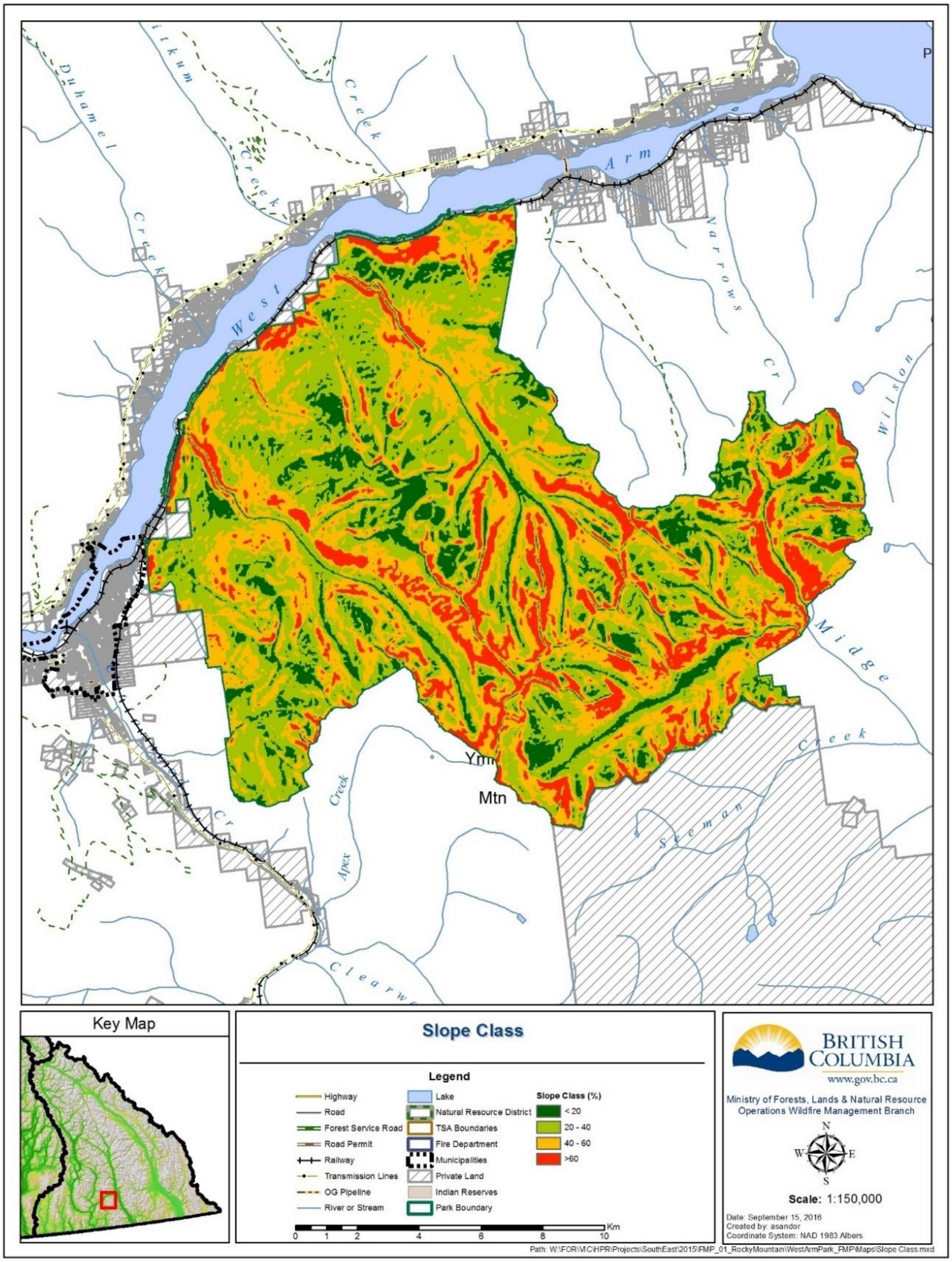

Figure 11-1. Slope classes in West Arm Provincial Park.

11.3 Fire Effects on Social Values

The potential effects on social values including archaeological sites, First Nations interests and recreation values are discussed below. An additional consideration is the potential for increased illegal mushroom harvesting occurring post-wildfire as has been experienced in the past (Amanda Weber-Roy, *pers. comm.*).

11.3.1 ARCHAEOLOGICAL SITES

The identified archaeological features of the Park are mostly located along the lakeshore, which based on location is less susceptible damaging effects due to fire. However, the rest of the Park has not been surveyed for archaeological sites.

11.3.2 FIRST NATIONS INTERESTS

A full understanding of the potential effects of fire on First Nations interests is unknown at this time.

11.3.3 RECREATION VALUES

In the event of a wildfire in the Park there may be effect to recreational users, such as the immediate danger to the lives and safety of individuals present in the Park. This is of particular concern for backcountry activities in West Arm Provincial Park where access is limited. Reduced air quality during and after a wildfire event is another direct effect on recreationists that use the Park. Wildfire and the impacts of preventing and suppression can have many other significant effects on social values, though these are not all well understood (Morehouse 2002). How wildfire affects recreation may differ depending on the recreation activity type, the individuals partaking in these activities, the pre-burn forest condition, and the fire characteristics such as burn timing, size and severity.

There may be both positive and negative responses to wildfire by recreationists. Some individuals may be interested in learning about the recovery process after a wildfire and enjoy spending time in a forest post-burn. For example, Englin et al. (2001) found that hikers increased their recreation activity after a burn in one area, as they were interested in learning about the recovery process and observing the post-burn wildflowers. In contrast, some individuals may find a landscape impacted by wildfire to be visually un-appealing and spend less time there. In a study on the effects of wildfire on hiking and biking demand in New Mexico, it was found that both recreational user groups exhibited decreased visitation in areas recovering from wildfires (Hesseln et al. 2003).

The response to wildfire may depend on the recreation activity type. For example, mountain bikers have been observed to respond more negatively towards crown fires than hikers (Loomis et al. 2001; Hesseln et al. 2003). Backcountry skiers in the Park may be less impacted by wildfire than bikers and hikers, as they visit the landscape when it is covered in snow, and would be less affected by changes to understory vegetation.

The severity of the fire may also factor into public response to fire. Loomis et al. (2001) found that the negative effects of fire on recreation values were higher in areas altered by high intensity crown fires, compared with surface fires. Additionally, visitation frequency of recreationists, in the short-term, decreased more in a wildfire scenario than in a prescribed surface burn scenario in New Mexico (Hesseln et al. 2003). If fire alters the canopy and wildlife habitat, it may influence recreationists that are interested in bird watching, wildlife viewing, nature photography, or hunting. The state of the forest prior to the burn is a factor. If the forest canopy has already been severely impacted by MPB, for example, a loss of canopy due to fire may not be viewed as negatively as a fire in a stand where the forest was healthy or considered old-growth.

Tree mortality and decay after a wildfire can also have negative effects on recreation use and safety. As trees decay and fail, recreational trail maintenance increases and hazard tree removal is required for visitor safety. In Parks with remote or dense trail networks, the scale of hazard tree mitigation and associated costs may limit the ability of Park managers to ensure trails are clear and safe for recreationalists, and in some cases trail closures may be necessary to ensure the safety of Park users.

The degree to which infrastructure, such as roads and trails, are impacted by fire will also affect how recreationists respond to fire. If access or critical infrastructure is damaged during a fire, it would likely result in a decrease in Park use by recreationists. Conversely, if fire suppression activities or fire prevention treatments result in more road access to the Park, recreation activity would be expected to increase.

It is important to note that the response of recreationists to wildfire has been found to differ regionally (Hesseln et al. 2003), and the desires and interests of various user groups in West Arm Provincial Park may differ from those observed elsewhere. It is also important to recognize that the public opinion on loss of forest canopy may be the same whether it is lost to wildfire, pine beetle, or fuel reduction treatments. The risks and ecological benefits of wildfire should therefore be considered over public perceptions.

11.4 Fire Effects on Adjacent Land Ownership and Tenure Values

Values adjacent to the Park are associated with a range of municipal and Provincial Crown land, and private land ownership bordering the Park, as described in Section 6.4 and illustrated in Figure 3-1 (overview of West Arm Park). Potentially affected land and forest resource users include residents or commercial operators (including CPR which maintains adjacent infrastructure), forest licensees, and trapping and mineral tenure holders. The associated values at risk from wildfire include, but are not limited to structures, critical infrastructure, timber, and biodiversity, and wildlife habitat. The wildland urban interface is a key consideration in determining potential wildfire consequences where the Park boundary meets the adjacent communities or other development. The CWPPs completed for the adjacent communities of Nelson and Harrop-Procter provide in depth analyses of potential effects to these communities (Blackwell 2016).

12 FUEL MANAGEMENT

The following section provides an overview of fuel management methods and describes some of the potential impacts to Park values related to fuel management. Note that the principles of fuel management are discussed in further detail in Appendix 4 – Principles of Fuelbreak Design.

12.1 Methods of Fuel Management

The objectives of fuel reduction treatments are to reduce forest surface fuel, increase the height to live crown, decrease crown density, and retain large trees of fire-resistant species. Fuels vary across landscapes and include live and dead organic material, forest floors, herbs and shrubs, twigs and branches, small trees (ladder fuels), and larger trees (canopy fuels). Treatments address some or all of these fuels; however, landscape and stand structure are key considerations in setting treatment targets. Effective methods to meet fuel reduction treatment objectives include prescribed burning, thinning (low, crown, and selective), and fuel break construction (Agee and Skinner 2005).

Prescribed fire is an effective method considering it reduces surface fuels (van Wagtendonk 1996) and can also increase canopy base height by scorching the lower crown of the stand (Agee and Skinner 2005). Burning can also be effective where canopy bulk density is already low enough that active crown fire spread is unlikely (Northern Arizona University 2010). Prescribed burning can be used in combination with thinning where appropriate. During prescribed burning nutrients are released into the system, and may emulate a natural fire regime more closely than thinning activities (Northern Arizona University 2010). However, thinning from below can reduce average canopy bulk density, and crown thinning can be very effective in reducing the risk of crown or stand-replacing fires. For thinning to be effective, the appropriate method needs to be selected and removal of residual must reduce fire behaviour. Residual fuels from the thinning process can increase fuel levels and exacerbate the initial fire hazard rather than ameliorate it (Agee and Skinner 2005; Northern Arizona University 2010). Furthermore, thinning allows for greater considerations of what is retained on the landscape after treatment. For example, tree spacing patterns can be varied (uniform or variable), or specific species can be retained or removed to reflect the desired species composition. It is worthy to note that thinning is more expensive than burning and often requires heavy machinery. In some circumstances, thinning can offset carbon emission from the burning of fossil fuels and can provide managers with the potential for economic gain. For example, in the Northern and Intermountain regions of the United States, the regional Fuels for Schools program utilizes small diameter wood as a bioenergy source to heat schools (McElroy 2007).

Management in BC Parks considers aesthetic, recreational, and ecological impacts of fuel management treatments. Fuel breaks are implemented to support fire suppression activities and to contribute to fuel reduction. The effectiveness of fuel breaks is most determined through strategic placement on the landscape. Breaks are used as a fuel reduction treatment but planned with consideration to fire suppression activities (Green 1977). Fuel break construction can be used in combination with prescribed fire or thinning to contribute to fuel reduction, and to maintain Park values. The development of fuel breaks includes methods such as understory and overstory tree removal.

12.1.1 HAND SLASHING AND PILE BURNING

Fuel treatments such as pruning and removal of small diameter understory ladder fuels can be done by hand. Hand treatments do not require large equipment or road access and can therefore be done in areas that would be ecologically sensitive to soil disturbance or that have difficult access. It is important to note that hand treatments can be very expensive with costs ranging between $6,000-14,000/ha. Hand treatments can also create high slash loads. Extensive areas of slash should be avoided, as they create high fire hazard surface fuel loads. Slash form treatments is commonly addressed by through pile burning.

If pile burning is not done appropriately, it can have negative ecological implications. For example, if piles are too large and burn too hot, they can have severe impacts on the soil and micro fauna below the pile (Oswald et al. 1999). Pile burning in the Park should follow certain restrictions:

- Piles should be kept less than or equal to 3 m in radius and less than 2 m high to avoid piles burning too hot;
- Piles should be created in openings where crown scorch from burning will be limited;
- Piles should be burned concurrently with thinning to reduce slash accumulations;
- Piles should only be burned when fire weather indices indicate low fire behaviour potential;
- Piles should only be burned when there is snow on the ground;
- Piles should only be burned when ventilation indices are compliant with MOE standards; and
- Piles should be seeded with native plants species from seed sources that are certified weed free to prevent the establishment of invasive plant species.

12.1.2 FUEL TREATMENT MAINTENANCE REQUIREMENTS

To ensure the long-term effectiveness of fuel treatments a maintenance schedule must be considered in treatment prescriptions. Ingrowth from coniferous fuels or tree mortality associated with forest health pathogens must be addressed periodically to maintain the desired treatment targets. The long-term costs associated and availability of ongoing funding to maintain treatments should be identified and considered during prescription development. Ideally, a maintenance schedule for review of treatments should be included in fuel treatment prescriptions. By following a maintenance schedule, costs for largescale re-treatment can be avoided but periodic expenditures for maintenance will be required and should be budgeted for.

12.2 Fuel Management Considerations

Fuel treatments need to identify short- and long-term management goals prior to implementation, and need to consider the ecological and social implications (Stephens Moghaddas 2005). Fuel management within the Park and treating strategic locations with the optimal method will reduce fire hazard, and has the potential to make a significant impact on the behaviour and pattern of wildfires (Finney 2001). One of the goals of reducing fuel loads and hazards is to create conditions that reduce fire severity and intensity. In ecosystems that have departed for historic natural conditions, fire behaviour and effects would be reduced and more closely emulate natural disturbance regimes. Promoting a more natural and controlled fire regime enhances the maintenance of a sustainable forest structure, and reduces the likelihood that stand replacing fires will occur (Omi and Martinson 2004).

Considering the benefits to fire hazard reduction from fuel reduction treatments, there are implications to physical, biological and social features that need to be regarded. The implications of fuel management activities are discussed below.

12.2.1 IMPLICATIONS OF FUEL MANAGEMENT ON PHYSICAL FEATURES

Thinning and fuel break activities can require roads and often entail the use of heavy machinery which can have a negative impact on the soil. Fuel break construction, prescribed burning, and thinning activities can, if not properly implemented, result in increases in soil erosion, debris slides or flows, increase runoff and change the soil chemistry which could alter water retention ability (Mataix-Solera and Doerr 2004; Wondzell and King 2003). Water retention is of particular concern considering the City of Nelson's dependence on the Park's watershed. With careful planning, treatments can be designed to protect watershed functions and reduce negative effects due to a wildfire.

12.2.2 IMPLICATIONS OF FUEL MANAGEMENT ON BIOLOGICAL FEATURES

Fuel reduction treatments can have implications on the biological features of the Park. Prescribed burning, thinning, and fuel break construction could be beneficial or detrimental to different features. Burning and thinning can enhance stand structure or be used to create a shift in the seral stage distribution. For example, early seral stages support species would provide deer species and grizzlies with preferred food sources. Conversely, adjusting stands to early seral stages could have negative implications on mountain caribou through increased predation, decreased lichen abundance, or a loss of critical habitat. To avoid this, strategic placement and design of treatments can protect values and areas of concern for specific species. Prescribed burning, thinning, and fuel breaks can also include measures to address invasive plant species or focus on addressing forest health concerns. For example, thinning of other coniferous species in whitebark pine habitat can reduce potential effects to this species. Prescribed burning can also be used to destroy dormant or active fungal pathogens in trees and soil.

Fuel management activities may lead to the colonization of invasive species on disturbed sites. Conversely, it has been suggested that prescribed burning and other restoration activities may aid in preventing the establishment of invasive plants. For example, thinning and burning in dry forests may increase both the productivity and diversity of native plant communities that are more resistant to invasive species establishment (Covington et al. 1997). However, invasive eradication through burning can be species and region specific (Keely 2006). Studies exploring the establishment of invasive species, with respect to disturbed sites, would need to be considered within the appropriate ecological context and invasive species control measures be considered during prescription development.

12.2.3 IMPLICATIONS OF FUEL MANAGEMENT ON SOCIAL FEATURES

The Park is a focal point for recreational activity and is surrounded by an urban area, ski resort, wildlife management area, private land (NCC), and various forest tenures. The public and stakeholders surrounding the Park hold various concerns regarding their personal safety, property, recreation uses, and water supply. Prescribed burning, thinning, and fuel break construction can help to protect the urban interface and the Park through reducing the fire hazard and by enhancing fire management capabilities. Lack of public education regarding the Park and the benefits of fuel management could hinder the implementation of treatments. Fuel treatments are critical to protect or enhance the recreational areas and watershed within the Park, human life, First Nations interests, and adjacent property.

13 SUMMARY OF PART 1

As discussed throughout the above sections, there are a number of physical, biological and social values and management issues in the Park. These values and management issues, and the implications on them by fire, suppression activities, and fuel treatments are summarized in Table 13-1.

Table 13-1. Summary of the implications of fire or fuel treatments on values in the Park as Identified in Part 1.

Values/ Management Issues in the Park	Potential Effects of Fire and Suppression Activities	Fuel Management Considerations
Forest Age Distribution	Reduction in old seral representation in the Park and an increase in younger seral stages. Could cause negative (e.g. increase in fuel loading) and positive changes (e.g. addressing forest pathogens) to habitat depending on species.	If treatments occur in beetle affected stands clearing of all lodgepole pine would change structural stages. However, the high mortality associated with the beetle will also affect structural attributes. In non-beetle affected stands, thinning from below and retention of coarse woody debris could emulate older stand structure.
Mountain Caribou	Fire could result in loss of critical old growth habitat and arboreal lichen winter food supply. It could also cause an increase in predation.	Treatments in caribou habitat would have negative implications. Strategically placed treatments could protect caribou habitat.
Grizzly Bears	Roads from suppression activities could increase human-bear encounters, while increased early seral habitats from fire provide increased food sources.	Bears would benefit from early seral habitat created from openings. Conversely, roads from treatments could increase human-bear encounters, until they are fully rehabilitated as soon as practicable, as per BC Parks policy.
Whitebark Pine	Fire could devastate what is left of the whitebark pine population. Conversely, whitebark pine could regenerate as young healthy saplings post-wildfire.	Stand thinning of other coniferous species in whitebark pine stands would decrease susceptibility to fire.
Invasive Plant Species	Fire can increase invasive species occurrence due to soil disturbance. Poorly planned suppression activities could transport invasive species into the Park. Some invasive species are killed by fire.	Treatments could potentially have no effect on invasive species if soil disturbance is minimal during treatments and equipment is clean. It is thought that prescribed burning can reduce some invasive species.
Community Watersheds	Wildfire can result in erosion, debris flows, mass wasting, potentially degraded water quality, and restoration costs.	Treatments could protect the watershed. Treatments could affect watershed hydrology and need to consider topography and stream ecology.

Values/ Management Issues in the Park	Potential Effects of Fire and Suppression Activities	Fuel Management Considerations
Archaeological Sites	The archaeology sites identified in the Park are along the Kootenay Lake shoreline which is not highly susceptible to fire damage.	Treatments would have little or no effects on the archaeological sites in the Park. BC Parks has archaeological procedures which indicate where archaeological overview assessments (preliminary field reconnaissance) are required before treatments/projects are conducted. Any new/additional identified archaeological sites would be exempt from any treatments requiring machinery.
First Nations Interests	Effects from fire and suppression activities on First Nations have not been identified at this time. BC Parks anticipates gaining a more comprehensive understanding of First Nations aboriginal interests through continued consultation.	BC Parks will consult with First Nations on all potential treatments
Recreation Values	Generally, the response of recreationists towards wildfire in outdoor recreation areas is negative due to aesthetic concerns.	Treatments could protect recreation areas from wildfire. Recreationists may have negative response to some treatments.
Adjacent Land Ownership and Tenure Values	If fire were to escape from the Park it could have detrimental effects on surrounding areas.	Treatments could protect adjacent land ownership, forest management, recreation, and wildlife management area.
Wildland Urban Interface	Fire poses a threat to human safety and property. It could also reduce air and water quality.	Treatments could protect human property, life, and safety.

Part 2: Fire Management Planning

1 PART 2 - INTRODUCTION

Part 2 of this document provides guidance on the development of subsequent operational fire management plans or strategies for the Park in the context of fire management and the values and background management issues identified in Part 1. Part 2 is intended to function as a guide to identify fire management objectives, planning considerations and recommendations, research and data needs to support future planning for the Park, and ongoing consultation requirements.

1.1 Overview of Management Objectives and Issues

Fire management and risk reduction are the overarching concerns that have directed this planning document. However, as discussed in Part 1, fire management must be guided by the values that the Park provides and protects. Where fire management measures are considered, these values must be accounted for during planning and should consider detail at the site level. While consideration of site specific information is beyond the scope of this Plan, the Plan provides strategic guidance and objectives for fire management in the Park. The main objectives identified to guide fire management planning in the Park are protection of watershed values, habitat and biodiversity values, and adjacent communities and the associated values such as recreation.

Protection of the watershed is of extreme importance to the City of Nelson and the region. A large-scale fire could have detrimental effects on water quantity and potentially quality, resulting in negative ecological and economic consequences. Fuel management may reduce the fire hazard in the watershed, but treatments need to be ecologically appropriate and consider effects to soil resources.

Habitat values are an important consideration in the Park for fire management planning. Protection of habitat, in particular for red-listed mountain caribou, was identified as a central objective for fire management in the Park, as an uncontrolled fire could destroy remaining old-growth habitat that is integral to the survival of the species.

The third objective of this Plan is to assist in the protection of Harrop-Procter, the Harrop-Proctor Community Forest, and the City of Nelson from wildfire and to prevent fire from spreading from a community into the Park. Fire management planning also takes into consideration public education, recreation management, First Nations interests, and adjacent land use planning.

2 FIRE MANAGEMENT ZONES

These three objectives informed the development of Fire Management Zones (FMZ), which were identified to best manage the principle value in each region of the Park (Figure 2-1). FMZ boundaries were based on natural topographical breaks, mountain caribou habitat, and proximity of the communities. The three FMZ identified are:

- Watershed FMZ;

- Mountain Caribou FMZ; and
- Harrop-Procter FMZ.

Management objectives and actions specific to each of the FMZ are provided; however, in the event of a fire, all of these FMZ are full suppression zones. A primary recommendation of this report is that tactical suppression response plans be developed for each FMZ.

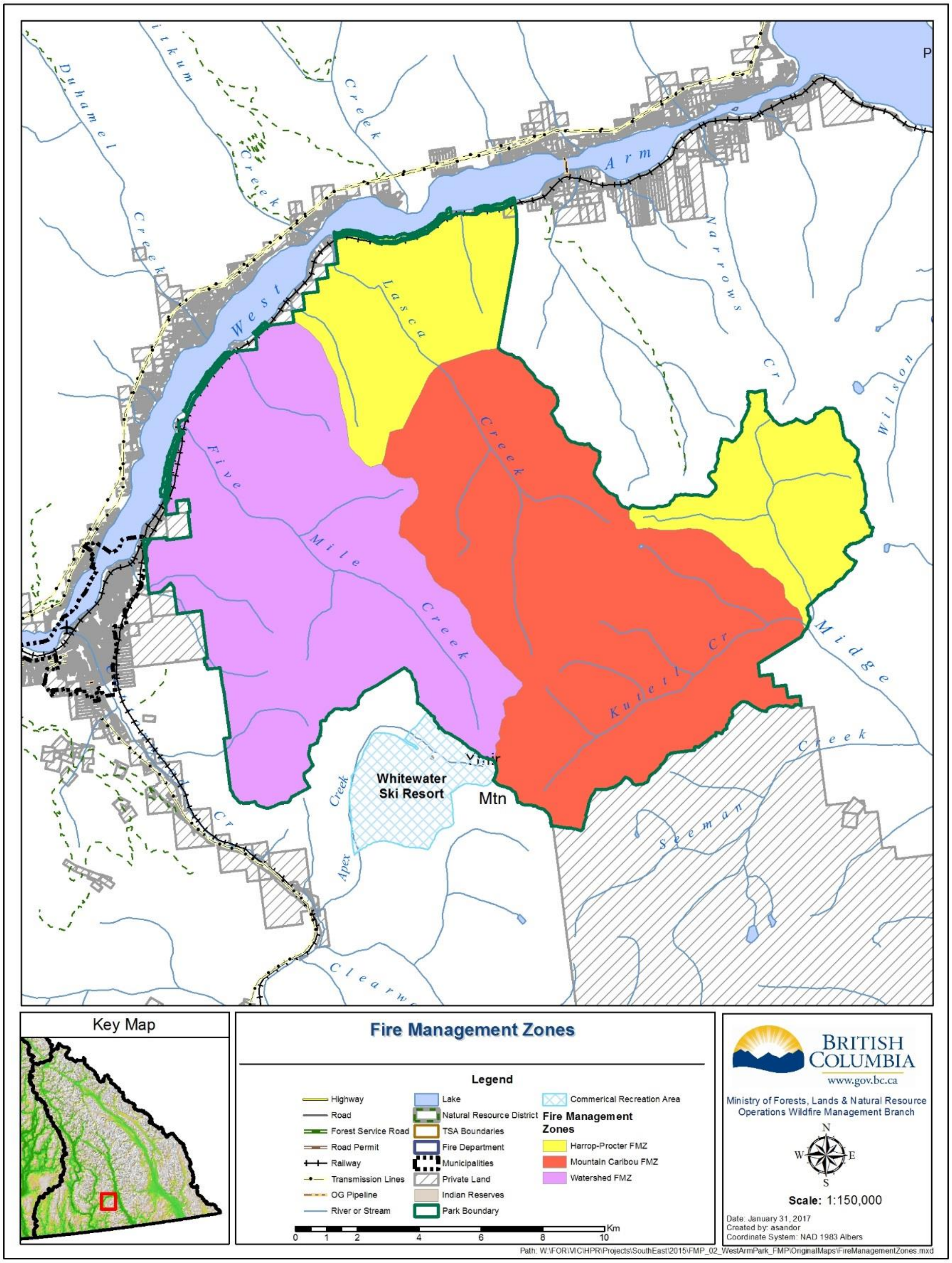

Figure 2-1. Fire Management Zones for West Arm Provincial Park.

2.1 Watershed Fire Management Zone

As illustrated in Figure 2-1, this zone follows the western Park boundary to the west and the ridge above Five Mile Creek to the east. It runs all the way from the northern to southern boundary of the Park, and is 9,830 hectares. It is adjacent to the Nelson WUI and the Whitewater Ski Resort interface. It also includes the highest use recreation areas.

The primary objective of this FMZ is to protect the watershed from wildfire through fuel management and tactical suppression planning. However, this FMZ also provides the dual role of addressing fire movement from the Park to Nelson or from the City to the Park. General recommendations for this zone include assessment of areas for fuel treatments, with particular emphasis on the lower portion of this zone below the watershed and in the interface areas. Detailed fire management objectives and actions for this FMZ are outline in Table 2-1.

Table 2-1. Fire Management Objectives and Actions to support fuel treatment prescription planning in the Watershed Fire Management Zone.

Management Issue	Objectives	Actions
Physical Features	Protect the community watershed from damaging forest fires	• Conduct field work to determine areas for strategically placed landscape level fuel breaks and/or stand level fuel treatments. • Develop prescriptions for fuel treatments, focused primarily in the lower reaches of this zone to protect the spread of fire from the interface into the watershed.
	Minimize the impacts of fuel reduction treatments on soils and hydrology	• Complete a terrain stability assessment prior to prescription development of treatments in areas where slopes are ≥ 60%. • Conduct fuel treatments by hand where possible to reduce the need for heavy machinery and roads. Refer to discussion of hand slashing and pile burning in Part 1. • Develop prescriptions with the consultation of a hydrologist and geomorphologist. • Limit road construction as much as possible, rehabilitate roads after treatments, and do follow-up reassessments and maintenance of the treatment area.
Biological Features	Protect mountain caribou winter habitat from damaging forest fires	• Strategically place fuel treatments to reduce the potential spread of fire from this zone up slope into the mountain caribou reserve zone. • Conduct surveys and identify any areas that are used by mountain caribou in this zone. Avoid treatment within close proximity to areas of use by mountain caribou.
	Enhance forest health	• Focus removal of trees on dead lodgepole pine affected by the mountain pine beetle. • Establish the full extent of pine beetle mortality in the watershed through aerial and on-the-ground surveys.

Management Issue	Objectives	Actions
	Maintain or increase biodiversity	• Increase the mosaic of seral stages across the landscape through treatments. Targets should be developed with consideration of biodiversity guidelines. • Encourage diversity of tree species through ecologically appropriate silvicultural practices.
	Prevent the spread of invasive plant species into the Park	• Regulate and ensure proper cleaning of equipment coming in and out of the Park for treatments. • Monitor for invasive species along the roads and trails in the lower reaches of this zone. • Encourage native herbaceous species growth through use of prescribed burning in treatments where appropriate. • If invasive species are identified conduct treatments to remove them, targeting especially those species with the ability to enhance fire behaviour and threaten biodiversity values.
	Manage for whitebark pine where appropriate	• Conduct terrestrial ecosystem mapping to identify the current whitebark pine population and suitable habitat. • Preferentially remove pine beetle attacked lodgepole pine to reduce the beetle stress on whitebark pine. • Retain all healthy, and cone producing whitebark pine trees. • Work with knowledgeable partners on the recommendations presented in the forthcoming Federal Whitebark Pine Recovery Strategy.
Social Features	Help protect Nelson and recreation areas from damaging forest fires	• Treatments in the Park should be integrated with treatments proposed outside the Park by neighbouring communities to protect Park watershed values, the urban interface, and to reduce the probability of fire moving from the Park into the interface and vice versa.
	Maintain a positive working relationship with the local mountain bike group	• Consult with local recreation groups prior to treatment prescriptions.
	Increase public education regarding fire hazard and fuel management	• Hold public meetings and educational seminars in Nelson, providing educational information about fire hazard in the Park and the theory of fuel management and its focus on protection of resource values. • Put up interpretive signs where fuel treatments are being implemented to raise public awareness about management in the Park. • Educate residents that live in close proximity to the Park about FireSmart principles so they can implement treatments on their properties.
	Protect archaeological values	• Conduct an archaeological overview assessment (AOA) of the potential treatment areas.

Management Issue	Objectives	Actions
	Protect First Nations Interests	• Continue to engage First Nations to identify and protect areas of interest. • Determine mitigation measures to protect identified areas of interest. Protect them through suppression planning or strategically placed fuel management if required.
General	Full suppression in the event of a fire	• Develop a tactical suppression plan (See Section 4.2 for details). • Develop a rehabilitation plan in the event of a fire. • Chemical retardants should be evaluated regarding the potential environmental effects in the watershed prior to their use in this zone.

2.2 Mountain Caribou Fire Management Zone

As shown in Figure 2-1, this FMZ encompasses the primary mountain caribou habitat; it is 9,326 ha and includes Kutetl creek and the upper portion of Lasca creek. It is a reserve FMZ, as it is recommended that this zone be free of treatments unless the treatments are designed with the focus of restoring mountain caribou habitat. Most fuel treatments will be focused in other sections around this FMZ to protect it from fire without conducting fuel treatments in this FMZ. Details on management objectives and action in this FMZ are outlined in Table 2-2.

Table 2-2. Fire Management Objectives and Actions in the Mountain Caribou Fire Management Zone.

Management Issue	Objectives	Actions
Biological Features	Clearly identify viable mountain caribou current range and potential habitat	• Conduct field surveys to identify current most valuable habitat and areas of use by the mountain caribou, and to locate areas of high suitability to be protected. • Use field data to enhance current caribou habitat mapping.
	Protect mountain caribou habitat from human encounters	• Treatments are not recommended in this zone unless designed to improve mountain caribou habitat (e.g. in areas affected by MPB). • Protect this zone from fire – fire is undesirable in this zone. • Roads should not be developed in this zone, but if temporary roads for suppression are created in adjacent zones ensure that they are monitored/rehabilitated to prevent unauthorized motorized activity from entering this zone.
	Manage for whitebark pine and blue-listed tender sedge where appropriate	• Conduct terrestrial ecosystem mapping to identify the current whitebark pine population and suitable habitat and to survey for the blue-listed tender sedge.
Social Features	Educate the public about mountain caribou habitat	• Develop means of education about mountain caribou habitat and vulnerability in the areas where recreation overlaps with important winter habitat such as backcountry ski areas.
General	Full suppression in the event of a fire	• Develop a tactical suppression plan (See Section 4.2 for details). • Develop a rehabilitation plan in the event of a fire. • This zone should be off limits to cat guard construction, as mountain caribou are sensitive to motorized activities.

2.3 Harrop-Procter Fire Management Zone

As shown in Figure 2-1, this FMZ is comprised of two separate areas. The upper area is 2,651 ha and is the portion of the Park that connects to the Midge Creek Wildlife Management Area to the east. The lower area is 3,281 ha at the base of Lasca Creek and adjacent to the Harrop-Procter interface area.

The primary objective in this FMZ is to protect the adjacent areas including the communities of Harrop and Procter, the Harrop-Procter Community Forest, and the Midge Creek Wildlife Management Area, as well as protecting mountain caribou habitat from wildfires spreading upslope from this FMZ. Protection of areas in this FMZ should include landscape level fuel breaks or stand level fuel treatments where needed and ecologically appropriate, and tactical suppression planning. This FMZ should be assessed for areas where natural fuel breaks could be enhanced through fuel management. To enhance treatments in the Park and better protect values in this zone, treatments are being recommended in Harrop-Procter and the Harrop-Procter Community Forest. Detailed fire management objectives and actions for this FMZ are outline in Table 2-3.

Table 2-3. Fire Management Objectives and Actions to support fuel treatment prescription planning in the Harrop-Procter Fire Management Zone.

Management Issue	Objectives	Actions
Physical Features	Minimize impact of fuel reduction treatments on hydrology and terrain	• If treatments are to be conducted on steep slopes, and/or in Lasca Creek, prescriptions should be developed with the consultation of a hydrologist and a Professional Geoscientist with experience in terrain stability assessment. • Minimize construction of roads and rehabilitate all roads/trails after treatments and do follow-up reassessments/maintenance treatments.
Biological Features	Protect mountain caribou winter habitat from damaging forest fires	• Strategically place any treatments/fuel breaks in the lower portion of this zone to reduce potential fire spread up Lasca Creek into the Mountain Caribou Reserve Zone. • Conduct surveys and identify any areas that are used by mountain caribou in this zone. Avoid treatment within close proximity to areas of use by mountain caribou.
	Maintain wildlife habitat connectivity between the Park the Midge Creek Wildlife Management Area	• Avoid treatments in the upper portion of this zone that will alter wildlife habitat connectivity between the Park the Midge Creek Wildlife Management Area. This is to be determined through a detailed habitat survey.
	Enhance Forest Health	• Focus removal of trees on dead pine affected by the mountain pine beetle.
	Maintain or increase biodiversity	• Increase the mosaic of seral stages across the landscape through treatments. Targets should be developed with consideration of biodiversity guidelines. • Encourage diversity of tree species through ecologically appropriate silvicultural practices.
	Prevent the spread of invasive plant species into the Park	• Regulate cleaning of equipment coming in and out of the Park for treatments. • Monitor for invasive species along the Canadian Pacific Railway and Lasca Creek Trail in the lower reaches of this zone. • Encourage native species herbaceous species growth through use of prescribed burning in treatments where appropriate. • If invasive species are identified conduct treatments to remove them, targeting especially those species with the ability to enhance fire behaviour and threaten biodiversity values.

Management Issue	Objectives	Actions
	Manage for whitebark pine where appropriate	• Conduct terrestrial ecosystem mapping to identify the current whitebark pine population and suitable habitat. • Preferentially remove pine beetle attacked lodgepole pine to reduce the beetle stress on whitebark pine. • Retain all healthy, and cone producing whitebark pine trees. • Work with knowledgeable partners on the recommendations presented in the forthcoming federal Whitebark Pine Recovery Strategy
Social Features	Help protect adjacent land use areas from damaging forest fires	• Treatments in the Park should be integrated, where practicable, with treatments proposed outside the Park by neighbouring communities. • Assess the areas in the upper portion of this zone for natural fuel breaks that could be enhanced through fuel treatments to protect the Midge Creek Wildlife Management Area, and the Harrop-Procter Community Forest. • Assess the lower portion of the Park for areas of potential fuel reduction treatments that could protect Harrop-Procter from fires spreading from the Park and vice versa.
	Protect archaeological values	• Conduct an archaeological overview assessment (AOA) of the potential treatment areas.
	Protect First Nations interests	• Continue to engage First Nations to identify and protect areas of interest. • Determine mitigation measures to protect identified areas of interest. Protect them through suppression planning or strategically placed fuel management if required.
	Increase public education regarding fire hazard and fuel management	• Hold public meetings and educational seminars in Harrop-Procter providing educational information about fire hazard in the Park and the theory of fuel management and its focus on protection of resource values. • Put up interpretive signs where fuel treatments are being implemented to raise public awareness about management in the Park. • Educate residents that live in close proximity to the Park about FireSmart principles so they can implement treatments on their properties.
General	Full suppression in the event of a fire	• Develop a tactical suppression plan (See Section 4.2 for details). • Develop a rehabilitation plan in the event of a fire.

3 FUELBREAK PLANNING

Based on the Provincial Strategic Threat Analysis (PSTA) and potential fire behaviour, and the values at risk within and adjacent to the Park, wildfire risk is high. Even incorporating fuel treatments that have been implemented in the Park around watershed infrastructure and in the adjacent jurisdictions of the City of Nelson and Regional District of Central Kootenay (RDCK), Electoral Area E, a significant amount of the fuels types in the Park are capable of impacting the adjacent interface areas and Park values, including the watersheds during periods of high and extreme fire weather danger.

3.1 Development of a Fuelbreak Plan

Fuelbreaks can be defined as strategically placed strips of low volume fuel where firefighters can make a stand against fire, and which provide safe access for fire crews in the vicinity of wildfires, often for the purpose of lighting backfires.

There has been significant debate about the use of fuelbreaks and their effectiveness during wildfire suppression activities. Debate has been focused on a range of issues including fuelbreak objectives, prescriptions, differences in fuel conditions, and variation in weather conditions. Fuelbreaks are not designed to stop fires but to allow suppression forces an increased probability of successfully containing a wildland fire.

Within the management context of BC Parks, which must be sensitive to visual, ecological and recreational concerns and public perception, shaded fuelbreaks in combination with specific area treatments using prescribed fire or other manual/mechanical methods are generally most appropriate. A shaded fuelbreak is created through reduction of surface fuels, increasing height to live crown, and lowering stand density through tree removal (Figure 3-1). However, where forest health issues are a concern, such as the current MPB outbreak in the Park, treatments must consider these issues.

Fuelbreaks can be developed through a variety of prescriptive methods combining understory and overstory fuel removal, timing of treatment, synergistic effects with other treatments, and placement on the landscape. In the case of fuelbreak treatments in the Park, where possible, structural characteristics of pole sapling or young forest stands can be altered to accelerate succession to mature forest structural conditions with lower stand densities and reduced ladder fuels. Additionally, treatments can be developed to incorporate the types of natural disturbances that have historically acted upon ecosystems, emulating the pattern and frequency of these disturbances while reducing hazardous fuel types.

Fuelbreak planning must also consider the long-term successional pathways and how these may affect future fire behaviour and biodiversity values. In particular, tree species regeneration and the implications for future forest species composition should be considered. Prescriptions should identify natural regeneration, site conditions, and the resultant stand composition expected. Where future stand composition is incompatible with the long-term maintenance objectives of the prescription, additional measures such as planting fire resistant species or conversion to deciduous species that are appropriate for site conditions and support biodiversity and habitat objectives should be prescribed. It should be noted that funding opportunities may constrain these activities; however, they should be included in prescriptions to ensure they are implemented where feasible.

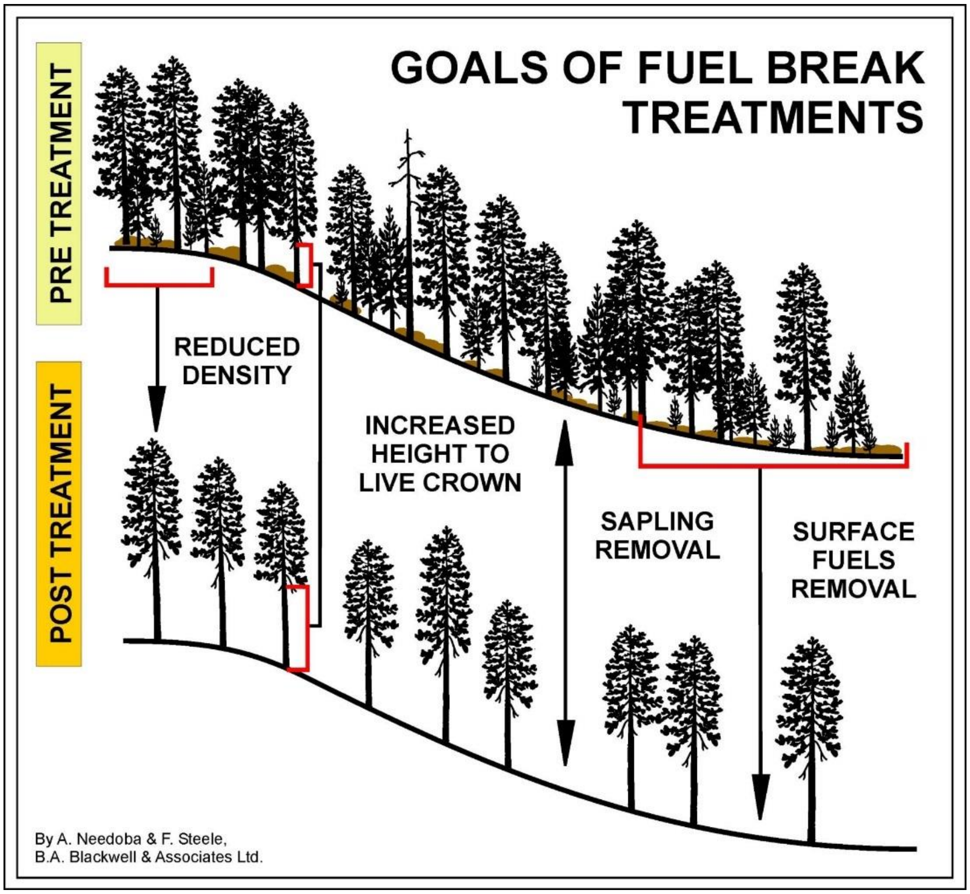

Figure 3-1. Conceptual diagram of a shaded fuelbreak pre-treatment and post-treatment.

The principles of fuelbreak design are detailed in Appendix 4. The principle objective behind the use of fuelbreaks and any other fuel treatment is to alter fire behaviour over the area of treatment and, as previously discussed, provide points of anchor for suppression activities. The key principles to be considered in designing fuelbreaks include:

- Fire Management Zones in the Park and the associated goals and objectives and recommended actions (section 2);
- Management of surface fire behaviour and intensity by removing or modifying surface fuels;
- Modification of conditions that initiate crown fire; and
- Modification of conditions that allow crown fire spread.

Appendix 4 includes additional discussion of the factors that contribute to the effectiveness of fuelbreaks.

3.2 Synergies between Fuelbreak and Biodiversity Objectives

BC Parks has identified ecosystem based management as the approach best suited to managing protected areas. Managing ecosystems and maintaining ecological processes that influence these systems are part of the principles that guide BC Parks' commitment to conservation. By understanding the processes and disturbances that shape ecosystems, fuelbreak treatments and objectives can be tailored to help emulate these. Fuel treatments, particularly in areas where natural disturbance has been actively excluded by humans, can be used to recreate more natural structure and reintroduce disturbance into ecosystems in a controlled manner.

Often the purpose of fuel treatment is to either accelerate stand succession from the stem exclusion stage toward the understory re-initiation stage or to create a disturbance that emulates a natural disturbance and resets the trajectory of the ecosystem. Both of these approaches are appropriate within the Park and are aligned with the BC Parks Conservation Policy and ecosystem-based-management planning approach, which recognizes the primary importance of ecological processes and maintenance of ecological integrity (MOE 2014). As forests age, the characteristics that define them change. The rate and type of change is dependent on the species present, site characteristics, stand origin, and natural disturbances acting on the forest. In the absence of disturbance, species mixes tend to shift from pioneer species to shade intolerant species and eventually, where a seed source is present, to more shade tolerant species. Densities rise sharply in pole sapling stands and then begin to decline until mature and old forest conditions are established. As tree density falls, more light becomes available, which increases the abundance and diversity of understory species and canopy tree layers.

Forests ecosystems are shaped by the site characteristics such as aspect, soil moisture, soil nutrient regime, vegetation community types, and the way in which successional pathways are influenced by these communities. Natural disturbances are also important in creating a mosaic of forest type and structure on a landscape level. Disturbances can range from the biotic: animals, disease, and human intervention, to the abiotic: fire, wind, avalanche and flooding. Each has a unique outcome, which varies according to the severity and frequency of the disturbance and pre-disturbance conditions.

Fuel treatments can emulate some of these changes through mechanical means by reducing stand density and the tree species retained. By reducing stand density through thinning, fuels can be reduced and the reestablishment of understory plants can be encouraged, which in turn provide forage, nesting, and other valuable habitat features for a variety of organisms. Density reductions can be achieved through variable spacing rather than the more uniform spacing associated with forest management for silvicultural objectives, creating gaps, patches, and uniform areas. Tree species can be retained or removed to reflect the selective pressures the natural disturbance types exert upon species mixes within forests. In forests where the dominant natural disturbance type is frequent, low severity fire, shade intolerant fire adapted species would be retained and more shade tolerant species with thinner bark and low crowns would be thinned. In areas with mixed severity fires, treatments would be designed to leave refugia patches of varying sizes and include dispersed retention of shade tolerant tree species. Stand replacing regimes would be best emulated with tree removal over large areas and regeneration with species requiring mineral soil as a seed bed.

By adopting an approach where treatments accelerate stand succession or emulate natural disturbances, where appropriate, a combination of fuelbreak and biodiversity objectives can be met. This is an important consideration for biodiversity, since a lack of habitat diversity at the landscape level can cause a decline in some species of concern (Carey 2003).

Surface fuel loads are a more important consideration for wildfire risk than for biodiversity since higher surface fuel loads increase fire severity. Fuel treatments focus upon small diameter coarse woody debris (CWD) and allow the retention of large CWD, as these are not as significant a contributor to fire spread but do provide important habitat for a variety of species, supporting biodiversity goals.

Retention of deciduous species is desirable both to help reduce wildfire risk and manage for biodiversity. From a wildfire perspective, deciduous species have lower flammability and reduce the horizontal continuity of fuels. Deciduous species also provide valuable and varied habitat and food sources within forested stands (Muir et al. 2002).

Forest health is not a direct concern of either objective, but the removal of diseased young trees increases the chances that the remaining trees will achieve long-term forest health goals. From a biodiversity perspective, the term forest health is not applicable since disease and senescence, especially in larger and older trees, provide habitat niches for many species (BC Ministry of Forests and BC Environment 1995). Since small trees are the main targets of thinning, conflict between the objectives is likely minimal.

Fuelbreaks are often located in lower elevation forest close to values at risk. These forests commonly experienced more frequent historic fire return intervals and lower severity fires than higher elevation forests. Maintenance of the historic stand conditions in lower elevation forests through shaded fuelbreaks can reduce the potential for fires to travel upslope and become stand replacing fires in high elevation forests, and negatively affect mountain caribou habitat in the Park.

4 MANAGEMENT ACTIONS TO SUPPORT WILDFIRE PLANNING

This section discusses fuelbreak design and the current gaps in information and planning for the Park that should be filled to support pre-fire planning and post-fire rehabilitation planning. Implementation of the recommendations in the following sections is subject to available funding and staff resources.

There are four principle actions that BC Parks should consider to support wildfire risk reduction and planning for the Park:

1. Creation of the landscape level fuelbreaks;
2. Development of tactical response plans;
3. Collection of Park inventory data to support planning; and
4. Development of a wildfire rehabilitation plan.

These four management actions are explained in detail in the following sections. Where applicable, the recommendations for each action have been prioritized based on their relative importance. However, the order in which they are completed will depend upon the funding and resources available. Some lower priority recommendations may be completed before those with higher priority based upon the ability of BC Parks to implement them. While the recommendations have been made to support planning in the Park, many of the recommendations will be best conducted or supported by partnering agencies, the City of Nelson, or the RDCK.

4.1 Fuelbreak Design for West Arm Provincial Park

4.1.1 CONSIDERATIONS IN LOCATING FUELBREAKS

Based on the supporting information presented in this Plan and field reconnaissance, potential fuelbreak review areas in the Park were identified in the Watershed FMZ and Harrop-Procter FMZ. The selection of these areas considered fire history, fire behavior, values at risk, topographic and logistic constraints in terms of fuelbreak construction, and natural fuelbreaks. This Plan has been developed in conjunction with Community Wildfire Protection Plans (CWPP) for the City of Nelson and adjacent Electoral Areas E and F of the RDCK, and it considers constructed fuelbreaks external to the Park that will enhance the effectiveness of a fuelbreak in the Park.

The recommended landscape level fuelbreaks for the FMZs cross jurisdictional boundaries and require coordination with other agencies including adjacent municipal jurisdictions, stakeholders such as adjacent communities, licensees, and utilities. Establishing landscape level fuelbreaks based on the considerations listed above and irrespective of the Park boundary, allows for optimal placement of the fuelbreaks to protect values at risk within and external to the Park.

The areas considered for landscape level fuelbreaks are primarily on the lower slopes of the Park. While fire threat and rates of spread are often higher in most of the large, steep valleys in the Park, due to a combination of topography and fuel types, fuel treatments are not recommended in these areas as logistics, costs, and potential impacts on slope stability are prohibitive. As most human caused ignitions occur on the lower slopes, preventing a fire from moving upslope into the Mountain Caribou FMZ is the most effective means of protecting higher elevation caribou habitat, while minimizing potential negative effects of fuel treatments on caribou. Rapid detection and suppression of ignitions in all areas of the Park is also important to reducing possible negative effects to caribou habitat.

The highest risk areas identified (where high rates of spread, high fire intensity, and values at risk occur) are east of the City of Nelson, in and below the Nelson community watershed, and west of Harrop-Procter. The Svoboda Road community is located in the midst of this area, and historic human caused ignition has also occurred frequently in this area.

Since 2009, the City of Nelson and Harrop-Procter have treated 145 ha adjacent to the Park and an additional 69 ha have been treated in the Park to reduce fire risk to watershed and Park values and improve suppression capability (Table 4-1; Figure 4-1). Additional fuel treatments are recommended in both the Watershed and Harrop-Procter FMZs. Figure 4-1 identifies areas where review of future treatments is recommended, principally along the Park boundary adjacent to Harrop-Procter, Nelson, and up Five Mile Creek.

The Interface Working Group has been formed with representation by senior staff from BC Parks, the City of Nelson and the RDCK to collaboratively plan and implement fuel management in the overlapping interface area of all these jurisdictions. Future fuel management planning in the Park will be subject to other BC Parks policies as they relate to: impact assessment, First Nations consultation, archaeological assessment, and public consultation.

4.1.2 RECOMMENDED FUELBREAK REVIEW AREAS

All of the following recommendations apply to areas considered for treatment; however, it must be noted that final operational fuel treatments will be subject to available funding and confirmation based on field work. Final prescription areas will also be subject to relevant BC Parks policies including: impact assessments, First Nations consultation, archaeological assessment, and public consultation.

The treatments have been identified based on a landscape level approach that considers adjacent values and fire behaviour and are the result of consultation and cooperation between BC Parks, municipal, and regional governments and other agencies and stakeholders. This collaborative planning has been effected in part through the quarterly meetings of the Interface Working Group represented by senior staff from City of Nelson, RDCK, and BC Parks.

The recommended fuelbreak review areas are located in lower elevation forest close to values at risk. These forests commonly experienced more frequent historic fire return intervals and lower severity fires than higher elevation forests. Maintenance of the historic stand conditions in lower elevation forests through shaded fuelbreaks can reduce the potential for fires to travel upslope and become stand replacing fires in high elevation forests, and negatively affect mountain caribou habitat in the Park.

These potential fuelbreak areas could also be designed to address forest health issues and restoration goals such as reintroducing fire into these ecosystems in a controlled manner and developing, over the long term, stand structures that are reflective of the natural disturbance types. Creation of these fuelbreaks will help protect the community watersheds from fires initiated in the wildland urban interface, reduce spread of fire into the Mountain Caribou FMZ, and provide an anchor point to base suppression efforts from in the event of a large wildfire.

In the Harrop-Procter and Watershed FMZs, there are four main areas where fuelbreak review is recommended. In the Harrop-Procter FMZ, along the Park boundary adjacent to Harrop-Procter, and in the Watershed FMZ from the water intake on Five Mile Creek to the previously treated areas and an expansion of the treatment area along the waterline (Figure 4-1; Figure 4-2; Figure 4-3). Area adjacent to the Svoboda Road community is also identified and will tie into the large existing fuel break in the Park.

In total, there are an additional 1,468 ha of forest fuels that have be identified for further field review to confirm their suitability for fuelbreak treatments adjacent to the Park in both the City of Nelson and community of Harrop-Procter. Within the Park, 568ha have been identified for fuelbreak review (Table 4-1; Figure 4-1). These are described in greater detail below.

Table 4-1. Past fuel treatments and areas proposed for review for fuelbreaks.

Description	Within Park (ha)	Outside Park (ha)	Total (ha)
Past Treatments	69	145	214
Proposed	568	1,468	2,036

4.1.2.1 HARROP-PROCTER FMZ FUEL BREAK REVIEW AREAS

Located in the Harrop-Procter FMZ, a 356-ha area was identified for review for fuel break treatments in the Park. The area was selected adjacent to Harrop-Procter to complement fuelbreaks proposed outside the Park to the west and south of the community (Figure 4-2). The area selected for treatment review was selected based for several additional reasons, including fire threat, ignition potential, proximity to the community, accessibility, and the potential to be used as an anchor for fire suppression activities.

The PSTA fire behaviour in these areas is mixed and includes PSTA classes with high fire threat (7, 8 and 9) but also some areas with lower fire threat. During prescription development, these areas will need to be field checked and treatment prescriptions should focus efforts on areas with higher threat. While historical ignitions are scattered throughout the FMZ, ignition potential due to human activity is likely higher due to greater human activity in this area.

The proximity of the Park to Harrop-Procter is a significant consideration to improving protection for the community. Development of fuel breaks in this area will help prevent the movement of fire with the prevailing winds from the southwest into the community. As part of the CWPP process (Blackwell 2016), a fuel break review area has also been identified south of Harrop-Procter that will help to prevent upslope movement of a fire from the community and protect the community from fire driven by winds that originate south of the community. There is existing access to the area along Lasca Creek Road and potentially from the Harrop-Procter review area. The location of the fuel treatment review area proposed in the Park and the recommended areas in the CWPP adjacent to Harrop-Procter (Blackwell 2016) will also provide BCWS suppression crews with locations to anchor suppression efforts from, providing protection for the Park and community.

4.1.2.2 WATERSHED FMZ FUEL BREAK REVIEW AREAS

Located in the Watershed FMZ, there are three areas recommended for fuel break review areas in the Park (Figure 4-3). The area located directly adjacent to the City of Nelson (140 ha) and the Svoboda residences (28 ha) were selected based on proximity to Nelson and Svoboda Road, fire threat, and ignition potential. The treatment review area located along Five Mile Creek (43 ha) was selected to tie into existing fuel breaks and the Five Mile Community Watershed infrastructure that has already had FireSmart protection.

The Park boundary is closer to the WUI of the City of Nelson in this area than at any other location (Figure 4-3). Movement of fire from the City into the Park is possible and establishment of a treatment unit in this area would help reduce the probability of fire spreading into the Park and affecting watershed values and values in the

Mountain Caribou FMZ. The location was also chosen as the PSTA fire threat in this area is high, in part due to MPB caused mortality, and ignition potential is elevated due to heavy recreation use in the area. As the prevailing winds come from the south and southwest, the treatment area would help provide protection from an interface fire moving into the Park. It also provides a good location to anchor suppression efforts from.

The treatment review area located along Five Mile Creek was chosen to increase protection for water supply infrastructure, reduce fire behaviour along Five Mile Creek, and help provide a fuelbreak and suppression anchor that connects to the 2009 treatments (Figure 4-3). While PSTA fire behaviour is not high along this area, the ease of access and strategic location of the area would help prevent a fire moving up Five Mile Creek into the watershed. By connecting to the 2009 treatment area, a treatment in this location would help create a fuelbreak that extends over 2 km east from the Park boundary. This would provide crews with a good anchor for suppression activities in the Watershed FMZ.

The treatment review area to the east and west of the Svoboda community was selected in response to community comments requesting that this area be assessed. Fuel types, fire behaviour potential and the proximity to the residences support the identification of this area. A fire moving from Burlington Northern Rail Trail has the potential to affect the community, and there is potential for a fire to move out of the community, uphill into the Park. The section to the west presents logistic challenges due to slope and access that may limit treatment opportunities, these will be characterized during the review of these areas and the opportunity for fuel treatments will be assessed. The eastern section would tie into the existing fuel treatment and increase the effectiveness of this treatment.

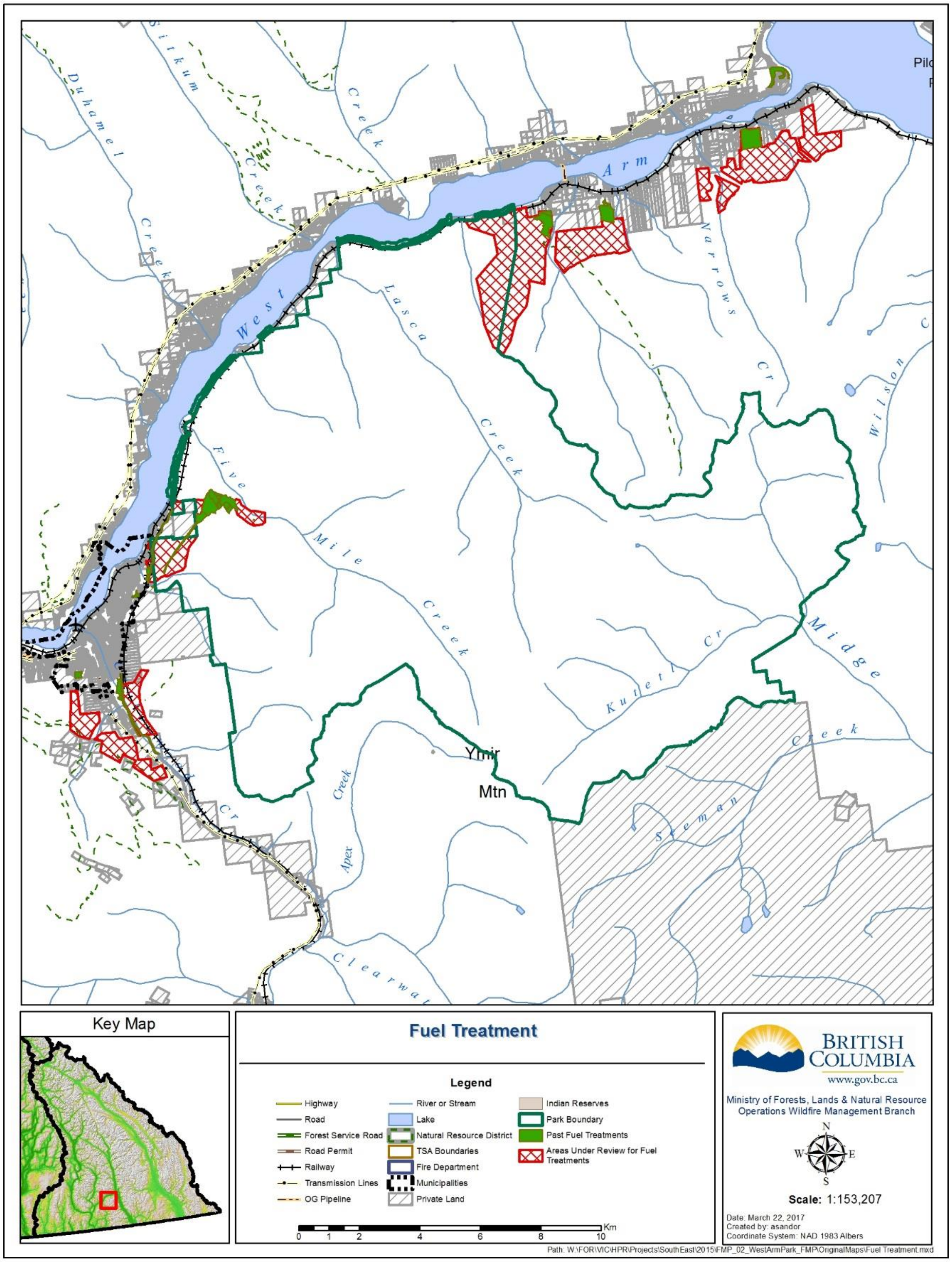

Figure 4-1. Previously treated fuelbreaks and areas recommended for review for fuelbreak establishment.

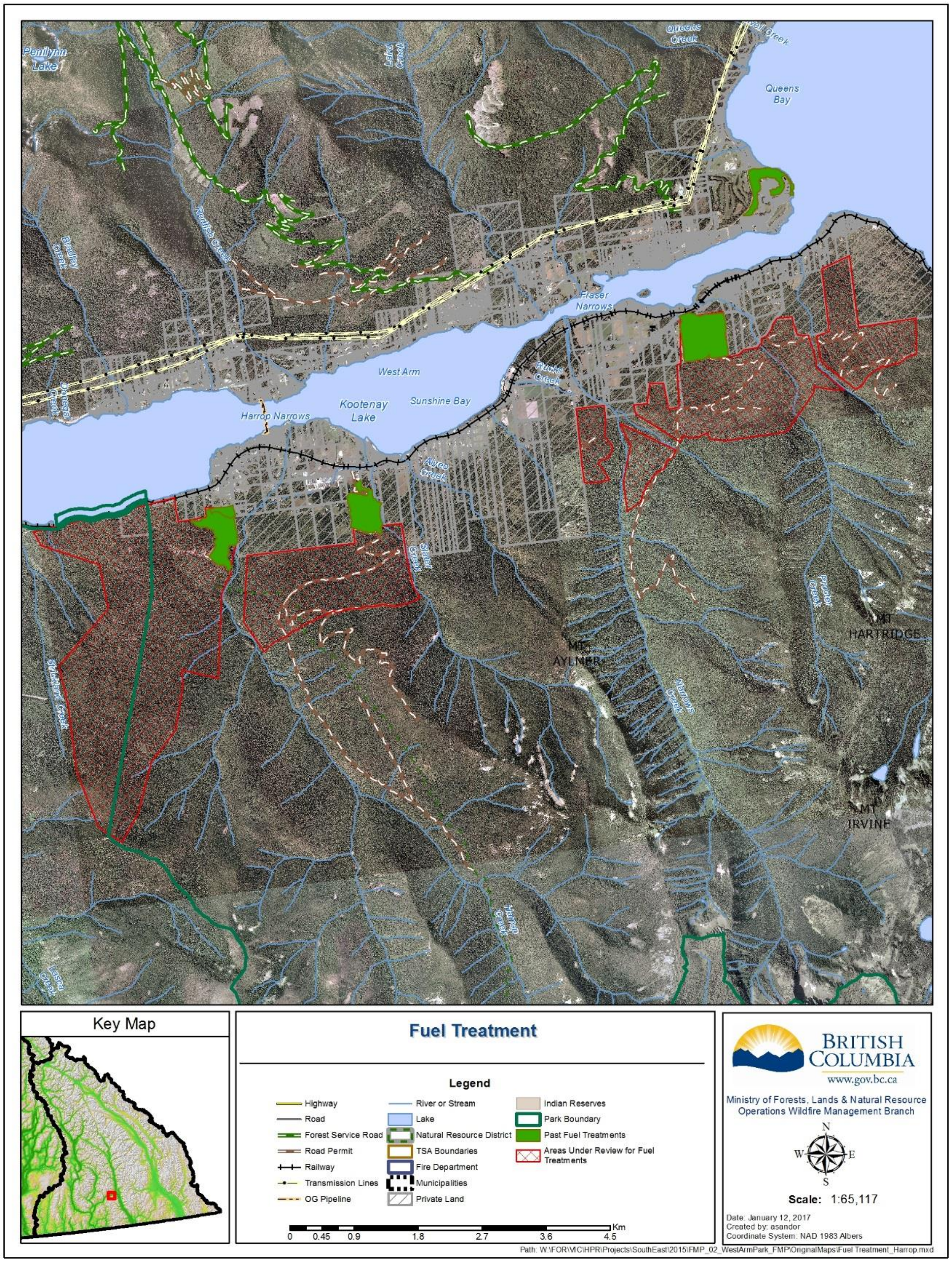

Figure 4-2. Fuelbreak areas recommended for review in the Harrop-Procter Fire Management Zone and fuelbreak review areas outside of the Park.

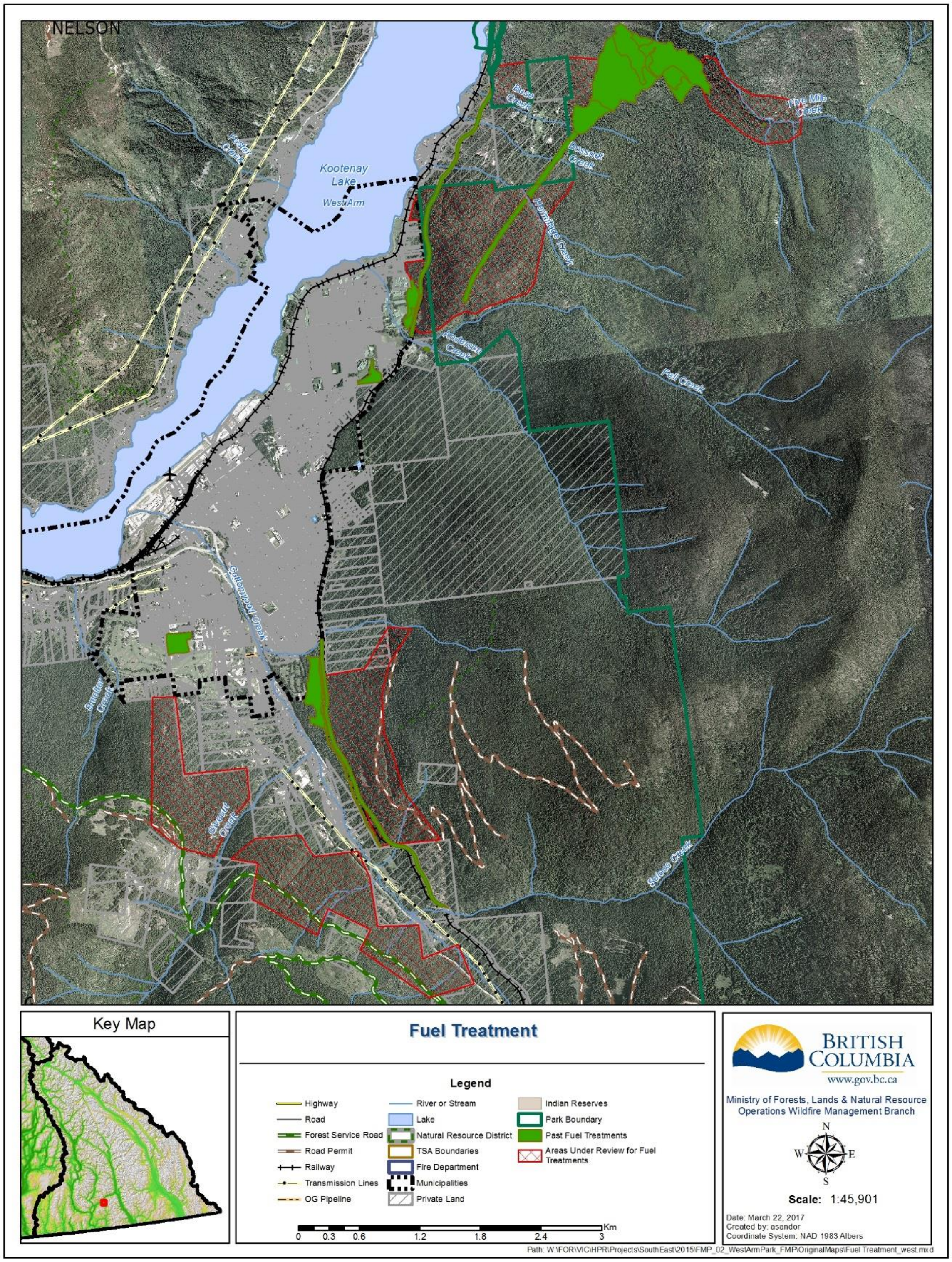

Figure 4-3. Fuelbreak areas recommended for review in the Watershed Fire Management Zone and fuelbreak review areas outside of the Park.

4.1.3 STEPS TO FUELBREAK IMPLEMENTATION

Prior to implementation of the fuelbreaks, there are a series of steps required including First Nation and public consultation, reconnaissance of the proposed areas, field work and engineering, and issuance of requests for proposals (RFP) that must occur. Depending on funding, a phased approach to implementation of the prescriptions may need to be developed. If required, this can be identified during or after the development of the prescriptions. The next steps required for development and implementation of the fuelbreaks include:

1. First Nation and public consultation on the fuelbreak review areas (conducted in part as part of consultation for this Plan);
2. Interface Working Group determines most appropriate recommended fuelbreak treatment to implement based on priorities, values and partnership opportunities;
3. Issuance of an RFP for fuel treatment prescription development informed by First Nations and public consultation;
4. Field reconnaissance of fuelbreak review areas to confirm suitability for prescription development and identification of preliminary treatment boundaries;
5. Fuel prescription development and engineering;
6. Conduct a BC Parks impact assessment of the proposed fuel treatment area/prescription as required;
7. Conduct an Archaeological Overview Assessment to identify any archaeological values in the proposed fuel treatment area as required;
8. First Nations and Public consultation on the fuel prescriptions and revision of the prescriptions as required;
9. Issuance of an RFP for fuel treatment implementation; and
10. Implementation of the fuel treatment.

4.1.4 EXISTING FUELBREAK MAINTENANCE

The existing 69 ha of fuelbreaks that were established in the Park should be reviewed to identify maintenance that may be required. The previously treated area along the City of Nelson water pipeline is included in the prescription review area and will be assessed to determine maintenance requirements as part of any prescriptions developed for this area. A prescribe burn was recommended for the previously treated area in the Five Mile Community watershed. As the burn was not conducted, a review of this area is recommended to characterize surface fuel loading and coniferous regeneration. Maintenance of this treatment area should consider maintenance options such as implementation of a prescribed burn, reduction of lodgepole pine regeneration, and planting of fire resistant tree species such as Douglas-fir, western larch, and ponderosa pine, depending on site and regional climatic conditions. Conversion to fire resistant coniferous species, with consideration of potential effects of climate on these species, could reduce the negative effects of future wildfires in the previously treated area.

4.2 Tactical Response Plans

All of the zones in the Park are full suppression zones. This means that in the event of a wildfire, full suppression should be implemented. In order to increase suppression efficiency and reduce the negative ecological impacts of poorly planned suppression activities, a tactical response plan should be developed for each of the FMZs. A tactical response plan is a detailed plan about how to respond in case of a fire, and identifies natural fuel breaks, areas that could be used for fire control and areas off limits for suppression activities like retardant drops and cat guard construction. The tactical response plans should be living documents that are updated as new pre- and post-fire planning information becomes available from the studies outlined in the following sections.

Tactical response plans are developed ahead of time for an 'in the event of a fire' scenario and would include the following items:

- An emergency evacuation plan;
- A wildfire detection plan during the fire season;
- A plan detailing potential suppression tactics including possible fuel breaks, road, helicopter landing, and sprinkler locations etc.;
- An air operations plan;
- An Emergency Contact phone list and radio frequencies;
- A list of special restrictions and cautions for the Park during times of high fire-weather;
- A stakeholder notification plan; and
- A communications and media plan.

4.3 Wildfire Rehabilitation Planning

Wildfire rehabilitation planning is important in all of the FMZs, and in particular for the City of Nelson community watersheds. Re-establishment of vegetation, such as trees and understory plants, as quickly as possible after a wildfire, is important in reducing negative effects to hydrologic functions, soil stability, habitat functions, and effects to social values.

Rapid post-wildfire response to rehabilitation is also important to ensure that public goodwill and support is maintained. A rapid response and clear communication of the goals, methods, and rationale behind the rehabilitation efforts is required. Involvement of the local community and stakeholders in rehabilitation planning and implementation is also important to ensure alignment with the expectations of the public and their continued support.

Wildfire rehabilitation planning is comprised of advanced planning (pre-planning) and post-fire planning and mitigation strategies. Pre-planning provides input and information to assist suppression planning and post-fire planning; an overview of pre- and post-fire rehabilitation planning considerations are provided below.

4.3.1 PRE-PLANNING

Pre-planning is used to inform the development of tactical response plans and post-fire stabilization and rehabilitation to reduce the effects of wildfire and suppression activities. In community watersheds and areas with steep slopes and soils with high erosion potential, the purpose of pre-planning is to inform suppression planning to reduce negative effects such as road construction on unstable soils, and to ensure a rapid post-fire assessment and response to ensure rehabilitation is completed before any storm events occur that might trigger undesirable post-wildfire effects. Assembling information in advance will subsequently allow for the rapid refinement of planned strategies such as emergency stabilization and short and long-term rehabilitation. Table 4-2 identifies recommendations to improve Park inventory data to support pre- and post-fire planning.

Pre-planning should identify priority areas for fire suppression and post-fire stabilization/rehabilitation based on the results of a terrain stability risk/consequence assessment. Given the need for quick action and the substantial resources that are often required for post-fire stabilization and rehabilitation, it is important to match the intensity of these activities with the level of risk to key values. The most comprehensive stabilization and rehabilitation activities should be directed at the areas with the highest values at risk, such as in the Watershed FMZ or where downslope values, such as Harrop-Procter, could be affected. Recommendations to support post-wildfire planning are provided in Table 4-3.

The tables provide a relative rating of the value of the recommendation, cost, type of effort required (e.g., desk or field based), and which agency or external resources might be required to implement the recommendation. Prioritization and implementation of the recommendations will depend upon available resources and funding.

Table 4-2. Recommendations to improve Park inventory data to support wildfire pre- and post-fire planning.

Value	Cost	Type	Resources Required	Recommendation
High	Low	Desk based	Existing Steering Committee Members	Identify potential values at risk, especially downstream that may be affected post-wildfire.
High	High	Field / Desk based	Selkirk College / External Contract	Conduct LiDAR mapping and high resolution aerial imagery to inform suppression planning, post-fire reclamation, and terrain stability assessments (it must be noted that at the time of writing, BC Parks is in preliminary discussions with Selkirk College to provide LiDAR mapping).
High	High	Field / Desk based	External Contract	Conduct terrain stability assessments to identify unstable terrain to guide suppression planning and post-fire rehabilitation.
High	Moderate	Desk based	External Contract	Conduct soil erosion hazard mapping to guide suppression planning and post-fire rehabilitation.
High	High	Field / Desk based	External Contract	Conduct terrestrial ecosystem mapping (TEM) and associated field work to inform wildlife habitat mapping, identification of rare or at risk ecosystems, and support fuelbreak planning and post-fire rehabilitation planning.
High	Moderate	Field / Desk based	External Contract	Conduct an Archaeological Overview Assessment (AOA) of potential treatment areas and areas of high archaeological potential. This work should be kept on record by BC Parks for future management planning.
Moderate	Low	Desk based	External Contract	Update structural stage in the TEM and identify areas affected by forest health pathogens to guide fuel treatment planning and inform wildlife habitat mapping.
Moderate	Moderate	Field / Desk based	External Contract	Conduct surveys to assess fuels in stands affected by forest health pathogens with the scope of identifying restoration and fuel reduction plans for more remote areas in the Park. The focus of treatments in these areas should be on restoration of habitat for focal species such as mountain caribou and to restore ecosystem functions.
Moderate	Low to High	Field / Desk based	External Contract / MOE	Conducted surveys or radio-telemetry to identify key data on mountain caribou. Collaborate with other research groups to collect caribou data to reduce costs and share information. This information should be used to inform habitat mapping.
Low	Low	Field / Desk based	External Contract	Identify whitebark pine populations and opportunities for potential thinning of other coniferous tree species to reduce vulnerability to wildfire.

Value	Cost	Type	Resources Required	Recommendation
Low	High	Field / Desk based	External Contract	Identify and treat existing populations of invasive plant species that may spread after a wildfire event.

Table 4-3. Recommendations for pre-fire planning efforts.

Value	Cost	Type	Resources Required	Recommendation
High	Low	Desk based	Parks / BCWS/ Municipal and Regional Governments	Identify organizations/individuals involved in pre-planning and clarify roles and responsibilities.
High	Moderate	Desk based	External	Develop post-fire rehabilitation prescription goals for priority areas (e.g., slope stabilization, soil erosion control, fire rehabilitation, and watershed rehabilitation). These goals must occur within the framework of ecosystem restoration and watershed management goals to ensure long-term targets can be met and important Park and watershed values are protected. As Park inventory is improved, the goals and the spatially identified areas should be refined.
Moderate	Moderate	Desk based	Parks / BCWS/ Municipal and Regional Governments	Conduct wildfire response scenarios with all relevant individuals and agencies to ensure coordination of agencies and ensure that pre-wildfire planning information is incorporated in suppression planning.
Moderate	Low	Desk based	External Contract	Identify suitable native plant species for rehabilitation and potential sources of plant stock. Species selection should be based on goals and broad site conditions expected after a fire (e.g., erosion control on dry / poor sites or browse protection for ungulates).

As discussed in Section 4.1, the Park inventory and planning information identified above should be used to create tactical response plans for each FMZ, in consultation with BCWS. The plans would provide detailed spatial information to identify the values at risk and the predicted fire behaviour in the Park. The information would be used to identify priority suppression areas based on pre-planning information. It would be used to coordinate suppression efforts and techniques in the watershed such as decisions on where; the use of fire retardant, building of roads, use of machines, or establishment of firebreaks is appropriate. The tactical plans would include information such as identification of areas with high habitat values, slope stability issues, rare plant communities, invasive species locations, etc. The tactical plans would provide guidance to suppression planning during a wildfire event to help reduce damage or loss of values in the Park from wildfire and negative effects caused by fire suppression activities.

4.3.2 POST-WILDFIRE PLANNING

The primary goal of post-fire rehabilitation planning is to prepare for a strategic, effective and rapid post-fire response (Pike and Ussery 2007). Although some post-burn scenarios can be forecast, the focus of the plan should be on information gathering rather than outcome prediction and preparation for all possible events. There are three categories of stabilization/rehabilitation: i) short-term emergency stabilization; ii) rehabilitation of fire suppression related effects; and iii) long-term rehabilitation.

Post-fire planning should consider a risk-based approach to assessing potential hazards from fire and post-fire conditions, and the potential consequences of such hazards on key Park values. *Post-wildfire Natural Hazards Risk Analysis* (Hope et al. 2015) provides a risk analysis procedure and standard considerations that should be used to help guide professionals in the assessment of wildfire effects.

It is important to consider the potential risk to watershed values from access, machinery, and materials in post-fire interventions. Rehabilitation plans for watersheds must consider the potential for negative effects on areas downstream of the fire site and address accompanying inter-jurisdictional issues (such as damage to roads, railways, community infrastructure and/or private property). Slope stability, erosion potential, and sediment transport all influence post-wildfire susceptibility and impacts. High intensity rainfall events, even of relatively short duration, on areas with water repellent soils have been shown to increase flooding and accelerate erosion.

Recommendations to support post-fire planning are provided in Table 4-4. The table provides a relative rating of the value of the recommendation, cost, type of effort required (e.g., desk or field based), and which agency or external resources might be required to implement the recommendation. Prioritization and implementation of the recommendations will depend upon available resources and funding.

Table 4-4. Recommendations to support post-wildfire planning.

Value	Cost	Type	Resources Required	Action
High	High	Field / Desk based	External Contract	Acquire new high-resolution aerial photography of the burned area to facilitate fire severity mapping and inform rehabilitation planning.
High	Moderate	Field / Desk based	City of Nelson / Regional District	Assess all infrastructure (including downslope) to inform risk reduction measures and reconstruction requirements.
High	High	Field / Desk based	MFLNRO / RDCK / External Contract	Conduct post-wildfire natural hazards risk analysis[7,8] to inform mitigation measures and reclamation planning. Periodic re-assessments should be conducted to document issues and guide reclamation planning.
High	High	Field / Desk based	External Contract / City of Nelson /	Develop and implement mitigation measures and rehabilitation prescriptions based on pre-wildfire planning, considering the results of the risk analysis, FMZ objectives, rehabilitation goals, ecology of the burned area.
High	Moderate	Field / Desk based	External Contract	Conduct invasive plant species surveys and develop an invasive species management plan if required.
High	Moderate	Desk based	BC Parks Internal / City of Nelson / External Contract	Produce an annual report that documents all activities and results, and provides a review of success and failures of post-fire restoration activities. The report should be used to update restoration practices as required.
High	Low	Field / Desk based	City of Nelson	Monitor water quantity and quality in Five Mile Creek for several years, or until hydrologic functions in the watershed have recovered.
High	High	Field / Desk based	BC Parks Internal / City of Nelson / External Contract	Develop a comprehensive annual monitoring program to coordinate and document all post-fire monitoring and management activities. The monitoring program should evaluate rehabilitation success against prescription goals and provide feedback to ongoing rehabilitation activities to improve results are required.

[7] https://www.for.gov.bc.ca/hfd/pubs/docs/lmh/lmh69.pdf

[8] http://www.rdck.ca/EN/main/services/emergency-management/geotechnical-hazards.html

Value	Cost	Type	Resources Required	Action
Moderate	Moderate	Infrastructure	City of Nelson	Consider installing a local weather station to inform hydrologic modelling to assess Five Mile Creek flows.
Moderate	Low	Field / Desk based	City of Nelson	Increase water monitoring frequency during high precipitation events or snowmelt to assist in forecasting the flooding and downstream effects.
Moderate	Moderate	Field / Desk based	MFLNRO / External Contract	Monitor forest health agents to identify if mitigation is required.
Moderate	Low	Desk based	Parks / BCWS/ Municipal and Regional Governments	Compile a list of qualified professionals with expertise in post-fire assessments, risk analyses, and emergency stabilization and rehabilitation to ensure a rapid response to emergencies. This list should be updated annually. The administrative and financial policies and procedures for retaining contract services in emergency situations should also be in place.

5 PLAN IMPLEMENTATION AND OUTREACH

This section provides recommendations on consultation and the agencies that may be involved in carrying out the recommendations over time.

It is recommended that BC Parks:

- Continue inter-agency cooperation and planning for wildfire management in and adjacent to the Park;
- Conduct consultation and outreach as required for successful implementation of this Plan;
- Provide opportunities for First Nations and the public to comment on suggested treatments/prescription (see below for more detail); and
- Develop a project implementation schedule for the recommendations in this report. The schedule should include identification of priorities, timelines for completion, cost estimates, and identify cooperating agencies that could help facilitate the implementation of the recommendations. This will provide a coordinated framework for implementing the recommended management actions outlined in the Plan.

The goals for consultation are to provide timely information and opportunities for participation in review of the Plan and in particular the fuelbreak recommendations. Successful consultation will provide significant benefits to BC Parks, agency and community stakeholders, First Nations, and the broader public. Effective engagement of stakeholders and the public will:

- Facilitate dialogue with all levels of government and key agencies;
- Facilitate dialogue with the public;
- Build trust, transparency, and accountability within the community;
- Improve understanding of the values and management objectives of the Park;
- Address concerns with proposed fire management activities;
- Fulfill the duty to consult with aboriginal groups and individuals; and
- Integrate local knowledge about the Park into the Plan.

Consultation with First Nations requires a commitment from the onset of the project and should be initiated as early as possible. The level of information sharing required with First Nations that have expressed and/or identified interests will be based on the impacts of the program activities on those identified interests.

5.1 Key Stakeholders

Possible issues and/or values of concern that may arise from implementation of this Plan should be reviewed and potential resolutions should be identified. The review may include an inventory of the values of concern and identification of potential stakeholders. Based on past experience with fire management in Nelson and in the Park, it is understood that key stakeholders will initially include management agencies associated with the Park. Management agency stakeholders include but are not limited to:

- BC Wildfire Service;
- Ministry of Forests, Lands, and Natural Resource Operations;
- Ministry of Transportation and Infrastructure;
- Ministry of Aboriginal Relations and Reconciliation;
- City of Nelson;
- Regional District of Central Kootenay;
- Community of Harrop-Procter;
- Harrop-Procter Community Forest;
- Interface Working Group;
- West Arm Interface Steering Committee (which includes many of the same agency members); and
- Other organized users, conservation, recreation, and naturalist groups.

These groups have communicated extensively in the past and there is good understanding and dialogue about the complexity of fire management both within and adjacent to the Park.

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APPENDIX 1 – FUEL TYPE DESCRIPTIONS

The following is a general description of the dominant fuel types within the study area. It must be noted that the example photos provided are not necessarily from the Park but were selected as representative images.

C2 Fuel Type

Structure Classification	Regeneration to Pole sapling
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Tsuga heterophylla* (western hemlock), *Thuja plicata* (western redcedar), *Larix occidentalis,* (western larch), *Pinus contorta* (lodgepole pine) and *Abies lasiocarpa* (subalpine fir)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Sparse – None (< 10% cover)
Age	20-60 yrs
Height	<10 m
Stand Density	>2000 stems/ha
Crown Closure	80 – 100 %
Height to Live Crown	Average 2 m
Surface Fuel Loading	< 3 kg/m^2
Burn Difficulty	Moderate to high; however, if fire is wind driven then there is a high potential for extreme fire behaviour and active crown fire.

Figure 1. Example of a high-density pole sapling stand – classified as a C2 fuel type.

C3 Fuel Type

Structure Classification	Late Pole sapling to late young forest
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Tsuga heterophylla* (western hemlock), *Thuja plicata* (western redcedar), *Larix occidentalis,* (western larch), *Pinus contorta* (lodgepole pine) and *Abies lasiocarpa* (subalpine fir)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Low (< 50% cover)
Age	40 – 80 yrs
Height	20 – 33 m
Stand Density	700 – 1,200 stems/ha
Crown Closure	40 – 100 %
Height to Live Crown	Average 8 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Moderate; however, if fire is wind driven then there is a high potential for extreme fire behaviour and active crown fire.

Figure 2. Example of evenly stocked, moderate density second growth stand – classified as a C3 fuel type.

C4 Fuel Type

Structure Classification	Pole sapling to Young Forest
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Tsuga heterophylla* (western hemlock), *Thuja plicata* (western redcedar), *Larix occidentalis,* (western larch), *Pinus contorta* (lodgepole pine) and *Abies lasiocarpa* (subalpine fir)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Low (< 25% cover)
Age	20 – 80 yrs
Height	10 – 30 m
Stand Density	700 – 2000 stems/ha
Crown Closure	40 – 80 %
Height to Live Crown	Average 4 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Moderate to high; however, if fire is wind driven then there is a high potential for extreme fire behaviour and active crown fire.

Figure 3. Example of a moderate to high-density second growth stand of lodgepole pine and redcedar classified as a C4 fuel type.

C5 Fuel Type

Structure Classification	Mature and old forest
Dominant Tree Species	*Pseudotsuga menziesii* (Douglas-fir), *Tsuga heterophylla* (western hemlock), *Thuja plicata* (western redcedar), *Larix occidentalis,* (western larch), *Pinus contorta* (lodgepole pine), *Abies lasiocarpa* (subalpine fir) and *Pinus ponderosa* (ponderosa pine)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Moderate (> 40% cover)
Average Age	> 80 yrs
Average Height	30 – 40 m
Stand Density	700 – 900 stems/ha
Crown Closure	40 – 100 %
Height to Live Crown	Average 18 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Low; however, if fire is wind driven then there is a moderate potential for active crown fire.

Figure 4. Example of mature forest of Douglas fir, western hemlock and western red cedar – classified as a C5 fuel type

C7 Fuel Type

Structure Classification	Young forest to mature forest
Dominant Tree Species	Pseudotsuga menziesii (Douglas-fir), Larix occidentalis (western larch), Pinus contorta (lodgepole pine) and Pinus ponderosa (ponderosa pine)
Tree Species Type	> 80% Coniferous
Understory Vegetation	Variable depending on site quality and moisture availability
Average Age	20 – 80 yrs
Average Height	10 – 30 m
Stand Density	Variable, typically less than 600 stems/ha
Crown Closure	20 – 40 %
Height to Live Crown	Average 4 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Low; however, if fire is wind driven then there is a moderate potential for active crown fire.

Figure 5. Example of a low-density Douglas-fir and lodgepole pine stand – classified as C7 fuel type.

D1/2 Fuel Type

Structure Classification	Pole sapling to Mature forest
Dominant Tree Species	Populus trichocarpa (black cottonwood), Populus tremuloides (trembling aspen) and Betula papyrifera (paper birch)
Tree Species Type	> 80% Deciduous
Understory Vegetation	High (> 90% cover)
Average Age	> 20 yrs
Average Height	>10 m
Stand Density	600 – 2,000 stems/ha
Crown Closure	20 – 100 %
Height to Live Crown	< 10 m
Surface Fuel Loading	< 3 kg/m^2
Burn Difficulty	Low

Figure 6. Moist rich site dominated by cottonwood and trembling aspen – classified as a D1 fuel type.

M1/2 Fuel Type

Structure Classification	Pole sapling, young forest, mature and old forest
Dominant Tree Species	Pseudotsuga menziesii (Douglas-fir), Tsuga heterophylla (western hemlock), Thuja plicata (western redcedar), Larix occidentalis, (western larch), Pinus contorta (lodgepole pine), Abies lasiocarpa (subalpine fir), Populus trichocarpa (black cottonwood), Populus tremuloides (trembling aspen) and Betula papyrifera (paper birch)
Tree Species Types	Coniferous 20-80% / Deciduous 20-80%
Understory Vegetation	variable
Average Age	> 20 yrs
Average Height	> 10 m
Stand Density	600-1500 stems/ha
Crown Closure	40 – 100 %
Height to Live Crown	6 m
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Moderate; however, if fire is wind driven then there is a high potential for extreme fire behaviour and active crown fire.

Figure 7. Mixed fir/lodgepole-pine site with a deciduous component of aspen and paper birch – classified as an M2 fuel type.

O1a Fuel Type

Structure Classification	Herb community
Dominant Tree Species	
Tree Species Types	
Understory Vegetation	Variable – low flammability herbs or short grasses
Average Age	< 10 yrs
Average Height	
Stand Density	
Crown Closure	0
Height to Live Crown	
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Low

Figure 8. O1a fuel type with low herbs and scattered fine woody debris.

O1b Fuel Type

Structure Classification	Shrub/herb community
Dominant Tree Species	
Tree Species Types	
Understory Vegetation	Variable – moderate to high flammability shrubs and tall grasses
Average Age	< 10 yrs
Average Height	
Stand Density	
Crown Closure	0
Height to Live Crown	
Surface Fuel Loading	< 5 kg/m^2
Burn Difficulty	Moderate to high surface fire potential, but generally low severity.

Figure 9. O1b fuel type with shrubs.

APPENDIX 2 - PROVINCIAL STRATEGIC THREAT ANALYSIS – INPUTS

Fire History and Density

Fire history and density uses the historic fire records from 1950 forward to identify the potential of fires greater than 4 ha and to identify the potential of fires > 500 ha because of the increased damage associated with these fires (MFLNRO 2015a).

Fire Intensity

The fire intensity subcomponent is a measure of the rate of heat energy released per unit time per unit length of fire front. It is based on the rate of spread and predicted fuel consumption of the fire, and is expressed in kilowatts per metre (Pyne 1984). Fire intensity is an important determinant of the difficulty associated with fire suppression efforts and is related to flame size, rate of spread and combustible fuel available.

Figure 1 shows the fire intensity in the Park. For the purposes of mapping and interpretation, fire intensity calculations were scaled between 0 and 10. The actual fire intensity measures are presented in Table 1.

Table 1. Actual measure of fire intensity (kilowatts per metre) and equivalent rating scale used for mapping and percent of land base by class.

kilowatts per metre[1]	ha	Percentage of Land Base by Class
> 25,000	252.8	1%
10,000-25,000	14,296.3	54%
4,001 - 10,000	4,772.1	18%
2,000 - 4,000	6,002.8	23%
500 - 2,000	142.9	1%
0 - 500	854.9	3%

[1] *Indicator of the rate of heat energy released*

Fire intensity in the Park is considerable. Figure 1 shows that most of the study area (including buffer) has the potential to release more than 2,000 kW/m. Above this level, suppression efforts will be limited once a fire is well established, given adverse weather conditions and topography. Rapid initial attack in the Park is essential during high to extreme fire weather if suppression efforts are to be successful under these conditions.

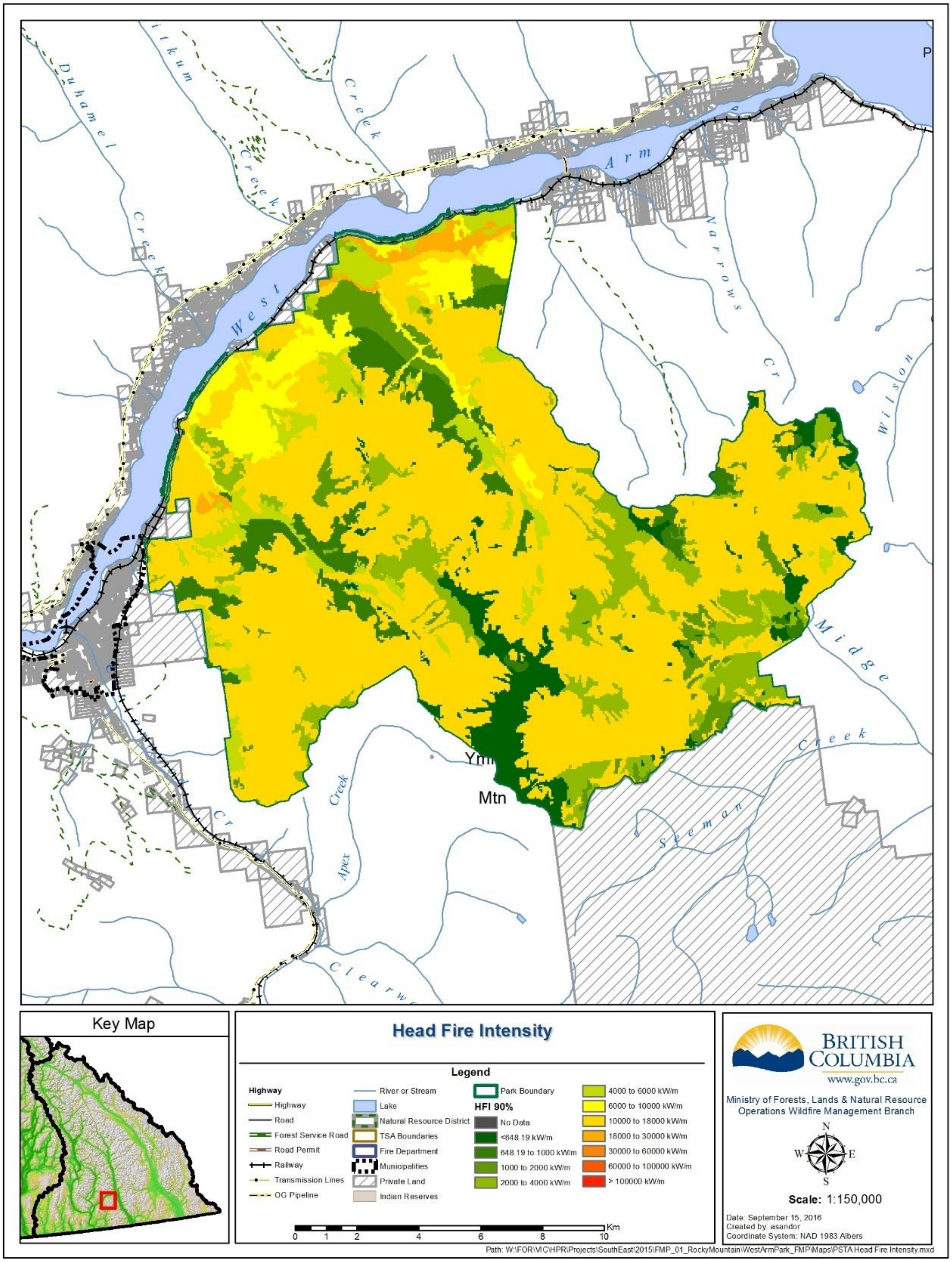

Figure 1. Head fire intensity in West Arm Provincial Park.

Rate of Spread

The rate of spread subcomponent is a measure of the speed at which fire expands its horizontal dimensions at the head of the fire. This is based on the hourly Initial Spread Index (ISI) value and is expressed in metres per minute. The rate of spread was adjusted for steepness of slope and interactions between slope direction and wind direction determined from the Build-Up Index (BUI).

For the purposes of mapping and interpretation, rate of spread calculations are scaled between 0 and 10. The actual rates of spread measures are presented in Table 2.

Table 2. Actual measure of rate of spread (metres per minute) and equivalent rating scale used for mapping.

ROS m/min[1]	Area (ha)	Percentage of Land Base by Class
> 40	5,427.6	21%
20 - 40	12,636.2	48%
10 - 20	4,945.9	19%
5 - 10	2,411.9	9%
1-5	45.1	<1%
0	854.9	3%

[1]*Indicator of the speed at which fire extends horizontally*

Rates of spread for the Park (Figure 2) are relatively high, largely due to steep topography and wind speed and direction combined with fuel types. Suppression efforts would be constrained to indirect and aerial attack under conditions where rates of spread exceed 5 m/min.

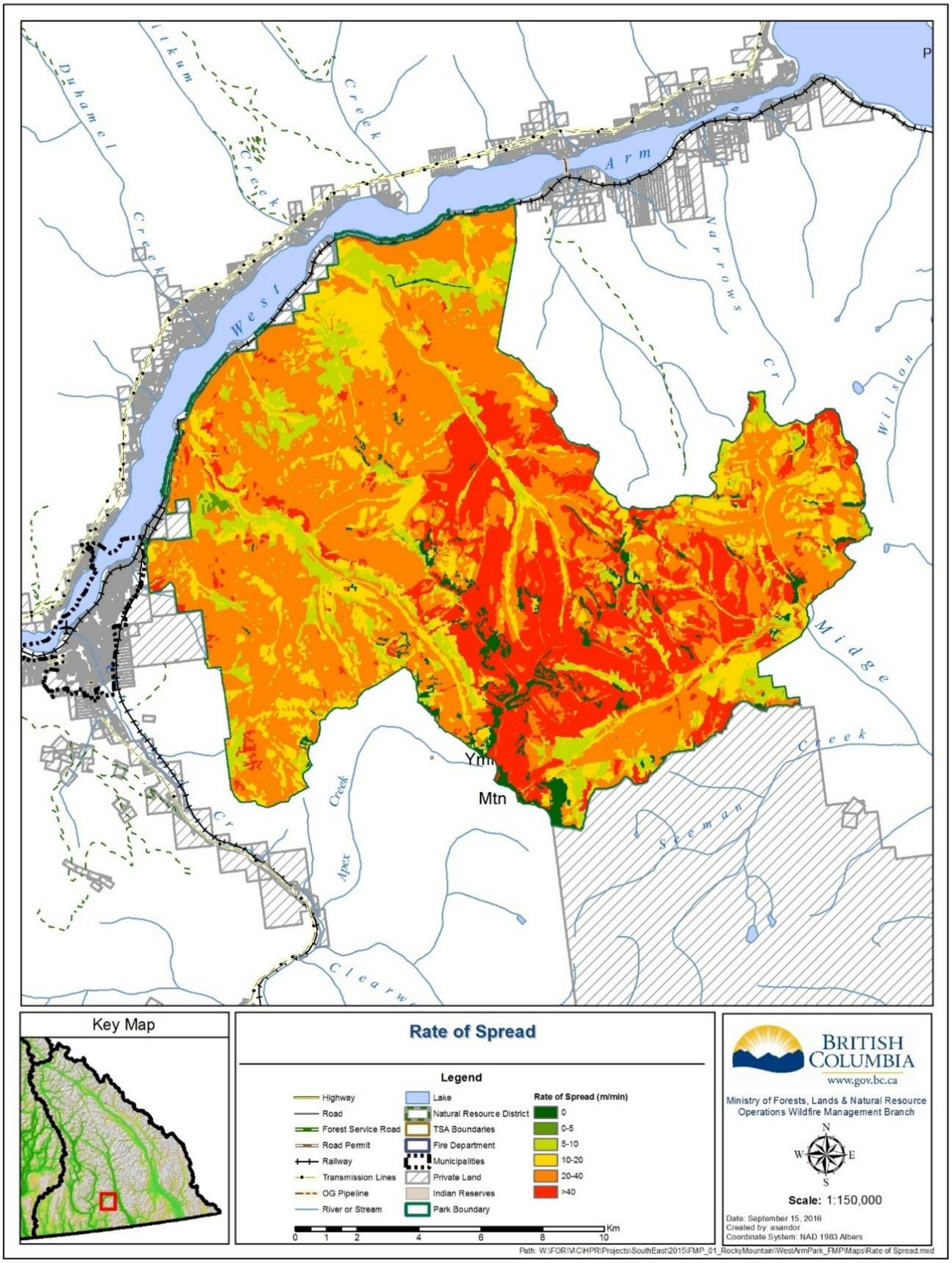

Figure 2. Rates of spread in West Arm Provincial Park.

Table 3 assists in the interpretation of the modelling results related to Fire Intensity and Rate of Spread. Fire Intensity Rank is also shown and descriptions and photographs of these can be seen in Appendix 2 – Fire Rank.

Table 3. Fire behaviour parameters – Fire intensity rank, rate of spread, and head fire intensity (modified from Alexander and Cole 1995).

Fire Intensity Rank	Rate of Spread (m/min)	Head Fire Intensity (kW/m	Interpretations
6	>18	> 10,000	The situation should be considered as "explosive" or super critical in this class. The characteristics commonly associated with extreme fire behaviour (e.g., rapid rates of spread, continuous crown fire development, medium to long-range spotting, firewhirls, massive convection columns, great walls of flame) are a certainty. Fires present serious control problems as they are virtually impossible to contain until burning conditions ameliorate. Direct attack is rarely possible given the fire's probable ferocity except immediately after ignition and should only be attempted with the utmost caution; an escaped fire should in most cases, be considered a very real possibility. The only effective and safe control action that can be taken until the fire run expires will be at the back and along the flanks.
5	6.0-18.0	4,000 to 10,000	Intermittent crown fires are prevalent and continuous crowning is also possible in the lower end of the spectrum. Control is extremely difficult and all efforts at direct control are likely to fail. Direct attack is rarely possible given the fire's probable ferocity except immediately after ignition and should only be attempted with the utmost caution. Otherwise, any suppression action must be restricted to the flanks and back of the fire. Indirect attack with aerial ignition (I.e., helitorch and/or A.I.D. dispenser), if available, may be effective depending on the fire's forward rate of advance.
4	3.0-6.0	2000 to 4000	Burning conditions have become critical as intermittent crowning and short range spotting is common place and as a result control is very difficult. Direct attack on the head of a fire by ground forces is feasible for only the first few minutes after ignition has occurred. Otherwise, any attempt to attack the fire's head should be limited to "medium" or "heavy" helicopters with buckets or fixed-wing aircraft, preferably dropping long-term retardants; control efforts may fail. Until the fire weather severity abates, resulting in the subsidence of a fire run, the uncertainty of successful control exists.
3	1.5-3.0	500 to 2,000	Both moderately and highly vigorous surface fires with flames up to just over 1.5 m (≈ 5 ft) high and intermittent crowning (i.e., torching) can occur. As a result, fires can be moderately difficult to control. Hand-constructed fire guards are likely to be challenged and the opportunity to "hotspot" the perimeter gradually diminishes. Water under pressure (e.g., fire pumps with hose lays) and heavy machinery (e.g., bulldozers, "intermediate" helicopter with a bucket) are generally required for effective action at the fire's head.
2	<1.5	10 to 500	From the standpoint of moisture content, surface fuels are considered sufficiently receptive to sustained ignition and combustion from both flaming and glowing firebrands. Fire activity is limited to creeping or gentle surface burning with maximum flame heights of less than 1.3 m (≈ 4 ft). Control of these fires is fairly easy but can become troublesome as adverse fire impacts can still result, and fires can become costly to suppress if not attended to immediately. Direct manual attack by "hotspotting" around the entire perimeter by firefighters with only hand tools and water from back-pack pumps is possible; a "light" helicopter(s) with bucket is also very effective. Fireguard construction with hand tools should hold.

Fire Intensity Rank	Rate of Spread (m/min)	Head Fire Intensity (kW/m	Interpretations
1	-	< 10	New fire starts are unlikely to sustain themselves due to moist surface fuel conditions. However, new ignitions may still take place from lightning strikes or near large and prolonged heat sources (e.g., camp fires, windrowed slash piles) but the resulting fires generally do not spread much beyond their point of origin and if they do, control is very easily achieved. Mop-up or complete extinguishment of fires that are already burning may still be required provided there is sufficient fuel and it is dry enough to support smouldering combustion.

Crown Fraction Burned

The crown fraction burned subcomponent is a measure of the proportion of the tree crowns consumed by fire and is expressed as a percentage value. It is based on rate of spread, crown base height and foliar moisture content.

For the purposes of mapping and interpretation, crown fraction burned calculations were scaled between 0 and 10. The actual crown fraction burned measures are presented in Table 4.

Table 4. Actual measure of crown fraction burned (%) and equivalent rating scale used for mapping.

%	Area (ha)	Percentage of Land Base by Class
50 - 100	16,797.9	64%
40 - 49	173.9	1%
20 - 39	561.9	2%
10 - 19	300.7	1%
1 - 9	38.8	<1%
0	8,448.3	32%

[1]*Indicator of the proportion of tree crowns consumed by fire (i.e., a measure of tree mortality)*

Crown fraction burned is an indicator of fire severity. In Table 4 and Figure 3, 64% of the Park has greater than 50% of tree crowns burned. For these areas, a high intensity crown fire is possible and suppression efforts would have minimal impact. As crown consumption increases, post-fire interception of rain and snow decreases. Winter snow packs would likely increase, and due to increased solar insolation during the spring, snowmelt runoff volumes would increase. Increased surface runoff due to decreased interception by canopies could also raise soil erosion and transportation rates which could negatively impact water quality.

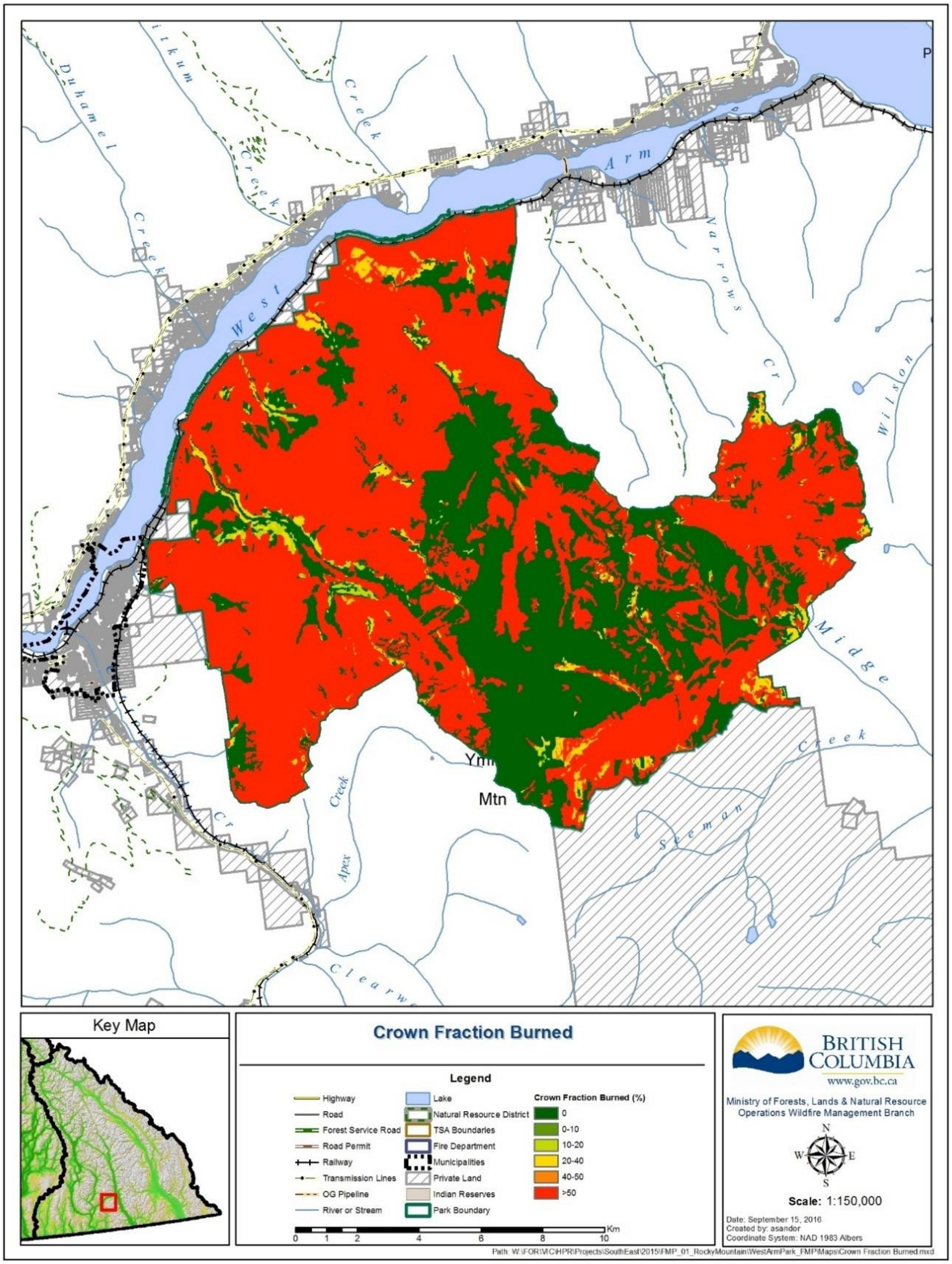

Figure 3. Crown fraction burned in West Arm Provincial Park.

APPENDIX 3 – FIRE RANK

The BCWS uses a ranking scale from 1 to 6 to illustrate fire behaviour and the difficulty associated with fire suppression in relation to rates of spread and fire intensity (Figure 1.) The following section is taken from the BCWS website:http://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/wildfire-management/wildfire-response/fire-characteristics/rank.

RANK 1 RANK 2 RANK 3 RANK 4 RANK 5 RANK 6

Figure 1. Fire rank 1 to 6 (BCWS, 2016)

Rank 1 – Smouldering ground fire

This is a smoldering ground fire or a fire that burns in the ground fuel layer. These fires have no open flame and produce white smoke with a slow (creeping) rate of spread.

Firebrands and fires tend to be virtually self-extinguishing unless high Drought Code and/or Build up index values prevail, in which case extensive mop-up is generally required. Firefighting tactics include direct attack with ground crews using hand tools and water delivery systems such as pumps and hose.

Rank 2 – Low vigour surface fire

This is a surface fire or a fire that burns in the surface fuel layer, excluding the crowns of trees. These fires produce visible open flame; have a slow rate of spread, which is the speed at which the fire extends; and have an unorganized flame front or a flame front that does not exhibit all the same characteristics.

Direct manual attack at fire's head or flanks by fire fighters with hand tools, water delivery systems, or heavy equipment possible. Constructed fire guard should hold.

Rank 3 – Moderately vigorous surface fire

This is a vigorous surface fire with a moderate rate of spread. They have an organized front and may display "candling", which is when a tree's fuels ignite and flare up, along the perimeter and/or within the fire.

Hand-constructed fire guards are likely to be challenged, whereas control lines constructed by heavy equipment will generally be successful in controlling fire.

Rank 4 - Highly vigorous surface fire with torching or passive crown fire

This type of fire produces grey to black smoke, has an organized surface flame front, and has a moderate to fast rate of spread along the ground. Short aerial bursts and short range spotting will occur with these fires.

Ground control efforts at fire's head may fail. Firefighting tactics include indirect attack to bring the head of the fire under control, parallel attack along the flanks to direct the head (i.e., to more favourable ground, fuels), and air operations to support ground crews.

Rank 5 – Extremely vigorous surface fire or active crown fire.

This type of fire produces black to copper smoke, has an organized crown fire front, moderate to long-range spotting and independent spot fire growth.

This type of fire is very difficult to control. Suppression action must be restricted to fire's flanks. Indirect attack with aerial ignition (i.e., helitorch and/or aid dispenser) may be effective. Ground operations are often restricted to fighting the least active sections of the fire or conducting ground ignitions subject to secure control lines, escape routes and safety zones.

Rank 6 - Blow-up or conflagration; extreme and aggressive fire behaviour.

Violent fire behaviour occurs with this type of fire. An organized crown fire front, long-range spotting and independent spot fire growth are characteristic of this fire type. There may be the presence of fireballs and whirls and violent fire behaviour is probable. Suppression actions should not be attempted until burning conditions ameliorate. Suppression efforts if safe and attempted will be well away from active fire behaviour (i.e., preparing structure protection measures, indirect large-scale ignition).

APPENDIX 4 – PRINCIPLES OF FUELBREAK DESIGN

The information contained within this section has been inserted from "*The Use of Fuelbreaks in Landscape Fire Management*" by James K. Agee, Benii Bahro, Mark A. Finney, Philip N. Omi, David B. Sapsis, Carl N. Skinner, Jan W. van Wagtendonk, and C. Philli Weatherspoon (1999). This article succinctly describes the principles and use of fuelbreaks in landscape fire management.

The principal objective behind the use of fuelbreaks, as well as any other fuel treatment, is to alter fire behaviour over the area of treatment. As discussed above, fuelbreaks provide points of anchor for suppression activities.

Surface Fire Behaviour

Surface fuel management can limit fireline intensity (Byram 1959) and lower potential fire severity (Ryan and Noste 1985). The management of surface fuels so that potential fireline intensity remains below some critical level can be accomplished through several strategies and techniques. Among the common strategies are fuel removal by prescribed fire, adjusting fuel arrangement to produce a less flammable fuelbed (e.g., crushing), or "introducing" live understory vegetation to raise average moisture content of surface fuels (Agee 1996). Wildland fire behaviour has been observed to decrease with fuel treatment (Helms 1979, Buckley 1992), and simulations conducted by van Wagtendonk (1996) found both pile burning and prescribed fire, which reduced fuel loads, decreased subsequent fire behaviour. These treatments usually result in efficient fire line construction rates, so that control potential (reducing "resistance to control") can increase dramatically after fuel treatment.

The various surface fuel categories interact with one another to influence fireline intensity. Although more litter and fine branch fuel on the forest floor usually results in higher intensities that is not always the case. If additional fuels are packed tightly (low fuelbed porosity), they may result in lower intensities. Although larger fuels (>3 inches [7-8cm]) are not included in fire spread models, as they do not usually affect the spread of the fire (unless decomposed [Rothermel 1991]), they may result in higher energy releases over longer periods of time when a fire occurs, having significant effects on fire severity, and reducing rates of fireline construction.

The effect of herb and shrub fuels on fireline intensity is not simply predicted. First of all, more herb and shrub fuels usually imply more open conditions. These should be associated with lower relative humidity and higher surface wind speed. Dead fuels may be drier, and the rate of spread may be higher, because of the altered microclimate compared to more closed canopy forest with less understory. Live fuels, with higher foliar moisture while green, will have a dampening effect on fire behaviour. However, if the grasses and forbs cure, the fine dead fuel can increase fireline intensity and localized spotting.

Conditions That Initiate Crown Fire

A fire moving through a stand of trees may move as a surface fire, an independent crown fire, or as a combination of intermediate types of fire (Van Wagner 1977). The initiation of crown fire behaviour is a *function of surface fireline intensity and of the forest canopy: its height above ground and moisture content (Van Wagner 1977). The critical surface fire intensity needed to initiate crown fire behaviour can be calculated for a range of crown base heights and foliar moisture contents, and represents the minimum level of fireline intensity necessary to initiate crown fire (*Table 1; Alexander 1988, Agee 1996*). Fireline intensity or flame length below this critical level may result in fires that do not crown but may still be of stand replacement severity. For the limited range of crown base heights and foliar moistures shown in Table 1 the critical levels of flame length appear more sensitive to height to crown base than to foliar moisture (Alexander 1988).*

Table 1. Flame lengths associated with critical levels of fireline intensity that are associated with initiating crown fire, using Byram's (1959) equation (Agee et al.1999)*.

Foliar Moisture Content (%)	Height of Crown Base in metres and feet							
	2 metres 6 feet		6 metres 20 feet		12 metres 40 feet,		20 metres 66 feet	
	M	ft	M	ft	M	ft	M ft	ft
70	1.1	4	2.3	8	3.7	12	5.3	17
80	1.2	4	2.5	8	4.0	13	5.7	19
90	1.3	4	2.7	9	4.3	14	6.1	20
100	1.3	4	2.8	9	4.6	15	6.5	21
120	1.5	5	3.2	10	5.1	17	7.3	24

**Table adapted from original publication*

If the structural dimensions of a stand and information about foliar moisture are known, then critical levels of fireline intensity that will be associated with crown fire for that stand can be calculated. Fireline intensity can be predicted for a range of stand fuel conditions, topographic situations such as slope and aspect, and anticipated weather conditions, making it possible to link on-the-ground conditions with the initiating potential for crown fires. In order to avoid crown fire initiation, fireline intensity must be kept below the critical level. Managing surface fuels can accomplish this such that fireline intensity is kept well below the critical level or by raising crown base heights such that the critical fireline intensity is difficult to reach. In the field, the variability in fuels, topography and microclimate will result in varying levels of potential fireline intensity, critical fireline intensity, and therefore varying crown fire potential.

Conditions That Allow Crown Fire Spread

The crown of a forest is similar to any other porous fuel medium in its ability to burn and the conditions under which crown fire will or will not spread. The heat from a spreading crown fire into unburned crown ahead is a function of the crown fire rate of spread, the crown bulk density, and the crown foliage ignition *energy. The crown fire rate of spread is not the same as the surface fire rate of spread, and often includes effects of short-range spotting. The crown bulk density is the mass of crown fuel, including needles, fine twigs, lichens, etc., per unit of crown volume (analogous to soil bulk density). Crown foliage ignition energy is the net energy content of the fuel and varies primarily by foliar moisture content, although species differences in energy content are apparent (van Wagtendonk and others 1998). Crown fires will stop spreading, but not necessarily stop torching, if either the crown fire rate of spread or crown bulk density falls below some minimum value.*

If surface fireline intensity rises above the critical surface intensity needed to initiate crown fire behaviour, the crown will likely become involved in combustion. Three phases of crown fire behaviour can be described by critical levels of surface fireline intensity and crown fire rates of spread (Van Wagner 1977, 1993): (1) a passive crown fire, where the crown fire rate of spread is equal to the surface fire rate of spread, and crown fire activity is limited to individual tree torching; (2) an active crown fire, where the crown fire rate of spread is above some minimum spread rate; and (3) an independent crown fire, where crown fire rate of spread is largely independent of heat from the surface fire intensity. Scott and Reinhardt (in prep.) have defined an additional class, (4) conditional surface fire, where the active crowning spread rate exceeds a critical level, but the critical level for surface fire intensity is not met. A crown fire will not initiate from a surface fire in this stand, but an active crown fire may spread through the stand if it initiates in an adjacent stand.

Critical conditions can be defined below which active or independent crown fire spread is unlikely. To derive these conditions, visualize a crown fire as a mass of fuel being carried on a "conveyor belt" through a stationary flaming front. The amount of fine fuel passing through the front per unit time (the mass flow rate) depends on the speed of the conveyor belt (crown fire rate of spread) and the density of the forest crown fuel (crown bulk density). If the mass flow rate falls below some minimum level (Van Wagner 1977) crown fires will not spread. Individual crown torching, and/or crown scorch of varying degrees, may still occur.

Defining a set of critical conditions that may be influenced by management activities is difficult. At least two alternative methods can define conditions such that crown fire spread would be unlikely (that is, mass flow rate is too low). One is to calculate critical wind speeds for given levels of crown bulk density (Scott and Reinhardt, in prep.), and the other is to define empirically derived thresholds of crown fire rate of spread so that critical levels of crown bulk density can be defined (Agee 1996). Crown bulk densities of 0.2 kg m^{-3} are common in boreal forests that burn with crown fire (Johnson 1992), and in mixed conifer forests, Agee (1996) estimated that at levels below 0.10 kg m^{-3} crown fire spread was unlikely, but no definitive single "threshold" is likely to exist.

Therefore, reducing surface fuels, increasing the height to the live crown base, and opening canopies should result in (a) lower fire intensity, (b) less probability of torching, and (c) lower probability of independent crown fire. There are two caveats to these conclusions. The first is that a grassy cover is often preferred as the fuelbreak ground cover, and while fireline intensity may decrease in the fuelbreak, rate of spread may increase. Van Wagtendonk (1996) simulated fire behaviour in untreated mixed conifer forests and fuelbreaks with a grassy understory, and found fireline intensity decreased in the fuelbreak (flame length *decline from 0.83 to 0.63 m [2.7 to 2.1 ft]) but rate of spread in the grassy cover increased by a factor of 4 (0.81 to 3.35 m/min [2.7-11.05 ft/min]). This flashy fuel is an advantage for backfiring large areas in the fuelbreak as a wildland fire is approaching (Green 1977), as well as for other purposes described later, but if a fireline is not established in the fuelbreak, the fine fuels will allow the fire to pass through the fuelbreak quickly. The second caveat is that more open canopies will result in an altered microclimate near the ground surface, with somewhat lower fuel moisture and higher wind speeds in the open understory (van Wagtendonk 1996).*

Fuelbreak Effectiveness

The effectiveness of fuelbreaks continues to be questioned because they have been constructed to varying standards, "tested" under a wide variety of wildland fire conditions, and measured by different standards of effectiveness. Green (1977) describes a number of situations where traditional fuelbreaks were successful in stopping wildland fires and some situations where fuelbreaks were not effective due to excessive spotting of wildland fires approaching the fuelbreaks.

Fuelbreak construction standards, the behaviour of the approaching wildland fire, and the level of suppression each contribute to the effectiveness of a fuelbreak. Wider fuelbreaks appear more effective than narrow ones. Fuel treatment outside the fuelbreak may also contribute to its effectiveness (van Wagtendonk 1996). Area treatment such as prescribed fire beyond the fuelbreak may be used to lower fireline intensity and reduce spotting as a wildland fire approaches a fuelbreak, thereby increasing its effectiveness. Suppression forces must be willing and able to apply appropriate suppression tactics in the fuelbreak. They must also know that the fuelbreaks exist, a common problem in the past. The effectiveness of suppression forces depends on the level of funding for people, equipment, and aerial application of retardant, which can more easily reach surface fuels in a fuelbreak. Effectiveness is also dependent on the psychology of firefighters regarding their safety. Narrow or poorly maintained fuelbreaks are less likely to be entered than wider, well-maintained ones.

No absolute standards for width or fuel manipulation are available. Fuelbreak widths have always been quite variable, in both recommendations and construction. A minimum of 90 m (300 ft) was typically specified for primary fuelbreaks (Green 1977). As early as the 1960's, fuelbreaks as wide as 300 m (1000 ft) were included in gaming simulations of fuelbreak effectiveness (Davis 1965), and the recent proposal for northern California national forests by the Quincy Library Group (see web site http://www.qlg.org for details) includes fuelbreaks 390 m (0.25 mi) wide. Fuelbreak simulations for the Sierra Nevada Ecosystem Project (SNEP) adopted similar wide fuelbreaks (van Wagtendonk 1996, Sessions et al. 1996).

Fuel manipulations can be achieved using a variety of techniques (Green 1977) with the intent of removing surface fuels, increasing the height to the live crown of residual trees, and spacing the crowns to prevent independent crown fire activity. In the Sierra Nevada simulations, pruning of residual trees to 3 m (10 ft) height was assumed, with canopy cover at 1 to 20% (van Wagtendonk 1996). Canopy cover less than 40% has been proposed for the Lassen National Forest in northern California (Olson 1997). Clearly, prescriptions *for the creation of fuelbreaks must not only specify what is to be removed, but must describe the residual structure in terms of standard or custom fuel models so that potential fire behaviour can be analyzed.*