Fuelbreak Effectiveness in Canada’s Boreal Forests: 
A synthesis of current knowledge

Final Report

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Table of Contents

INTRODUCTION 3
TERMINOLOGY 3
METHODS 3
LITERATURE REVIEW 5
AGENCY PRACTICES 7
AGENCY FUELBREAK CHARACTERISTICS 12
EXPERT OPINION SURVEY 19
CHALLENGED FUELBREAK INCIDENTS 23
WORKSHOP 26
PROJECT SUMMARY 28
ACKNOWLEDGEMENTS 29
APPENDIX A – LIST OF PROVINCIAL DOCUMENTS 30
APPENDIX B – CANADIAN AGENCY FUELBREAK EXAMPLES 31
APPENDIX C – CFFDRS FUEL TYPES 33
APPENDIX D – EXPERT OPINION SURVEY 34
APPENDIX E – CHALLENGED FUELBREAK INCIDENTS IN UNITED STATES 38
APPENDIX F – CHALLENGED FUELBREAK INCIDENTS IN CANADA 46
REFERENCES 48
Introduction

Most North American fire management agencies have initiated fuel management programs to reduce the effect of wildfire on human, property and resource values. Although fire behavior principles are considered when developing fuel management treatments there is little in the literature that attempts to measure the effectiveness of various treatment options for different fuel types. Consequently, fuel treatments that are conclusively supported by science and validated with case studies are rare. Nevertheless, it is recognized within the fire community that experienced-based knowledge, gained from extensive fire experience, is an important source of information used for designing effective fuel treatments.

This project aimed to synthesize the current state of knowledge of fuelbreak effectiveness from conventional sources of information, augmented by agency practices and experience-based knowledge from fire personnel.

Terminology

The term fuelbreak often means different things to different people within the fire community and among the public and the media. For the purposes of this project, a fuelbreak was defined as a distinct area outside a community (or other value at risk) of any size and shape where anthropogenic modifications of forest fuels (i.e. fuel treatments) have been conducted to aid in the protection of that community from future wildfires. Fuel treatments may include any combination of a reduction or removal of canopy fuels, surface fuels, and/or ladder fuels through any method.

An effective fuelbreak was defined as one that can, or has, significantly altered fire behaviour such that suppression forces can, or could have, safely mitigated the fire spread to values.

Methods

Literature Review

The first step in this project was a literature review of existing published studies and other reports. This work was necessary to ensure the literature sources had been adequately researched. Literature included, but was not limited to, articles in peer-reviewed journals, unpublished literature, agency documents, and web sources.

Agency Practice Review

A review of fuel management programs of Canadian fire agencies was conducted to determine the processes that guide fuel treatment projects designed to protect communities at risk from wildfire. Any agency guidelines, protocols, manuals, and supplementary information used by agency personnel for community fuel treatment planning and implementation were identified.
Agency Fuelbreak Characteristics

Information was collected on the physical characteristics of existing fuelbreaks in Canada that have been designed by agency personnel to slow a fully engaged crown fire. By collecting basic information on existing fuelbreaks in all fuel types, we hoped to tease out commonalities in treatment design that may provide insight into these design decisions. The information collected included:

- fuel type
- fuelbreak length and width, and/or area
- types of treatment (spacing, crown base height, surface fuels)
- year of treatment
- method of treatment
- maintenance schedule
- maps, and
- any available costs

It was anticipated that each of the Canadian fire agencies that have active fuel management programs would be able to provide this data for all of their fuelbreak projects. The target sample size was 40 fuelbreak projects; approximately 6-8 examples from each agency.

Challenged Fuelbreaks

Field experiments to determine fuelbreak effectiveness can rarely, if ever, be conducted due to the prohibitive cost and potential hazards. Therefore, incidents where a wildfire has challenged an existing fuelbreak system can potentially provide Canadian fuel treatment planners and researchers a valuable, and much needed, base of data on fuelbreak effectiveness. Agency websites, grey literature and anecdotal accounts were reviewed to identify potentially relevant incidents. Data collection was to include information on the characteristics of the fuelbreak, as listed above, well as the characteristics of the fire behaviour such as:

- fire type - crown/intermittent/surface
- fire intensity & rate of spread
- how did fire reach the fuelbreak - at a point or flanked?
- areas where the fuelbreak was challenged
- areas where the fuelbreak was breached
- suppression resources used - did fuelbreak become part of suppression tactics?
- qualitative descriptors of the fuelbreak effectiveness, excluding spotting

Expert Opinion Survey

Experts in the Canadian fire community were surveyed to uncover common ideas regarding the characteristics that make an effective fuelbreak. Expert opinion and judgment was elicited using a simple survey questionnaire where respondents could draw on their experiences and knowledge regarding fuelbreak effectiveness. The survey consisted of two parts: (1) the collection of observations of an actual event in which a fuelbreak (man-made or natural) was challenged by wildfire (2) the collection of opinions on the use fuelbreaks for community protection. For the part one of the survey the respondents were instructed to consider a fuelbreak to be any interruption in fuel continuity, man-made or natural. The project proponents felt that observations of all types of breaks in fuel will help us better understand what physical
characteristics should be designed into a proactive fuelbreak to better protect a community, or other values at risk.

**Workshop**

The final component in this project was to host a workshop with agency fire management personnel and Canadian experts in fire behavior and fuels management. The main objectives for this workshop were: (1) a critical analysis/validation of findings by the experts and (2) the development of a best-practices document for fuelbreak design in Canada.

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**Literature Review**

The initial search for published literature was conducted in November 2007 using the keywords: ‘fuelbreak’, ‘firebreak’, and ‘defensible fuel zone’ on search engines for academic journals at the University of Alberta Science Library. Other sources included the Canadian Forest Service Library in Edmonton and the Alberta Government Libraries in Edmonton. Additional grey literature\(^1\) was obtained through municipal, provincial and federal government websites and university research websites. Subsequent searches expanded the search terms to include ‘fuel treatment’ and fuel management’. Over the course of this project 113 documents were reviewed for information on fuelbreak effectiveness. An additional 24 documents were identified but copies could not be obtained for review.

Fuelbreaks are widely used throughout the Western United States. As a result, the bulk of the literature and documents reviewed focus on fuel types commonly found in those regions. France has a very active national fuel management program (Rigolot *et al.* 2002, Xanthopoulos *et al.* 2006). Australia uses fuelbreaks extensively to control bushfires. The only Canadian reference found in this literature/document search was the International Crown Fire Modeling Experiment fuel treatment trials in the Northwest Territories where Alexander and Lanoville (2004) tested the value of trembling aspen stands as fuelbreaks.

**Fuelbreak Advantages**

There is consensus in the literature that modification of forest fuels will alter wildland fire behaviour (Agee *et al.* 2000, Alexander and Lanoville 2004, Fites and Henson 2004, Hirsch *et al.* 2001, Martinson and Omi 2003, Martinson and Omi 2006, Omi *et al.* 2007, Graham *et al.* 2004 and others). The literature suggests that the primary purpose for fuelbreaks is to change fire behaviour as it enters the fuel-altered zone (Stratton 2004) resulting in limited, or slowed, fire spread (Davis 1951, Duguy 2007, Dennis 2005, Green and Schimke 1971, van Wagendonk 1996); reduced flame lengths (van Wagendonk 1996); and reduced probability of torching and independent crown fire (Agee *et al.* 2000). A fuelbreak can provide other numerous advantages as well: it can be used as an anchor point for indirect attack (Salazar and Caban 1987, Murphy *et al.* 1967); it can facilitate the rapid construction of a fireline/firebreak by suppression forces

\(^1\)Grey literature is defined as "information produced on all levels of government, academia, business and industry in electronic and print formats not controlled by commercial publishing". Available at: [http://toby.library.ubc.ca/subjects/subjpage2.cfm?id=877](http://toby.library.ubc.ca/subjects/subjpage2.cfm?id=877). Accessed March 18, 2010.
(Bevers et al. 2004, Murphy et al. 1967); it can provide safe access for ground suppression crews (Salazar and Caban 1987, Murphy et al. 1967); and can allow greater penetration to surface fuels of fire retardants dropped from the air (Agee et al. 2000, Murphy et al. 1967).

**Fuelbreak Characteristics**

To date, fuelbreak practices have focused primarily on nearly linear treatments (Bevers et al. 2004); however, there is emerging debate over the merits of linear versus area-wide fuelbreaks (Inglasbee 2005). Nevertheless, there were no absolute standards for fuelbreak width or fuel manipulation in the literature. In general, fuelbreaks need to be tailored to the terrain, fuels, historic fire regimes and expected weather conditions of the landscape in which they are placed (Green and Schimke 1971, Reinhardt et al. 2008, Agee et al. 2000, Omi 1996, Williston 1970, Martinson and Omi 2003).

Fuelbreak widths were quite variable in the literature. Widths range in size from 65m to 2800m (Crandall 1980, Green and Schimke 1971, van Wagendonk 1996, QLG 1997, Weir 2003, Government of South Australia 2005, Ingalsbee 2005, Dennis 2005, Wilson 1988, Sipe 1953). Many authors suggested that a wider fuelbreak will make the job of holding a fire on it easier and safer and that fuelbreaks should be wide as possible to achieve maximum usefulness in controlling big fires under hazardous conditions (Green and Schimke 1971, Agee et al. 2000).

Many authors stressed that a fuelbreak should not be constructed solely by thinning. The existing surface fuel load and height to live crown must also be treated (Ingalsbee 1997, Agee et al. 2000, Ingalsbee 2005, Reinhardt et al. 2008, Graham et al. 1999). In addition, enough large trees and/or groups of smaller trees should be left to shade the ground to discourage the establishment and growth of understory vegetation (Anderson 1971). Remaining trees should be the largest, healthiest, most wind-firm trees from the dominant and co-dominant species of the stand. It may be necessary in Lodgepole pine and Engelmann spruce stands to develop a fuelbreak over several years to allow the timber stand to ‘firm-up’ (Dennis 2005). At the stand level, fuelbreak projects should follow a step-wise progression working from the ground up, rather than the crown down. The objective should be to slowly raise the canopy up over time through multiple light entries of thinning from below rather than rapidly opening up the canopy in a single intensive overstory treatment (Ingalsbee 2005). Surface and ladder fuels should be the initial treatments (Graham et al. 2004).

Where possible, fuelbreaks should be tied into existing natural fire barriers such as lakes, rivers, natural openings and recent burns (Dennis 2005). Bare strips across fuelbreaks at specified intervals may reduce the possibility of fire spreading rapidly along the length of a fuelbreak (Green and Schimke 1971).

**Fuelbreak Effectiveness**

It is difficult to assess the effectiveness of fuelbreaks because of the variability of numerous factors: the prescriptions (width, fuel reduction, maintenance), the locations in which they are placed (fuels, topography, microclimate), the intensity of the wildfires approaching them, and the objectives and expectations of fuelbreaks (Agee et al. 2000).
The weakest link in a fuelbreak program is believed to be maintenance (Schimke and Green 1970). The main factor accounting for the poor performance of fuelbreaks in California was the lack of brush maintenance (Ingalsbee 1997, Sapsis 1997). Without proper maintenance, fuelbreak effectiveness decreases over time and an un-maintained fuelbreak can lead to a false sense of security among residents and fire suppression personnel (Dennis 2005). Fuelbreaks must be maintained to remain effective (Murphy and Murphy 1965) and therefore require long-term funding (Ingalsbee 1997). Some research suggests that the use of prescribed burning increases the effectiveness of a fuelbreak (Finney et al. 2005; Pollet and Omi 2002, Carey and Schumann 2003).

The effectiveness of a fuelbreak depends not only on its design characteristics but also on the behaviour of fires approaching it. Such behaviour is strongly determined by fuel spatial pattern in the adjacent areas (Duguy 2007, Bevers et al. 2004, Sapsis 1997) and any thinning beyond the fuelbreak will improve its effectiveness and is, therefore, highly recommended (Dennis 2005, Agee et al. 2000). Consequently, fuel treatments in adjacent lands would determine fuelbreak width and canopy alteration therein (Agee et al. 2000). A fuelbreak network on a landscape scale is deemed ideal (Agee et al. 2000). Patterns of disconnected fuel treatment patches that overlap in the heading fire spread direction are theoretically effective in changing forward fire spread rate (Finney 2001).

Summary

Fuelbreaks around developed areas have been recognized as an effective fire management strategy (Omi 1996), but the documentation is largely theoretical and the existing evaluations are limited to experiments using models that predict fire behaviour as it encounters a fuelbreak (van Wagtendonk 1996, Kaiss et al. 2007, Bellemare et al. 2001, Bevers et al. 2004, Fites-Kaufman 2007, Duguy et al. 2007, Johnston et al. 2007, Theisen 2003, Loehle 2004, Finney 2001, Horschel 2007, Ott and Jandt 2005). There are anecdotal accounts of fuelbreak effectiveness but these often fail to provide detailed information on break size, terrain, fuel type and fire behaviour that is necessary for analysis (Bower 1963, Davis 1951, Graham 2003, Murphy and Murphy 1965, Salazar and Caban 1987, Wagstaff 1942). Case studies on challenged fuelbreaks are an excellent source of relevant and useful information for determining fuelbreak effectiveness; however, these are site and situation specific making analyses challenging and drawing conclusions complex. There have been recent efforts to collect fire behaviour data in situ as wildfires encounter fuel treatments (Fites and Kauffman 2004), but most published natural experiments have relied on post facto analysis (Salazar and Caban 1987, Murphy and Murphy 1965, Lawson 2003) which do not provide detailed data on the fire behaviour, nor pre-burn fuel conditions. While many authors and researchers agreed that a fuelbreak has the ability to effectively modify fire behaviour, the specifics behind this ability have not yet been empirically proved (Reinhardt et al. 2008, Carey and Schumann 2003).

Agency Practices

British Columbia

In 2004, the Provincial Strategic Threat Analysis was developed by a private consultant (Bruce Blackwell) for the Ministry of Forests and Range. The analysis identified high-risk communities in the province, which were informed by Ministry personnel of their risk status and encouraged to develop and implement a Community Wildfire Protection Plan (CWPP). A Fuels Management Working Group was also established and members include representatives from Ministry of Forests and Range (MOFR) (fuel management specialists); Union of British Columbia Municipalities (UBCM) and First Nations Emergency Services Society (FNESS). The working group receives reviews and accepts CWPPs and operational plans for funding. The working group also maintains a Fuels Management Information System which stores the CWPPs and operational plans accepted for funding in the province.

The process in British Columbia is based on professional reliance where consultants are Registered Professional Foresters (RPFs) who prepare CWPPs and prescriptions for communities in the province. The provincial government relies on the Association of British Columbia Forest Professionals to ensure its members are working within the scope of their expertise. Municipalities and/or regional districts are responsible for choosing and hiring consultants to complete work associated with their fuel management projects whether on crown land or on municipal/regional lands. MOFR representatives offer guidance and technical advice to communities within their zone, relying on his/her own experience and knowledge. Currently, there are no provincially mandated recommendations for fuelbreak design within British Columbia’s fuel management program.

**Alberta**

Alberta Sustainable Resource Development (ASRD) has developed their own FireSmart Guidebook for Community Protection that describes a four-step process to guide and assist government departments responsible for fire and emergency services, industry stakeholder groups, FireSmart consultants, municipal development planners, and Alberta’s citizens with reducing wildfire threat to provincial values-at-risk. This guidebook is closely linked to the manual developed by Partners in Protection, FireSmart: Protecting Your Community from Wildfire. The ASRD guide compliments the Partners in Protection manual by providing a more operational focus.

ASRD has under provincial contract a group of private consultants who are qualified and experienced FireSmart planners (RPF/RPFT designation) to assist and support Alberta with the community wildfire protection effort. ASRD supports the use of vegetation management (fuel conversion; fuel isolation; fuel reduction) to achieve FireSmart landscape objectives. The project plan or prescription format may vary to suit the situational need; however, current vegetation conditions and future desired conditions must be documented.

ASRD works with the forestry sector to strategically design FireSmart landscapes, near communities and in remote areas, by incorporating FireSmart best practices into their detailed forest management planning. Forest management strategies such as vegetation management, access management, prescribed burning, cutblock design, sequencing, debris and slash...
management, and regeneration can proactively reduce the potential for extreme fire behaviour, decreasing the area burned.

Vegetation management projects that occur on crown land, outside of the detailed forest management planning process, undergo a series of ASRD directives and standard operating procedures prior to being implemented. Site specific modifications are made based on the vegetation management prescriptions for that area and the knowledge and expertise of ASRD staff and its consultants.

The Alberta Fire & Vegetation Monitoring Program is a long-term provincial monitoring program, initiated in 2006, designed to gather empirical evidence and build a provincial database and decision support tool that will support controlled burn operations and FireSmart fuels treatments. Monitoring plots are designed to capture pre-treatment fuel and vegetation information, post-treatment effects, and long-term vegetative response to various vegetation management prescriptions. The basis for Alberta’s methodologies was the FIREMON program in use by the US Forest Service.

Information on treatments conducted on crown land is stored in the provincial FIRES Database. The information collected includes only size of area treated, date of treatment, method of treatment, and treatment cost. Detailed information regarding fuel treatments is stored regionally and is of no standard format. Maintenance of these records varies by district.

**Saskatchewan**

The Ministry has completed provincial community wildfire risk assessments for several at-risk communities in the province; 104+ to date. These risk assessments are from the community boundary to a 20km radius. District forest protection officers are tasked with the responsibility of educating these communities about their respective wildfire risk and encouraging them to develop community wildfire protection plans and fuel treatment plans.

The Ministry provides communities with wildfire risk assessments within community boundaries, technical advice, recommendations, assistance with plan development and assistance locating funding sources. The Ministry wants to build capacity within communities so that they are able to manage their own wildfire risk. On crown land, the Ministry will design, fund and implement fuel treatments.

The Ministry has established a standard planning process and a standard form to be used for all fuel treatment project proposals. Proposals include location, rationale, maps, size of treatment, type and method of treatment, cost estimate, funding source, environmental considerations, and maintenance and monitoring. Fuel treatment proposals must be signed off by the proponent, the Education & Prevention Coordinator and the District Forest Protection Officer. Copies of community fuel management plans (for both crown and municipal lands) and approved proposals are kept at the Provincial Fire Centre in Prince Albert in their fuel treatment database.

The Ministry has developed their own *Guide to Managing Community Wildfire Risk* that outlines fuel treatment planning considerations and recommended specific fuel treatment strategies for
different fuel types. This guide was designed to assist community leaders to manage wildfire risk within their jurisdiction.

**Ontario**

The Ontario Ministry of Natural Resources (MNR) does not, at this time, have a formal provincial fuel management program regarding fuelbreaks for community protection; however, aspects of the FireSmart Program from Partners in Protection are being adopted by the province. For communities interested in developing a community wildfire plan, the MNR will provide advisory support that includes training, meeting facilitation, and plan review. The MNR provides a community wildfire planning guidance document, PowerPoint presentations, and a risk assessment tool (all based on FireSmart principles) to assist a community in developing their wildfire protection plan and treatment plans. Thinning, limbing, and coarse woody debris removal standards are all in accordance with the standards presented in the FireSmart Manual and if required, the MNR would advise communities on how to incorporate all three components into the design of a community fuelbreak. The community is responsible for selecting contractors to complete the work. If fuel treatments are required on crown land, the community must approach their district MNR office for advice, assistance and approval of work to be done.

There has been a handful of fuel management projects completed throughout the province, particularly in the northern regions. Because provincial documentation standards do not currently exist, data on these projects are not available through provincial channels at this time. Ministry personnel are attempting to locate, collect and collate information on these existing fuel treatments.

**Northwest Territories**

The Wildfire Risk Management Program in the NWT began less than a year ago. Because the territorial government does not have RPFs on staff or in the private sector, it has hired a wildfire professional consultant from BC to create CWPPs and prescriptions for the highest fire risk-rated communities in the territories (about 8). The CWPPs and prescriptions will encompass lands within and outside of the municipal boundaries.

The department of the Wildfire Risk Management Coordinator assists communities in seeking out funding to complete recommended treatments. Guidance can be provided from government personnel in forest regions (forest managers/forest officers depending on the region) in terms of high-level supervision and possibly contract management.

The NWT government has limited expertise in forest or fuel management and therefore does not have any best practices or protocols. However, by hiring a single consultant, plans for territorial communities will be consistent for all communities in the territories and will be all-encompassing.

The NWT was recently awarded federal funding of 1.3M as part of a job stimulation program to use for fuel treatments across the territories. Unfortunately there are no completed CWPP plans in place that, ideally, would precede any operational plans. But in order to get the funding, work had to start sooner than plans could be completed. Therefore regional staff has been working with 14 communities this winter to develop impromptu plans to take advantage of the funding.
These communities are small with little infrastructure in the WUI, thus fuel treatment prescriptions were deemed to be less complicated and easily handled by regional forest managers.

**Yukon**

The Yukon government contracted Ember Research Services from Victoria, in association with Applied Ecosystem Management Ltd. and Trans Northern Management Consulting (both from the Yukon), to develop a territory-wide fire management plan known as the Ember Plan. The plan was completed in 2000 and covers each community in the Yukon. The Ember plan includes community specific risk ratings, community fire risk reduction plans and mitigation strategies. Principles and recommendations in the Partners in Protection FireSmart Program were incorporated into Yukon’s Ember Plan. The Whitehorse area has its own fire management plan, also created by Ember Research Services and Applied Ecosystem Management. The Whitehorse Fuel Management Plan was completed in 2002 and goes into greater detail than the territory-wide Ember Plan. The Whitehorse Fuel Management Plan is referenced for all Whitehorse area projects.

Municipalities apply to the Yukon Government for funding and hire a consultant to develop their community protection plan. Fuel treatment prescriptions are prepared and implemented by territorial Zone Protection Managers (ZPM) and FireSmart officers using the Ember Plan (or the Whitehorse Fuel Management Plan) and the FireSmart Manual. ZPMs and FireSmart Officers consult with the appropriate authorities to build these prescriptions (i.e. riparian areas (DFO); caribou habitat (Environment Yukon); merchantable timber (Forest Operations); etc.) and rely on their collective experience-based knowledge. Fuel treatments are conducted through this FireSmart Program, and through the Forest Management Branch. These two programs are coordinated to some degree.

A prototype monitoring protocol for fuel treatments in white spruce forests of southwest Yukon has been developed by Brad Hawkes with the CFS. The Fuel Treatment Prescription Compliance and Effectiveness Monitoring Protocol is part of a more complete manual, the Yukon Forestry Monitoring Program: Field Manual and Monitoring Protocol (Ogden, 2008) that is being used to document the ecological impacts of forest harvesting and effectiveness of management activities in reaching desired outcomes.

**Parks Canada**

By law, the management of each park is guided by a Park Management Plan. This public document approved by the Minister, guides management actions including fire management within the national parks. Park Management Plans conform to the National Parks Act, Parks Canada Policy, directives and standard operating procedures. Specific to each park is a Fire Management Plan, which guides wildfire, prescribed fire and fuels management actions. Each national park has its own fire/vegetation specialist and/or fire management officer that is responsible for developing and implementing site-specific fuel treatment plans. All plans and prescriptions for fuel management projects are done in-house; fire/vegetation specialists and fire management officers rely on their experienced-based knowledge, existing research and the sharing of information across field units and other agencies through colleague collaboration and peer discussions. It is up to each park to decide on treatment methods to be used. Any vegetation
treatments in national parks are subject to the Environmental Assessment Act and must go through that process to be approved. Significant importance is placed on a communication strategy with stakeholders and the public.

Each park maintains its own records and documentation related to a planned or completed fuel management project. There is no formalized process in place for documentation and the amount and type of documentation varies park by park and by project. Also, there is no formally established monitoring or maintenance protocol; monitoring and maintenance is conducted informally at the discretion of each park’s fuel management team.

Summary
The FireSmart principles developed by Partners in Protection have become ubiquitous within the fuel treatment programs of provincial fire agencies across Canada. Since the launch of their manual, most Canadian fire agencies have, to varying degrees, come to use its principles and recommendations (see Page 13 of this report) as the basis for the design of fuelbreaks for communities in their jurisdiction. Some provincial fire agencies have developed their own vegetation assessment and fire-risk assessment tools and protocols (see Appendix A); however, outside of the FireSmart recommendations the provinces do not appear to have any formal guidelines/protocols/manuals to help their personnel make decisions concerning the specifics of fuelbreak design (i.e., tree spacing, changes to crown base height, coarse woody debris removal, treatment width, etc.).

Ultimately, Canadian fire agency personnel typically rely on experience-based knowledge, colleague collaboration, peer discussions, and existing research in conjunction with the FireSmart principles/recommendations to design fuelbreaks to mitigate the fire-risk around communities. These decision-making processes are informal, take place project by project, and are typically not documented. Several Canadian fire agencies (British Columbia, Alberta, Yukon and Northwest Territories) rely heavily on professional fuel management consultants to help communities design their wildfire protection plans and subsequent treatment plans/prescriptions. These professional consultants also use their extensive experience and acquired knowledge, along with existing research and, in some cases, fire behaviour models to develop these plans.

Agency Fuelbreak Characteristics
The collection of fuelbreak characteristic information from Canadian agencies was more difficult than expected. The ability of agency staff to locate the information requested was hampered by various combinations of the following:

- requested information not maintained in a central location;
- requested information not organized in a searchable format;
- poor organization, and/or misplacement, of documentation at district offices;
- documentation standards did not include the requested information;
- a substantial reliance on the memories of agency staff involved in the project;
- documentation often included project draft proposals, but no final reports;
- maps kept in separate locations;
- documentation files not updated or maintained, and therefore not current;
agency personnel not permitted to disclose all requested details;

Because of these difficulties, the task of searching for the fuel treatment information requested required more time and effort than most agency personnel could afford within the scope of their normal duties. As a result, only 26 fuelbreak examples were collected from Canadian fire protection agencies (see Appendix B) and not all the requested information was provided for all examples. Several more Alberta examples were identified from the agency’s website, but few of these examples were described in the detail required for this analysis. Fifty additional British Columbia examples were indentified in the BC Forest Practices Board (FPB) Special Report (2010) on fuel management. While only limited information was available on most, it was, nevertheless, included in this report. Ontario and the Northwest Territories were not able to provide any information on fuelbreaks in their jurisdiction for this report.

Project goals, values at risk, fuel types, topography, terrain features, public appetite, ecological concerns, funding, all vary from one site to the next and will dictate the design features of a community fuelbreak. While the over-riding goal of a fuelbreak project is to protect a community or some other value(s)-at-risk, this goal is often tempered by the expectations and requirements of project stakeholders (industry, ecologists, private land owners, First Nations, etc.). In some cases, particularly in ecologically sensitive areas, compromises are often made to such an extent that planners are left to wonder whether their final treatment will have any effect in modifying wildfire behaviour. All of the above mentioned variants make each fuelbreak project truly unique. Nevertheless, there were common physical features observed among our 26 examples of existing community fuelbreaks in Canada.

**FireSmart Guidelines**

A fuelbreak will contain any combination of the fuel treatment elements: (1) spacing or thinning of overstory, (2) modification of ladder fuels (spacing of understory; increasing crown base height, etc.) and (3) modification of existing surface fuels, including dead and down materials. As mentioned in Agency Practices, most Canadian fire protection agencies use, to varying degrees, the standards presented in the manual produced by Partners in Protection, *FireSmart: Protecting Your Community from Wildfire*. This manual provides specific guidelines for three aspects of community wildfire protection:

1. vegetation/fuel management
2. structural options (roofing; siding; windows; decks, etc.)
3. infrastructure (roadways; water supply; utilities, etc.)

For the purposes of this report only the guidelines and standards presented in the FireSmart manual for vegetation/fuel management, as they relate to a community fuelbreak, are relevant.

The FireSmart manual outlines minimum standards for vegetation/fuel management around individual structures and describes a community fuelbreak as a wide area outside the

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2 Available at: [http://www.srd.alberta.ca/ManagingPrograms/PreventingFightingWildfire/FireSmartCommunities/Default.aspx](http://www.srd.alberta.ca/ManagingPrograms/PreventingFightingWildfire/FireSmartCommunities/Default.aspx)
3 Ian Pengelly, Parks Canada Fire/Vegetation Specialist, Banff Field Unit, personal communication, October 2, 2009.
5 The FireSmart manual uses the term ‘community fireguard’.

community in which a combination of these standards have been applied. These standards include:

- complete vegetation/fuel removal or conversion to non-flammable shrubs and ground vegetation
- thin forest canopy to 3-6m crown spacing
- remove understory trees
- retained understory requires a minimum of 4m stem spacing
- increase crown base height to 2m

The manual also specifies minimum width standards for community fuelbreaks:

- 30m  < 5% slope
- 40m  5-15% slope
- 50m  > 15% slope

Other standards outlined for community fuelbreaks\(^6\) include only a general discussion on debris disposal methods and maintenance requirements. Alternative fuel reduction standards for use in interface areas with a substantive and established crown fire danger are also presented\(^7\); however, the fuel types that might fall into this category are not specified:

- 100m minimum fuelbreak width for most situations; 200m on steeper slopes
- thin 4-8m between stems depending on the crown diameter, slope and proximity of values-at-risk.
- if fuel modifications must be decreased for aesthetic reasons and/or to minimize windthrow, then fuelbreak width should be increased (distance not specified).

**Shape and Size**

A fuelbreak is often regarded as a linear feature on the landscape; however, the use of polygons to build a community fuelbreak, or fuelbreak system, is common, especially in areas with significant topography. In these cases, linear fuelbreaks are not feasible or even necessary because of local terrain features. Among our examples, linear fuelbreaks were more common among projects in the central to northern boreal forests of Alberta, Saskatchewan and the Yukon, and polygons were more common in the mountain parks and through-out British Columbia.

Because fuelbreaks are often made up of a series of polygons and contain multiple treatment units, it is sometimes difficult to describe a fuelbreak by its width. For example, a fuelbreak on Sulphur Mountain in Banff National Park, AB (Figure 1) is a landscape level fuelbreak designed specifically to reduce the risk of crown fire reaching the townsite of Banff. In contrast, the Jeanette Lake fuelbreak in Saskatchewan could easily be described by its width (Figure 2). Consequently, agencies do not always record the width of their fuelbreaks but rather their overall size. Cost estimates, proposals and project cost tracking are all submitted on a per hectare basis, so there is no administrative need to record fuelbreak width.

The fuelbreak examples provided to us by the agencies ranged in overall size from 2ha to 545ha. The two largest fuelbreaks were in national parks: 325ha in Prince Albert National Park, a linear

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\(^6\) In Chapter 3, pages 16-18.
\(^7\) In Appendix 2 of the FireSmart Manual.
fuelbreak around the community of Waskesiu; and 545ha in Banff National Park, a series of fuel treatment polygons creating a landscape level fuelbreak to ultimately protect the Town of Banff.

Of our 26 examples, 11 recorded fuelbreak width. These ranged from 50m to 3000m, with the most common width between 150-200m. The fuelbreak with widths up to 3000m was the Carrot Creek fuelbreak in Banff National Park. This is a large landscape level fuelbreak designed to prevent crown fire from reaching to, or spotting near the Town of Banff. The next widest fuelbreak was a project at Hall Lake, Saskatchewan. The planners had incorporated existing harvesting operations to create the fuelbreak resulting in widths between 200-600m. Of the fifty examples indentified by the FPB report, overall size of fuel treatments, where stated, ranged from 2ha to 189ha and widths ranged from 30m to 100m. The size and/or width of a fuelbreak, unfortunately, often has more to do with available funding than with fire behaviour principles.

![Figure 1. Sulphur Mountain fuelbreak in Banff National Park, AB.](image1)

![Figure 2. Jeanette Lake fuelbreak, SK.](image2)
Treatments

Treatment prescription details were not available for all of our agency fuelbreak examples, but where details were available many followed quite closely to the FireSmart guidelines - regardless of fuel type.

Only one of our examples, near Chisholm, AB was constructed by completely removing all vegetation to expose the mineral soil. Overstory (Layer 1), crown spacing was between 3-5m for most of our examples for which we had data (20). Some notable exceptions were: the Bonnevier fuelbreak in Manning Park, BC where the overstory stem spacing was between 8-12m; the Silverstar fuelbreak near Vernon, BC, where a crown closure target of 25% was specified, rather than spacing distances; the Redstreak fuelbreak near Radium, BC where a target density of 20-50 stems/ha for Douglas-fir and 4-6 stems/ha for Lodgepole pine was specified; the Carrot Creek fuelbreak near Banff, AB that removed all stems less than 15, 20 or 25 cm DBH, site and species depending. These examples were in either a provincial or national park.

Only three of our agency examples provided treatment specifics for the understory (Layer 2). One example specified 4-6m stem spacing (Bonnevier), another required the removal of 85% of intermediate stems, and the last specified 2m crown spacing. Crown base height was specifically addressed in 10 of our agency fuelbreak examples ranging from 1.5 to 3m, with 2m being the most common. The two examples in BC Parks stated that crown base height would be determined on site. In the remaining examples, crown base height was not addressed in the prescription.

Treatment specifics for surface fuels were not recorded by the agencies, although some general comments were made in approximately half of our agency fuelbreak examples. These general comments included: (1) complete removal, (2) removal of the majority, (3) no removal, (4) accumulations removed, (5) to be determined by agency representative. Only the Bonnevier and Silverstar fuelbreaks specified a target for surface fuels (<20m³/ha). This may be due, in part, to the higher scrutiny placed on harvesting activities in parks (both Bonnevier and Silverstar fuelbreaks are within a BC Provincial Park) and, in part, to the ecological background of the fuelbreak planners and designers.

Although treatment specifics were not available for all of the fuelbreak examples from Alberta, all included a notation stating that the projects were completed to FireSmart standards. For the additional British Columbia examples identified in the FPB report, crown spacing distances, where stated, ranged from 2-4m; overstory density targets were less than 100 stems per hectare; and pruning heights ranged from 1.5 to 3m (6m in one very dense area).

Maintenance

Maintenance schedules for existing fuelbreaks were rarely identified by their agencies. Saskatchewan, however, stated a maintenance schedule of 10 years for all the fuelbreak examples they provided to us. Although fuelbreak maintenance does not seem to be formally addressed in many agency plans, it is part of most agency personnel job descriptions. As such, the task is left up to district personnel’s discretion and availability as to when site visits are conducted. The lack of maintenance scheduling may be due to uncertainties surrounding future funding, local capacity, and resource availability.
**Special Features**

In most cases our fuelbreak examples were tied into or made use of existing roads, trails, utility right-of-ways, lakes, aspen stands, existing fireguards, harvest blocks, and previous fuel treatments.

**Fuel Type**

The Canadian Forest Fire Danger Rating System (CFFDRS) fuel types for most of the fuelbreak examples were provided by the agency and some could be estimated from available forest vegetation maps. The fuel types for the examples provided by the agencies included; C1, C2, C3, C4, C7, and M1/2 (See Appendix C for definitions). Fuel type or stand type information was not described for the BC examples in the FPB report.

**Costs**

Although project costs were rarely available from agencies, it is well known that fuel treatment costs can be widely variable. They depend on the method of treatment, site topography, site conditions, the ability of local governments to offset costs and resource availability at the time, and place, of treatment. In northeast and central Alberta, the cost per hectare of mechanical treatments is currently between $5,000 and $7,500 and between $7,500 and $10,000 for manual treatments.\(^8\)

**Summary**

Although fuelbreak width and/or size varied considerably across all provided examples, crown spacing (between 3-5m) and crown base height (approximately 2m) were found to be similar, despite the variety of geographic regions and fuel types, and did not deviate greatly from the FireSmart standards. This indicates the degree to which FireSmart has influenced the design of fuelbreaks in Canada. Fuelbreaks in the national and provincial parks, however, were an exception where the restoration of historical stand conditions and the rehabilitation and protection of wildlife habitat play a more prominent role than elsewhere. The FireSmart document was the first and only attempt to date to establish standards for fuel treatments in Canada. Coupled with the lack of empirical research, it is not surprising to find that these standards are being implemented rather consistently across the provinces. Table 1 summarizes the results from the sample set of fuelbreak examples.

There are, however, limitations to these conclusions. First, our sample size of 26 fuelbreak examples was small. Very small, in fact, considering the number of fuel treatment projects believed to be underway and completed across the country. As well, the lack of complete data on these 26 fuelbreaks effectively reduced our sample size even further.

Second, there is a high probability that our sample suffers from selection bias. Selection of specific fuelbreak examples was left to agency personnel with our only requirement that the example chosen have as much of the required information as possible. It is possible that agency staff chose fuelbreaks where treatments conformed to FireSmart standards, or perhaps only those

\(^8\)Wendell Pozniak, Area Forester, Alberta Sustainable Resource Development, Fort McMurray, AB, personal communication February 3, 2010.
fuelbreaks whose treatments conformed to FireSmart standards were well documented. In either case, we understand that our sample may not be wholly representative of fuelbreaks in Canada.

Table 1. Summary of results from a small sample set of Canadian fuelbreaks.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Results Summary*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape/Size</td>
<td>varies: 2 - 545ha if polygons; &lt;25 - 3000m if linear</td>
</tr>
<tr>
<td>Crown Spacing</td>
<td>3-5m for provincial agency projects; varies for parks projects</td>
</tr>
<tr>
<td>Understory Spacing</td>
<td>4-6m for provincial agency projects; varies for parks projects</td>
</tr>
<tr>
<td>Crown Base Height</td>
<td>1.5 - 3 m</td>
</tr>
<tr>
<td>Surface Fuel</td>
<td>complete; partial; no removal</td>
</tr>
<tr>
<td>Maintenance Schedule</td>
<td>none; 5 years; 10 years</td>
</tr>
</tbody>
</table>

*Based on a very limited sample set.

Third, available agency documentation may not accurately represent actual fuelbreak features. Most of the available documentation was in the form of plans and proposals. During the actual implementation of a fuel treatment/fuelbreak prescription, agency personnel and consultants will routinely make ad hoc adjustments to the treatment prescriptions based on their observations of stand conditions during site visits. Adjustments are often required for various reasons, including but not limited to: aesthetics, perceived blowdown potential, and unexpected pockets of accumulated surface fuels. The extent of these modifications depends quite heavily on the experience of the individual, and his or her comfort level in adjusting a pre-approved prescription. While planners do their best to create accurate and practical prescriptions, the actual characteristics of a fuel treatment are ultimately determined on site through the expertise and knowledge of the professionals involved, while simultaneously juggling the unique challenges of the site and the project. These modifications may or may not be documented, as there is no apparent protocol for post-treatment measurements within most agencies.

Finally, our sample did not include fuelbreaks that are in the planning phase, under construction, or very recently constructed. Indications are that different prescriptions outside of the FireSmart guidelines are now taking place in many areas to reduce blowdown potential. In addition, since fuelbreaks are governed by economics, FireSmart standards cannot always be met due to current financial constraints.

This review of agency fuelbreak characteristics revealed that province-wide collection of fuel treatment information is limited to information needed for financial due diligence and accounting purposes. The central fuel treatment databases developed and used by Alberta, British Columbia, and Yukon, specifically, have been designed primarily to record only financial information and lack the capability to act as a repository of information for fuelbreak design. The specifics of a given fuelbreak project design may be filed regionally by the agency personnel involved and generally follow no data collection standards.
**Expert Opinion Survey**

The survey was developed with advice and assistance from Jim Gould from CSIRO\(^9\). It was designed to be completed in 20 minutes or less and had 20 questions; 15 with tic-box answers and 5 with open-ended answers. The survey questions were chosen by the project proponents. See Appendix D for a copy of the survey. The survey was tested on two fire experts so that refinements could be made. The survey was emailed to 60 Canadian fire experts during the summer of 2009.

Of the 60 surveys sent, 43 were completed and returned. Respondents included, air attack officers, fire base managers, fire researchers, fire technicians, fire behaviour specialists, wildfire prevention officers, fire ecologists, fuels management program managers and planners, forest protection officers, fire operations specialists, and a fire centre coordinator. The average operational experience of survey respondents was 28 years. 84% of respondents have had experience on 20 or more large wildfires and 86% have had experience on wildfires that threatened communities.

**Respondents’ Observations**

Survey respondents were asked to recount their observations of an actual event where a wildfire challenged a break in forest fuels, man-made or natural. Examples came from all over Saskatchewan, Alberta and British Columbia and one from the Northwest Territories.

The prevalent fuel types in the respondent’s examples were: C1; C2; C3; C4; M1; M2; O1; D1 (See Appendix C for descriptions). 54% of the examples were in the C2 fuel type. Terrain was flat to undulating/moderate for all examples but two where the terrain was recorded as steep (Mount Robson Provincial Park, BC and Kootenay National Park, BC). For 60% of the examples, respondents recounted fire weather hazard as extreme, 30% of the examples were described as high and 10% were described as moderate. For 70% of the examples, respondents recounted a head fire intensity (HFI) of >10,000 kW/m\(^{10}\); 18% had HFI of 4000-10000 kW/m; 12% had HFI <4000 kW/m. Of the 43 examples recounted by respondents, 60% were man-made fuelbreaks (roads/highways and fireguards, primarily) and 40% were natural fuelbreaks, the majority of which were watercourses.

There are several factors that can lead to the success or failure of a fuelbreak. The survey attempted to ascertain the most common factors our experts felt had the greatest influence on the success or failure of a fuelbreak challenged by wildfire. Because the majority of the fuelbreaks in respondents’ examples were either roads/highways, fireguards (to mineral soil) or water courses, factors relating to stand conditions such as crown spacing, surface fuels and ladder fuels within the fuelbreak were not relevant. These factors were, however, relevant in adjacent fuels yet very few respondents indicated that these substantially affected either the success or the failure of the fuelbreak in their example.

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\(^9\)Jim Gould, Team Leader of the Bushfire Dynamics and Applications Group in Australia’s Commonwealth Scientific and Industrial Research Organization (CSIRO) and was on secondment with the Canadian Forest Service.

\(^{10}\)Head fire intensity (HFI) is measured in kilowatts per metre (kW/m).
Of the 43 examples recounted by respondents, 14 (33%) were of a successful fuelbreak, i.e. where it was not breached by the wildfire. Fire weather hazard during these events was described as high to extreme. For 60% of these successful fuelbreak, the HFI was described as >10,000 kW/m. Interestingly, 50% of the successful fuelbreaks were less than 25m wide, and 30% were between 25-100m wide. Respondents indicated that the factors that had the greatest influence on the success of these fuelbreaks was suppression capabilities (i.e. back-burning and patrolling primarily, with one case of aerial application of retardant), fuel type and wind direction/speed.

66% of the respondents’ examples were breached by wildfire. Wind (direction/speed) was the highest rated factor that led to the failure of these fuelbreaks. Fuel type, crown fire potential, width and suppression capabilities, were also described as the most important factors that lead to fuelbreak failure. Fuelbreak widths of less than 25m made up 14% of respondents’ failed fuelbreaks, 36% were between 25-100m and 43% were greater than 100m. When asked about the primary cause of fuelbreak failure, 93% of respondents indicated spotting. Radiant heat was described by 21% of respondents as either the primary or secondary cause. Flame contact was described by 11% of respondents as either the primary or secondary cause.

There were 6 examples where the fuelbreak width was greater than 500m. Four were water courses, one was a fireguard and one was a clear-cut harvest block. All these failed as an effective fuelbreak. The fire weather was described as high to extreme and the HFI was described as >10,000 kW/m. Respondents indicated that wind was the most important factor in the failure of these fuelbreaks and the primary cause of the failure was spotting.

Only two respondents provided examples of a wildfire challenging a pro-active fuel treatment. In Mount Robson Provincial Park, a prescribed burn had been conducted on the slopes along Moose River to create a landscape level fuelbreak. A wildfire ignited from a lightening strike up the valley and the prescribed burn, combined with Moose River, effectively prevented the wildfire from moving into the main Robson Valley. Crown fire behaviour was suppressed as it encountered the previously burned surface fuels and the wildfire was not able to spot over the large area of the prescribed burn. The fuelbreak area was greater than 100ha. The second example was at Morrison Coulee in Banff National Park. The fuelbreak was a thinned pine stand (approximately 5m spacing), 25-100m wide. The stand was treated and piles burnt in the spring. In the same year, an August wildfire burned into and through the thinned stand with no observable change in fire behaviour. Radiant heat from adjacent forest and the size of the fuelbreak were believed to be the cause of the failure.

**Respondents’ Opinions**

Survey respondents were asked whether they supported pro-active initiatives to design and construct fuelbreaks for the protection of communities from future wildfires. Respondents were also asked to describe what they felt to be the advantages and disadvantages of such fuelbreaks. Despite several disadvantages described by most of the respondents, they unanimously supported the use of fuelbreaks for community wildfire protection.

The most common advantage of a fuelbreak as described by respondents was the ability of fire operations personnel to utilize it for suppression activities (increased ground access for fire crews, increased penetration of aerial fire suppressants, anchor point for back-burning activities,
The placement of sprinkler lines, etc. The second most common advantage noted by respondents was the ability of a fuelbreak to modify fire behaviour, i.e. reduce an active crown fire to an active surface fire that is potentially actionable by suppression forces. Only two respondents discussed the potential of a fuelbreak to reduce spotting potential.

The most common disadvantage described by respondents was the limited ability of a fuelbreak to have an effect on fire behaviour in extreme conditions. Other disadvantages included the false sense of security a fuelbreak can give a community and even fire operations personnel; increased public access which may increase incidences of human-caused ignitions; the need for, and lack of, maintenance; and the potential for increased in-stand wind speed and increased drying of surface fuels.

There are many factors to consider when designing a fuelbreak and its treatments. To get a sense of where the focus should be during the design phase, survey respondents were asked what they felt were the five most important factors to consider when designing a fuelbreak for community protection from wildfire. The top five in order are listed below:

<table>
<thead>
<tr>
<th>Factor</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Type</td>
<td>(1)</td>
</tr>
<tr>
<td>Adjacent Fuels</td>
<td>(2)</td>
</tr>
<tr>
<td>Crown Fire Potential</td>
<td>(3)</td>
</tr>
<tr>
<td>Suppression Capabilities</td>
<td>(3)</td>
</tr>
<tr>
<td>Width</td>
<td>(4)</td>
</tr>
<tr>
<td>Distance from Community</td>
<td>(5)</td>
</tr>
<tr>
<td>Surface Fuel Management</td>
<td>(5)</td>
</tr>
<tr>
<td>Maintenance</td>
<td>(5)</td>
</tr>
</tbody>
</table>

One of the last questions in the survey asked respondents how they would design a fuelbreak with unlimited funding. By combing the answers the ideal fuelbreak would have the following features: it would tie into existing natural fuelbreaks and contain a linear non-fuel strip, as straight as possible with only gentle curves, with extensive fuel management up to a kilometer (or more) along either side. Fuel management would involve extensive crown thinning of conifers, but many respondents would like to see the replacement of conifers with deciduous stems. As well, there would be significant, if not complete, removal of surface and ladder fuels. The fuelbreak would be tied into an existing water source or, if none existed, a water source would be created (i.e. dugouts). The fuelbreak would allow easy access for fire crews and would facilitate the easy deployment of high volume sprinkler lines in advance of an approaching wildfire. There would be annual or biennial monitoring, and maintenance, of surface fuels. Only a handful of respondents provided specific metrics for fuel treatments: crown closure should be less than 35%; surface fuel amounts less than 5kg/m²; treatment should be about 1 kilometer from value; non-fuel strip should be 10-30m wide. There were mixed comments about grass fuels in a fuelbreak; if cured, grass fuels can carry a vigorous surface fire with sufficient energy to support a crown fire in an adjacent stand. However, grass fuels can be easily maintained, and if done so, will slow rate of fire spread and reduce potential for a crown fire. One respondent

11 Ian Pengelly, Fire/Vegetation Specialist, Parks Canada, Banff Field Unit.
offered an approach to fuelbreak design that differed from the others: clear narrow trails (6-8m wide, every 30-40 m) perpendicular to the probable wind direction. Essentially, clear 20% of the stand and treat the remaining 80% for surface fuels. The idea is to maintain low in-stand wind speeds and reduce blowdown. This respondent suggested that in areas with suspected blowdown problems, thinning should be avoided and to treat only the ladder and surface fuels.

**Summary**

Respondents’ opinions regarding the use of fuelbreaks were not surprising. The most common comments made by respondents were that fuelbreaks:

- need to be made wide as possible;
- must be treated extensively;
- are just one component in community protection and not effective in isolation;
- are needed to aid suppression efforts;
- will likely fail in extreme conditions.

Respondents’ accounts of actual incidents suggest, somewhat surprisingly, that if suppression action is present, a fuelbreak does not need to be excessively wide (80% of successful fuelbreak examples in the surveys were less than 100m wide; 43% of failed fuelbreaks examples were >100m wide). According to the examples provided by the respondents, the primary factors involved in both fuelbreak failures and successes were wind, fuel type and lack of timely suppression action (Table 2).

<table>
<thead>
<tr>
<th>FACTOR</th>
<th>CAUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Failure:</strong></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>spotting</td>
</tr>
<tr>
<td>Fuel type</td>
<td>radiant heat/flame contact</td>
</tr>
<tr>
<td>Suppression Action</td>
<td>inadequate or lacking</td>
</tr>
<tr>
<td><strong>Success:</strong></td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>favourable direction/speed change</td>
</tr>
<tr>
<td>Fuel Type</td>
<td>less flammable fuels</td>
</tr>
<tr>
<td>Suppression Action</td>
<td>adequate and timely</td>
</tr>
</tbody>
</table>

Both the opinions and observations provided by respondents emphasized the strong relationship that exists between a successful fuelbreak and a successful fire suppression strategy. The survey responses suggest that these two components of community protection are deeply interconnected and, in most cases, you cannot have one without the other. This reinforces the idea that not only must the suppression strategy be considered when designing a fuelbreak, but that planning task force and local fire suppression forces must anticipate and plan how the fuelbreak can be used during an emergency.\(^\text{12}\)

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\(^\text{12}\) Brad Hawkes, Fire Research Officer, Canadian Forest Service, Natural Resources Canada, personal communication February 12, 2010 regarding the activities conducted in Logan Lake, BC by Tom Lacey, Fuel Management Consultant.
Challenged Fuelbreak Incidents

Information on challenged fuelbreaks was the most difficult data to collect. We were able to identify 50 incidents of where a wildfire challenged a fuel treated area; 45 were in the United States and 5 were in Canada. Although only 2 of the US incidents were in a boreal forest type (Jack pine), all the identified US incidents were considered for review as it was believed that they may provide valuable information that could be extrapolated to the Canadian experience. However, incidents that occurred in conifer dominated stands were the priority. Of the 45 US incidents, 23 identified a conifer species as the dominant species type - in most cases it was Ponderosa pine, Douglas-fir or, simply identified as mixed conifer.

United States Incidents

Of the 45 incidents identified in the United States, case studies for only 11 could be obtained for review (Table 3). Depending on the authors’ professional background and study focus, these case studies did not always include a description of actual fire behaviour observations (fire type, fire intensity, rate of spread) but instead used post-fire measurements of fire severity (bole scorch, crown scorch, tree mortality). Some of these case studies also omitted details regarding weather and the fuel treatments, such as size of treatment area, treatment specifics, age of treatments, etc., and operational details regarding suppression activities. This wide range of scientific rigor made an evaluation of these case studies difficult. Brief summaries of these eleven case studies are presented in Appendix E. Only the key observations from those studies are summarized here.

<table>
<thead>
<tr>
<th>Incident</th>
<th>Location</th>
<th>Year</th>
<th>Species/Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>American River Complex Fire</td>
<td>California</td>
<td>2008</td>
<td>mixed conifer; Ponderosa pine, Douglas-fir; White fir</td>
</tr>
<tr>
<td>Angora Fire</td>
<td>California</td>
<td>2007</td>
<td>mixed conifer</td>
</tr>
<tr>
<td>Biscuit Fire</td>
<td>Oregon</td>
<td>2002</td>
<td>mixed conifer, Douglas-fir dominant</td>
</tr>
<tr>
<td>Black Mountain II Fire</td>
<td>Montana</td>
<td>2003</td>
<td>Douglas-fir dominant</td>
</tr>
<tr>
<td>Cascade Fire</td>
<td>Idaho</td>
<td>2007</td>
<td>Subalpine spruce; Lodgepole pine; Engelmann spruce at higher elevations; Ponderosa pine, Douglas-fir and Lodgepole at lower elevations.</td>
</tr>
<tr>
<td>Cavity Lake Fire</td>
<td>Minnesota</td>
<td>2006</td>
<td>Jack pine dominant</td>
</tr>
<tr>
<td>Cone Fire</td>
<td>California</td>
<td>2002</td>
<td>Ponderosa pine</td>
</tr>
<tr>
<td>Fontainbleau Fire</td>
<td>Mississippi</td>
<td>1999</td>
<td>Slash pine (a long-needle pine)</td>
</tr>
<tr>
<td>Grass Valley Fire</td>
<td>California</td>
<td>2007</td>
<td>Coulter pine; Sugar pine; Jeffery pine; Douglas-fir</td>
</tr>
<tr>
<td>Hayman Fire</td>
<td>Colorado</td>
<td>2002</td>
<td>Ponderosa pine; Douglas-fir</td>
</tr>
<tr>
<td>Wheeler Fire</td>
<td>California</td>
<td>2007</td>
<td>mixed conifer</td>
</tr>
</tbody>
</table>

Many of these US case studies suggested that the removal of surface and ladder fuels may play a more important role in changing fire behaviour than thinning of overstory canopy fuels. They
also showed that crown fire momentum will carry high fire intensity into treated areas, but the fire will eventually drop to the surface and burn with lower intensity, given sufficient width of the treated area. Several case studies suggested that treatment history was less important than the characteristics of the last treatment, including time since treatment and unit size. They emphasized the importance of repeating treatments to maintain fuel conditions that mitigate wildfire severity. A common thread in all eleven case studies was that suppression action, in and around an established fuel treatment, is critical to ensuring that fuel treatment’s effectiveness. At the same time, the existence of fuel treatments greatly enhance the ability of suppression forces to successfully and safely action a fire.

An additional 426 incidents in the United States have been identified by Dr. Mark Cochrane, from South Dakota State University, who is currently working on a project to quantify the effectiveness of fuel treatments across the United States in terms of their measurable effects on fire severity and fire spread\textsuperscript{13}. The landscape level effect of the fuel treatments on real-world fires is assessed through modeling of fire spread. This thorough and comprehensive study is expected to be completed in 2010/2011 and is expected to provide wildland fire managers and policy makers with a better understanding of how conditions and location will affect the effectiveness of treatments.

**Canadian Incidents**

Despite the increase in fuel treatments in Canada in the past decade and an increased number of interface fires, only 5 incidents of challenged fuelbreaks were identified (Table 4). Of these 5 Canadian incidents, documentation could only be obtained on the Crutwell Fire in the form of an informal, internal agency report. Information on the Morrison Coulee Fire and the Moose River Fire were obtained from the expert opinion surveys; however, no official agency documentation is believed to exist on these two events. No information was made available to us on either the Glenrosa Fire or the Alexis Creek fire; however, BC agency personnel informed us that there are plans to document these two events. Brief summaries of the Crutwell Fire, the Morrison Coulee Fire and the Moose River Fire are presented in Appendix F.

**Table 4. The five Canadian incidents described in this report.**

<table>
<thead>
<tr>
<th>Incident</th>
<th>Location</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glenrosa Fire</td>
<td>British Columbia (2009)</td>
<td>no information; likely Ponderosa pine</td>
</tr>
<tr>
<td>Alexis Creek Fire</td>
<td>British Columbia (2009)</td>
<td>no information; likely Lodgepole pine</td>
</tr>
</tbody>
</table>

As did the accounts from the United States, the Crutwell Fire and the Morrison Coulee Fire emphasized the relationship between fuelbreak and suppression action. Suppression action along roadways in the Crutwell Fire was unsuccessful, but was finally successful along the fuelbreak. In the case of the Morrison Coulee Fire, there was no suppression action along the fuelbreak.

\textsuperscript{13} Project details can be found at http://globalmonitoring.sdstate.edu/projects/ftedis/
which was subsequently breached by the wildfire, despite 5m crown spacing. Although the Moose River Fire was successfully stopped in the absence of suppression action, the scale of this landscape fuelbreak was significant (>100ha in size plus tied into Moose River), and most of the fuels had been removed only days before by a prescribed burn.

Summary

The lack of documented incidents of challenged fuelbreaks in Canada is not entirely surprising for two reasons. First, the production of reliable and consistent wildfire documentation is, in general, a failing of all wildfire agencies in North America. Currently, less than 1/10\textsuperscript{th} of 1 percent of all wildland fires are properly analyzed and documented (Alexander 2003). In Canada, and likely elsewhere, there is no position within fire agencies that is tasked with the responsibility of documenting wildfires. During a wildfire event, fire operations will trump documentation and research. Fire agencies simply lack the capacity to measure challenges as they are occurring. Fuel and fire behaviour specialists are often wearing several operational hats at once and cannot be spared to conduct documentation. Although a handful of wildfire case studies are produced each year through the Wildland Fire Behaviour Specialist Course\textsuperscript{14}, none have described an incident where wildfire challenged a fuelbreak.\textsuperscript{15}

Second, there may simply not be many challenged fuelbreak incidents in Canada. In general, Canada’s population densities are low in the areas where there are large fires. Fewer communities at risk, means fewer fuelbreaks and less chance that any given fuelbreak will be challenged by wildfire. However, increased activity within the provinces’ fuel management programs and increased wildfire fire activity due to climate change will certainly result in more challenged fuelbreaks in Canada. Challenged fuelbreaks provide our greatest opportunity to obtain actual field information - not modeled or simulated - on fire behaviour in fuelbreaks in Canadian fuel types.

Both the Canadian and US accounts emphasized three important points: (1) extensive thinning does not reliably modify fire behaviour; (2) surface and ladder fuels may play a more important role in fire behaviour than canopy fuels; (3) the importance of the inherent and interdependent relationship between suppression action and fuelbreak, where the success of one heavily relies upon the presence of the other.

\textsuperscript{14} The Wildland Fire Behaviour Specialist Course is one of two national fire behaviour training courses sponsored by the Canadian Interagency Forest Fire Centre and is the highest level of wildland fire behaviour training available in Canada.

\textsuperscript{15} Martin E. (Marty) Alexander, PhD, RPF. Senior Fire Behavior Research Officer, Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre. Personal communication February 19, 2010.
Workshop

Due to travel restrictions for agency personnel in 2009, a small online workshop was conducted by FPInnovations from the offices of the Forest Protection Branch of the Saskatchewan Ministry of Environment in Prince Albert; SK. Workshop participants are listed in (Table 5).

<table>
<thead>
<tr>
<th>Name</th>
<th>Position</th>
<th>Agency/Department</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paul Maczek</td>
<td>Fire Science Specialist</td>
<td>Science and Planning Section</td>
</tr>
<tr>
<td></td>
<td>Saskatchewan Ministry of Environment</td>
<td></td>
</tr>
<tr>
<td>Larry Fremont</td>
<td>Education and Prevention Coordinator</td>
<td>Education, Prevention and Safety Section</td>
</tr>
<tr>
<td></td>
<td>Saskatchewan Ministry of Environment</td>
<td></td>
</tr>
<tr>
<td>Chris Dally</td>
<td>Fire Ecologist Specialist - Prince Albert</td>
<td>Education, Prevention and Safety Section</td>
</tr>
<tr>
<td></td>
<td>Saskatchewan Ministry of Environment</td>
<td></td>
</tr>
<tr>
<td>Mike Dittaro</td>
<td>Superintendent Fuels Management</td>
<td>Protection Branch</td>
</tr>
<tr>
<td></td>
<td>British Columbia Ministry of Forests and Range</td>
<td></td>
</tr>
<tr>
<td>Adam Gossell</td>
<td>FireSmart Community Plan Specialist</td>
<td>Wildfire Prevention Section</td>
</tr>
<tr>
<td></td>
<td>Alberta Sustainable Resource Development</td>
<td></td>
</tr>
<tr>
<td>Wes Nimco</td>
<td>Wildland Fire Prevention Officer, Lac La Biche Area</td>
<td>Wildfire Management</td>
</tr>
<tr>
<td></td>
<td>Alberta Sustainable Resource Development</td>
<td></td>
</tr>
<tr>
<td>Brad Hawkes</td>
<td>Fire Research Officer, Pacific Forestry Centre</td>
<td>Natural Resources Canada</td>
</tr>
<tr>
<td></td>
<td>Canadian Forest Service</td>
<td></td>
</tr>
<tr>
<td>Bruce Sundbo</td>
<td>Fire Management Officer</td>
<td>Lake Louise/Yoho/Kootenay Field Unit</td>
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</tr>
<tr>
<td>Stew Walkinshaw</td>
<td>Fuel Management Specialist</td>
<td>Registered Professional Forester</td>
</tr>
<tr>
<td></td>
<td>Montane Forest Management Ltd.</td>
<td></td>
</tr>
<tr>
<td>Dennis Quintilio</td>
<td>Fire Behaviour Specialist</td>
<td>Private Consultant</td>
</tr>
</tbody>
</table>

Validation of Findings

Each participant was provided access to five interim reports prior to the workshop so that they could familiarize themselves with the findings. The five interim reports discussed each line of investigation:

- Literature Review
- Agency Practice Review
- Agency Fuelbreak Characteristic
- Survey Results
- Challenged Fuelbreaks

During the workshop, each line of investigation was discussed in turn and each agency representative was asked to validate the findings pertaining to their agency and the overall state of knowledge.

Overall, the experts felt the findings in the interim reports accurately represented the current state of knowledge of fuelbreak effectiveness in Canada. Some minor changes and clarifications were required and thus included in the relevant sections of this final report.
**Development of Best Practices**

Participants agreed that because fuel management is relatively new in Canada and due to a lack of empirical research on fuel treatment theory, fuelbreak design in Canada is mostly trial and error. Planners and designers rely primarily on personal experience and observations, as well as the anecdotal observations of their peers and colleagues. Many individual fuelbreak projects are run by committee where a handful of professionals (forest management; fuels management/fire behaviour; and others) collaborate to create treatment prescriptions, each bringing their specific expertise to the table. Currently, no form of national best practices for fuelbreak design currently exists, but it is believed that this may be the best way to share the knowledge gained thus far.

What is meant by best practices? Consensus was that best practices must contain only general guidelines to help direct those with less experience. They shouldn’t utilize a cookie-cutter approach because of the variety of ecosystems, objectives and values in Canada. Potential treatments and treatment regimes could be listed with the advantages and disadvantages of each, and factors to consider, including public appetite. Professional guidance will still be required on individual sites. Best practices should not include standards, as agencies risk being held to those standards regardless of the challenges commonly faced in any given project – financial, ecological, aesthetics, etc. In the development of a best practices document, it is important to not set expectations too high by keeping in mind what can realistically be delivered by a fuelbreak. Best practices need to be kept simple and reasonable. Objectives should be clearly identified and treatment design must focus on complimentary suppression action; a vital component in community protection.

**Summary**

Although it was anticipated that through the five lines of investigation (literature review; agency practice review; fuelbreak examples; challenged fuelbreak incidents; and an expert opinion survey) some elements of best practices could be determined. The research has shown, and the experts agreed, that the information required to do so does not exist at this time and that best practices will have to be developed by consensus through a committee of fire experts and agency representatives.
Project Summary

Fuel management is relatively young in Canada. While it has evolved greatly in the past decade, certain aspects (data collection and dissemination, research, etc.) are still in their infancy. Agencies are making advances in fuelbreak design, but the facilitation of the sharing of information across agencies is needed for these advances to continue. This project was viewed by the experts as an important first step in advancing our knowledge of fuelbreak effectiveness.

Conclusions

This project aimed to synthesize the current state of knowledge of fuelbreak effectiveness for Canadian fuel types. The research has resulted in the following conclusions:

1. The FireSmart manual by Partners in Protection is the only formal document outlining fuelbreak standards for Canada.

2. The principles and guidelines of Partners in Protection FireSmart program have been adopted, at various scales, by most of the Canadian provincial fire agencies.

3. Canadian fire agencies rely on the experience-based knowledge of their personnel and hired consultants for fuelbreak design.

4. The FireSmart standards regarding stem spacing have been found to be inappropriate for creating effective fuelbreaks in some Canadian ecosystems.

5. Provincial finance and accounting requirements drive the type of data collected from fuelbreak projects.

6. No conduit exists to facilitate the sharing of fuelbreak information within or between Canadian agencies and fuel management experts.

7. A critical component of an effective fuelbreak is the use of suppression action during a wildfire event.

8. There are no formally documented incidents of challenged fuelbreaks in Canada.

9. Lack of research and lack of shared information limits our understanding of the factors that contribute to effective fuelbreaks.

Recommendations

A national working group/committee for fuels management in Canada is recommended to facilitate some recommended national initiatives:

- increased wildfire documentation, especially those in which fuelbreaks have been challenged
- development of a common data model for fuelbreak data collection
- a sharing network for fuelbreak information
- the development of best practices
- increased research on fuel treatment theory in Canadian fuel types
Acknowledgements

I would sincerely like to thank the following individuals for their patience and support in sharing with me their knowledge and providing valuable information. Without your cooperation, this project could not have been completed. I would also like to thank all those who participated in the Expert Opinion Survey. I appreciate the time and effort put into the responses.

Adam Gossell  Alberta Sustainable Resource Development
Brad Hawkes  Canadian Forest Service
Bruce Sundbo  Parks Canada
Breanne Ringheim  Saskatchewan Ministry of Environment
Bruce Blackwell  B.A. Blackwell and Associates
Chris Boland  Government of Yukon
Chris Dallyn  Saskatchewan Ministry of Environment
Dave Smith  Parks Canada
Dennis Qunitilio  Fire Behaviour Consultant
Fred Jennex  Government of Yukon
Gary Dakin  FPInnovations
Herman Stegehuis  Alberta Sustainable Resource Development
Ian Pengelly  Parks Canada
Jim Gould  CSIRO
Jim Murphy  Ontario Ministry of Natural Resources
John Davis  Davies Wildfire and Ecosystem Management
John Trewhitt  British Columbia Ministry of Environment
Judy Millar  British Columbia Ministry of Environment
Kris Johnson  Government of the Northwest Territories
Larry Fremont  Saskatchewan Ministry of Environment
Lyle Gawalko  British Columbia Ministry of Forests and Range
Marty Alexander  Canadian Forest Service
Mike Dittaro  British Columbia Ministry of Forests and Range
Mike Gall  British Columbia Ministry of Environment
Paul Dunn  British Columbia Ministry of Environment
Ray Ault  FPInnovations
Roy Campbell  Alberta Sustainable Resource Development
Steve Newton  British Columbia Ministry of Forests and Range
Stew Walkinshaw  Montane Forest Management
Tracey Price  Alberta Sustainable Resource Development
Travis Abbey  Government of the Northwest Territories
Wes Nimco  Alberta Sustainable Resource Development
Appendix A – List of Provincial Documents

The following lists, provided by Canadian fire agencies, summarize the guiding documents used by personnel in each agency when designing and constructing fuelbreaks for community protection.

British Columbia
- British Columbia Provincial Strategic Threat Analysis
  - Blackwell, Bruce; Beck, Judi and Simpson, Brian
- WUI Wildfire Threat Rating System; Guidelines and Forms
  - Morrow, Bruce; et al.
- FireSmart: Protecting Your Community From Wildfire (Partners in Protection)

Alberta
- Alberta Forest Management Planning Standards (FireSmart Annex)
- Debris Management on Agricultural Dispositions (ASRD Directive)
- Debris Management Standards for Timber Harvest Operations (ASRD Directive)
- FireSmart Guidebook for Community Protection (ASRD)
- FireSmart: Protecting Your Community From Wildfire (Partners in Protection)
- Vegetation Management Prescription (ASRD Standard Operating Procedure)
- Forests Act and Timber Management Regulation
- Public Lands Act and Regulations
- Forest and Prairie Protection Act and Regulations
- Local Municipal Bylaws

Saskatchewan
- A Guide to Managing Community Wildfire Risk
- Community Wildfire Risk Assessment Report
- Community Risk Profiles
- FireSmart: Protecting Your Community From Wildfire (Partners in Protection)

Ontario
- Community Wildland Fire Hazard Planning Guidance Document
- Community Risk Assessment Analysis Document
- FireSmart training support tools

Northwest Territories
- none

Yukon
- FireSmart Program – Best Management Practices
- FireSmart Project Layout Guidelines
- FireSmart Policy #10 Appendix B – Prescriptions
- FireSmart Data Base System (records projects and financial information)

Parks Canada
- Park Management Plan
- Park Fire Management Plan
- Fire Management Directive 2.44
- Environmental Assessment Act
- Best Practices for Fire Management Operations
<table>
<thead>
<tr>
<th>Name</th>
<th>Agency</th>
<th>Shape</th>
<th>Length (m)</th>
<th>Width (m)</th>
<th>Area (ha)</th>
<th>Forest Fuel Type</th>
<th>Treatment Specifics</th>
<th>Special Features</th>
<th>Year of Treatment</th>
<th>Maintenance Schedule</th>
<th>Approx. Cost</th>
<th>Map (Y/N)</th>
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</thead>
<tbody>
<tr>
<td>East Trout Lake SK</td>
<td>linear</td>
<td>2200</td>
<td>150</td>
<td>33</td>
<td>Y</td>
<td>60 MW 30 JP 10 BS</td>
<td>3m crown spacing complete removal</td>
<td>clear cut, progressive thinning</td>
<td>2006-2008</td>
<td>10 years</td>
<td>$9,500.00</td>
<td>Y</td>
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<tr>
<td>Hall Lake SK</td>
<td>linear</td>
<td>2600</td>
<td>200-600</td>
<td>58</td>
<td>Y</td>
<td>50 JP 50 BS</td>
<td>3m crown spacing complete removal</td>
<td>clear cut and mechanical hand thinning</td>
<td>2006-2009</td>
<td>10 years</td>
<td>$93,240.00</td>
<td>Y</td>
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<tr>
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<td>3400</td>
<td>200</td>
<td>67</td>
<td>Y</td>
<td>100 JP</td>
<td>3m crown spacing complete removal</td>
<td>mechanical thinning, reduction</td>
<td>1998-2001</td>
<td>10 years</td>
<td>no cost</td>
<td>Y</td>
</tr>
<tr>
<td>La Plonge (a) SK</td>
<td>linear</td>
<td>1200</td>
<td>50</td>
<td>6</td>
<td>N</td>
<td>50 BS 50 JP</td>
<td>3m crown spacing complete removal</td>
<td>road right-of-way expanded to act as a firebreak</td>
<td>2003-2006</td>
<td>10 years</td>
<td>$36,000.00</td>
<td>Y</td>
</tr>
<tr>
<td>La Plonge (b) SK</td>
<td>polygons</td>
<td>450</td>
<td>150</td>
<td>7</td>
<td>Y</td>
<td>75 BS 25 JP</td>
<td>3m crown spacing complete removal</td>
<td>ties into lakes and aspen stands</td>
<td>2006-2009</td>
<td>10 years</td>
<td>$8,750.00</td>
<td>Y</td>
</tr>
<tr>
<td>Jeanette Lake SK</td>
<td>linear</td>
<td>3400</td>
<td>200</td>
<td>67</td>
<td>Y</td>
<td>100 JP</td>
<td>3m crown spacing complete removal</td>
<td>mechanical thinning, reduction</td>
<td>1998-2001</td>
<td>10 years</td>
<td>no cost</td>
<td>Y</td>
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<td>200</td>
<td>67</td>
<td>Y</td>
<td>100 JP</td>
<td>3m crown spacing complete removal</td>
<td>mechanical thinning, reduction</td>
<td>1998-2001</td>
<td>10 years</td>
<td>no cost</td>
<td>Y</td>
</tr>
<tr>
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<td>linear</td>
<td>3400</td>
<td>200</td>
<td>67</td>
<td>Y</td>
<td>100 JP</td>
<td>3m crown spacing complete removal</td>
<td>mechanical thinning, reduction</td>
<td>1998-2001</td>
<td>10 years</td>
<td>no cost</td>
<td>Y</td>
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<td>Jeanette Lake SK</td>
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<td>200</td>
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<td>Y</td>
<td>100 JP</td>
<td>3m crown spacing complete removal</td>
<td>mechanical thinning, reduction</td>
<td>1998-2001</td>
<td>10 years</td>
<td>no cost</td>
<td>Y</td>
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<tr>
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<td>linear</td>
<td>3400</td>
<td>200</td>
<td>67</td>
<td>Y</td>
<td>100 JP</td>
<td>3m crown spacing complete removal</td>
<td>mechanical thinning, reduction</td>
<td>1998-2001</td>
<td>10 years</td>
<td>no cost</td>
<td>Y</td>
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<td>200</td>
<td>67</td>
<td>Y</td>
<td>100 JP</td>
<td>3m crown spacing complete removal</td>
<td>mechanical thinning, reduction</td>
<td>1998-2001</td>
<td>10 years</td>
<td>no cost</td>
<td>Y</td>
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<tr>
<td>Name</td>
<td>Agency</td>
<td>Shape</td>
<td>Size (Length (m), Width (m), Area (ha))</td>
<td>Multiple Units (Y/N)</td>
<td>Forest Fuel Type</td>
<td>Treatment Specifics</td>
<td>Special Features</td>
<td>Year of Treatment</td>
<td>Maintenance Schedule</td>
<td>Approx. Cost</td>
<td>Map (Y/N)</td>
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<td></td>
</tr>
<tr>
<td>Grande Cache</td>
<td>AB</td>
<td>polygons</td>
<td>- - 25 Y C3</td>
<td></td>
<td></td>
<td>3m crown spacing</td>
<td>mechanical thinning; hand pruning; only information available states it was to FireSmart standards</td>
<td>2004-2004</td>
<td>-</td>
<td>n/a Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Janvier</td>
<td>AB</td>
<td>polygons</td>
<td>- - 31 Y C1</td>
<td></td>
<td></td>
<td>3m crown spacing</td>
<td>thinning; prescribed burns; only information available states it was to FireSmart standards</td>
<td>2004-2007</td>
<td>-</td>
<td>n/a Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marten Beach</td>
<td>AB</td>
<td>linear w/ polygons</td>
<td>- - 3 Y C2</td>
<td></td>
<td></td>
<td></td>
<td>hand thinning, pruning; tied to aspen stands; incorporates a 30-40m wide fireguard</td>
<td>-</td>
<td>n/a N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fort McMurray</td>
<td>AB</td>
<td>polygon</td>
<td>25000 - - N</td>
<td></td>
<td></td>
<td>manually thinned and pruned</td>
<td>thinned 20m out from powerline right of way</td>
<td>2002-2002</td>
<td>-</td>
<td>n/a N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fort McMurray</td>
<td>AB</td>
<td>polygons</td>
<td>- - 7 Y C1</td>
<td></td>
<td></td>
<td></td>
<td>manually thinned and pruned two patches east side of power corridor</td>
<td>2002-2002</td>
<td>-</td>
<td>n/a N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smith</td>
<td>AB</td>
<td>polygons</td>
<td>- - 90 Y C1</td>
<td></td>
<td></td>
<td>3m crown spacing</td>
<td>commercial harvesting; manual thinning and pruning; only information available states it was to FireSmart standards, some maintenance</td>
<td>2002-2007</td>
<td>-</td>
<td>n/a N</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silver Star</td>
<td>BC</td>
<td>polygons</td>
<td>- - 200 Y ICH</td>
<td></td>
<td></td>
<td>25% crown closure</td>
<td>detemined on-site</td>
<td>2004-2007</td>
<td>-</td>
<td>n/a Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bonnevier North</td>
<td>BC</td>
<td>polygons</td>
<td>- - 135 Y ICH, Ms</td>
<td></td>
<td></td>
<td>avg 10m³/ha</td>
<td>determined on-site</td>
<td>2006-2008</td>
<td>-</td>
<td>n/a Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM-001</td>
<td>BC</td>
<td>polygons</td>
<td>- - 16 N C3</td>
<td></td>
<td></td>
<td>3.7m stem spacing - remove 15% removed; heavy shrubs burned</td>
<td>-</td>
<td>2009</td>
<td>-</td>
<td>n/a Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM-002</td>
<td>BC</td>
<td>polygons</td>
<td>- - 43 Y M2, M2 (Fd, Pl)</td>
<td></td>
<td></td>
<td>retain deciduous; 3m crown spacing; remove all Layer 1 Pl; 2m crown spacing of Layer 2 FD &amp; Pl</td>
<td>-</td>
<td>2009 review in 3 years</td>
<td>n/a N</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>FM-004</td>
<td>BC</td>
<td>polygons</td>
<td>- - 2 Y C2, M2</td>
<td></td>
<td></td>
<td>3-4m crown spacing; retain deciduous</td>
<td>-</td>
<td>- review in 5 years</td>
<td>n/a N</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FS-249</td>
<td>YK</td>
<td>linear</td>
<td>50 - 4 N C3</td>
<td></td>
<td></td>
<td>5m stem spacing</td>
<td>majority removed</td>
<td>2007-2008</td>
<td>96000 ha</td>
<td>Y</td>
<td></td>
<td></td>
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<tr>
<td>FS-205</td>
<td>YK</td>
<td>linear</td>
<td>50 - 4 N C2</td>
<td></td>
<td></td>
<td>5m stem spacing</td>
<td>majority removed</td>
<td>2008-2009</td>
<td>96000 ha</td>
<td>Y</td>
<td></td>
<td></td>
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</tbody>
</table>
Appendix C – CFFDRS Fuel Types

Summary of selected Fire Behaviour Prediction (FBP) System fuel types from the Canadian Forest Fire Danger Rating System (CFFDRS). A complete list and descriptions of the FBP System fuel types can be found in Forestry Canada Information Report ST-X3 (Forestry Canada Fire Danger Group, 1992).

<table>
<thead>
<tr>
<th>Forest Floor and Organic Layer</th>
<th>Surface and Ladder fuels</th>
<th>Stand Structure and Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Type C-1 (Spruce-Lichen Woodland)</strong></td>
<td>Very sparse herb/shrub cover and down woody fuels; tree crowns extend to ground.</td>
<td>Open black spruce with dense clumps; assoc. sp. jack pine, white birch; well-drained upland sites</td>
</tr>
<tr>
<td>Continuous reindeer lichen; organic layer absent or shallow, uncompacted.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Type C-2 (Boreal Spruce)</strong></td>
<td>Continuous shrub (e.g., Labrador tea); low to moderate down woody fuels; tree crowns extend nearly to ground; arboreal lichens, flaky bark.</td>
<td>Moderately well-stocked black spruce stands on both upland and lowland</td>
</tr>
<tr>
<td>Continuous feather moss and/or Cladonia; deep, compacted organic layer.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Type C-3 (Mature Jack or Lodgepole Pine)</strong></td>
<td>Sparsely conifer understory may be present; sparse down woody fuels; tree crowns separated from ground.</td>
<td>Fully stocked jack or lodgepole pine stands; mature</td>
</tr>
<tr>
<td>Continuous feather moss; moderately deep, compacted organic layer.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Type C-4 (Immature Jack or Lodgepole Pine)</strong></td>
<td>Moderate shrub/herb cover; continuous vertical crown fuel continuity; heavy standing dead and down, dead woody fuel.</td>
<td>Dense jack or lodgepole pine stands; immature</td>
</tr>
<tr>
<td>Continuous needle litter; moderately compacted organic layer.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Type C-7 (Ponderosa Pine-Douglas-fir)</strong></td>
<td>Discontinuous grasses, herbs, except in conifer thickets, where absent; light woody fuels; tree crowns separated from ground except in thickets.</td>
<td>Open ponderosa pine and Douglas fir stands; mature uneven-aged; assoc. sp western larch, lodgepole pine; understory conifer thickets.</td>
</tr>
<tr>
<td>Continuous needle litter; absent to shallow organic layer.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Types M-1 and M-2 (Boreal Mixedwood)</strong></td>
<td>Moderate shrub and continuous herb layers; low to moderate dead, down woody fuels; conifer crowns extend nearly to ground; scattered to moderate conifer understory.</td>
<td>Moderately well stocked mixed stand of boreal conifers (e.g., black/white spruce, balsams/subalpine fir) and deciduous species (e.g., trembling aspen, white birch). Fuel types are differentiated by season and percent conifer/deciduous sp. composition.</td>
</tr>
<tr>
<td>Continuous leaf litter in deciduous portions of stands; discontinuous feather moss and needle litter in conifer portions of stands; organic layers shallow, uncompacted to moderately compacted.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Type D-1 (Leafless Aspen)</strong></td>
<td>Moderate medium to tall shrubs and herb layers; absent conifer understory; sparse, dead, down woody fuels.</td>
<td>Moderately well-stocked trembling aspen stands; semi-mature; leafless (i.e., spring, fall or diseased).</td>
</tr>
<tr>
<td>Continuous leaf litter; shallow, uncompacted organic layer.</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fuel Type O-1 (Grass) Subtypes: O-1a (matted grass), O-1b (standing grass)</strong></td>
<td>Continuous standing grass (current year crop). Standard loading is 0.3 kg/m², but other loading can be accommodated; percent cured or dead must be estimated. Sparse or scattered shrubs and down woody fuel. Subtypes for both early spring matted grass (O-1a) and late summer standing cured grass (O-1b) are included.</td>
<td>Scattered trees, if present, do not appreciably affect fire behavior</td>
</tr>
<tr>
<td>Continuous dead grass litter; organic layer absent to shallow and moderately compacted.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix D – Expert Opinion Survey

#### FUEL BREAK EFFECTIVENESS

**Expert Opinion Survey**

**Q1.** Have you witnessed a wildfire approach a fuelbreak, either natural\(^1\) or man-made\(^2\)?

- [ ] yes, skip to Q8
- [ ] no

\(^1\) Natural fuelbreaks can include any naturally occurring change in fuel type: river; low wet area; open area; swamps; willow-patches; recent burns (not prescribed); etc.

\(^2\) Man-made fuelbreaks can include transportation corridors; golf courses; utility right-of-ways; any proactive bio-fuel treatment; etc.

**Q2.** As best you can, please provide a brief description of this particular fire event.

<table>
<thead>
<tr>
<th>a. Location</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>b. Date*</td>
<td></td>
</tr>
</tbody>
</table>
| c. Terrain | Flat  
| | Undulating  
| | Moderate slope  
| | Steep slope  |
| d. Fuel type(s) being burned | C-1 (Spruce-Lichen Woodland)  
| | C-2 (Boreal Spruce)  
| | C-3 (Mature Jack or Lodgepole Pine)  
| | C-4 (Immature Jack or Lodgepole Pine)  
| | C-5 (Red and White Pine)  
| | C-6 (Conifer Plantation)  
| | C-7 (Ponderosa Pine - Douglas Fir)  
| | D-1 (Leafless Aspen)  
| | M-1 (Boreal Mixedwood - Leafless)  
| | M-2 (Boreal Mixedwood - Green)  
| | M-3 (Dead Balsam Fir Mixedwood - Leafless)  
| | M-4 (Dead Balsam Fir Mixedwood - Green)  
| | S-1 (Jack or Lodgepole Pine Slash)  
| | S-2 (White Spruce-Balsam Slash)  
| | S-3 (Coastal Cedar-Hemlock-Douglas Fir Slash)  
| | O-1 (Grass)  
| | Other (please describe)  |
| e. Weather conditions/fire hazard: | Low  
| | Moderate  
| | High  
| | Extreme  |
| f. Head fire intensity category (from the FBP System): | < 10 kW/m  
| | 10-500 kW/m  
| | 500 - 2000 kW/m  
| | 2000 - 4000 kW/m  
| | 4000 - 10000 kW/m  
| | > 10000 kW/m  |
| g. Longest spotting distances observed: | No spotting observed  
| | < 50m  
| | 50m-100m  
| | 100m-500m  
| | > 500m  |
Q3. As best you can, please describe the nature of this fuelbreak:

a. This fuelbreak was:
   - natural
   - man-made

b. If natural, choose one of the following:
   - a change in fuel type
   - a water course
   - a low wet area/swamp/bog/fen
   - an open area
   - an old burn (not prescribed)
   - other (please describe)  

   c. If man-made, choose one of the following:
   - a golf course
   - a utility right-of-way
   - a railway right-of-way
   - a road/highway
   - an old or new fireguard
   - a proactive fuel treatment (please answer Q3.d and e)
   - other (please describe)  

   d. If this fuelbreak was a **man-made proactive fuel treatment**, please select all that apply to the best of your knowledge:
   - thinning/crown spacing
   - removal of dead and down fuels
   - increasing the crown base height/liming
   - prescribed burn
   - other (please describe)  
   - unsure

   e. If this fuelbreak was a **man-made proactive fuel treatment**, please estimate the age of this treatment:
   - < 5 years
   - 5-10 years
   - >10 years

f. What was the shape of this fuelbreak?
   - linear corridor
   - polygon

g. What was the approximate width or area of this fuelbreak?
   - < 25m
   - 25m - 100m OR
   - 100m - 500m
   - > 500m
   - < 10 ha
   - 10-50 ha
   - 50-100 ha
   - >100 ha

h. Was this fuelbreak effective at protecting values at risk?
   - yes, effective
   - no, not effective
   - not applicable/no values at risk
Q4. Did suppression forces make use of this fuelbreak?
  yes
  no
  If yes, in what manner?
    backburning
    patrolling
    other (please describe)
  If yes, were these tactics successful?
    yes
    no

Q5. Did the fire breach this fuelbreak?
  yes
  no
  If yes, what caused the breach?
    spotting
    flame contact
    radiant heat
    fallen tree
    other (please describe)

Q6. What factor(s) do you feel most contributed to the success/failure of this fuelbreak?

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Presence/lack of maintenance on fuel break</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind direction/speeds</td>
<td>Tied/not tied into existing breaks (natural or human-caused)</td>
</tr>
<tr>
<td>Local general climate</td>
<td>Access/ no access through fuel break</td>
</tr>
<tr>
<td>Crown-fire potential</td>
<td>Fuel break width</td>
</tr>
<tr>
<td>Historical fire regime</td>
<td>Crown spacing within fuel break</td>
</tr>
<tr>
<td>Terrain</td>
<td>Crown base height within fuel break</td>
</tr>
<tr>
<td>Tree Height</td>
<td>Surface fuel management within fuel break</td>
</tr>
<tr>
<td>Suppression capabilities</td>
<td>Crown spacing in adjacent fuels</td>
</tr>
<tr>
<td>Other (please describe)</td>
<td>Crown base height in adjacent fuels</td>
</tr>
<tr>
<td>Other (please describe)</td>
<td>Surface fuel management in adjacent fuels</td>
</tr>
</tbody>
</table>

Please explain your answers:
Q7. Are there any other pieces of information that you recall about this event that might be relevant?

Q8. Do you support proactive initiatives to design and construct fuelbreaks to protect communities from wildland fire?
   yes
   no

Q9. Based on your experiences, what do you believe to be the advantages and/or disadvantages of using fuelbreaks for the protection of communities from wildland fire?

Q10. We define an effective fuelbreak as one that can significantly alter fire behaviour such that suppression forces can contain the fire safely. Given that you had sufficient funding, what features (physical and otherwise) would you design into a fuelbreak to make it effective? (Can be in any fuel type and please disregard spotting).

Q11. Referring to the table below, what do you believe to be the five most important factors to consider when designing an effective fuelbreak? (1 = most important)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuelbreak Width</td>
<td></td>
</tr>
<tr>
<td>Surface Fuel Management</td>
<td></td>
</tr>
<tr>
<td>Increase Crown Spacing</td>
<td></td>
</tr>
<tr>
<td>Increase Crown Base Height</td>
<td></td>
</tr>
<tr>
<td>Distance From Community</td>
<td></td>
</tr>
<tr>
<td>Access Through Fuelbreak</td>
<td></td>
</tr>
<tr>
<td>Tie Into Natural or Human-Caused Breaks</td>
<td></td>
</tr>
<tr>
<td>Ignitions History</td>
<td></td>
</tr>
<tr>
<td>Maintenance</td>
<td></td>
</tr>
<tr>
<td>Crown Fire Potential</td>
<td></td>
</tr>
<tr>
<td>Suppression Capabilities</td>
<td></td>
</tr>
<tr>
<td>Terrain</td>
<td></td>
</tr>
<tr>
<td>Historical Fire Regime</td>
<td></td>
</tr>
<tr>
<td>Tree Height</td>
<td></td>
</tr>
<tr>
<td>Other (please describe)</td>
<td></td>
</tr>
<tr>
<td>Other (please describe)</td>
<td></td>
</tr>
</tbody>
</table>

Q12. Please provide a few details on your background:
   a. Current position: ____________________________
   b. Years of operational experience: _____________
   c. Number of large wildfires: _________________
   d. Number of wildfires that threatened communities: ________________
   e. Number of years fuel management experience: ________________
   f. Fuel type(s) in which you have had the most experience: ________________

Q13. We welcome any comments you may have about this topic or this survey. Please use the space below.
Appendix E – Challenged Fuelbreak Incidents in United States

**American River Complex Fire** *(Safford 2008)*

The American River Complex Fire ignited in June 2008 and burned through extremely complex topography, under mostly moderate weather conditions and relatively high ambient and fuel moisture conditions. Overall the fire severity was primarily low to moderate with some high severity effects occurring on a single day when temperatures and wind speeds rose and humidity dropped. The fire encountered a number of fuel treatments, mainly pine plantations where shrubs had been masticated and mature forests with commercial thinning. Only one thinned treatment had evidence of surface and ladder fuel removal.

Masticated units burned intensely with 100% tree mortality and all but one thinned units experienced moderate to severe fire effects. The thinned units had reduced crown torching and slightly increased canopy tree survival, but only the unit with surface and ladder fuel removal succeeded in changing the fire to a surface fire and preserving most of the stand.

The authors concluded that mastication only redistributed the fuels on site and that they were much drier and more easily ignited than live fuels. The thinned stands were somewhat less likely to experience crown torching than neighbouring untreated stands, but fire behaviour was still severe enough to cause high levels of crown scorch and tree mortality.

**Angora Fire** *(Safford et al. 2009 and Murphy et al. 2007)*

The Angora Fire burned 1243 ha of pine and mixed conifer forest in the Lake Tahoe Basin, California in June 2007. The Angora Fire burned at unusually high severity due to heavy fuels; strong winds; warm, dry weather; and unseasonably low fuel moistures. Fuel dryness was in the 90th percentile for the season, wind speeds were 20-35 km/hr with gusts up to 65 km/hr, and the Fire Danger Rating was ‘Very High’. The fire started in a dense stand of fir and pine and quickly transitioned into an active crown fire.

Most of area within the fire perimeter was characterized by multi-storied mixed conifer with moderate to heavy dead woody fuel and mixed brush in understory, and topography ranged from flat to >40% slope. Within the Angora fire perimeter, there were 17 different treatment units conducted between 1995 and 2005; approximately 194 ha. Treatments were strategically placed to modify fire behavior to protect private and public assets in the Angora Creek watershed and to provide increased safety, visibility, and operability for fire suppression efforts. Although piles in most treatment units had been burned, some were not and underburning for all treatment areas was still in the planning stages. Tree (stem) spacing within the treatments was 6m. Conditions in untreated stands were mostly dense, multi-storied stands with abundant ladder fuel.

Approximately 164 ha of fuel treatments burned with surface fire intensity, 30 ha burned as crown fire. The treatment units that burned entirely as surface fire (11 units) had elicited the desired fire behaviour change from crown fire to surface fire. In most cases, crown fire behavior changed to surface fire within 50m of encountering a fuel treatment. All of the fuel treatments that burned with high intensity (crown fire) were situated directly in the path of the head of the
fire on steep slopes. The slope steepness had led to lower levels of fuels removal due to local standards for erosion prevention.

Although the majority of the fuel treatments in the Angora Fire were effective at modifying fire behaviour, they would not have been effective at protecting the community without suppression action.

**Biscuit Fire** *(Raymond and Peterson 2005a and 2005b)*

Lightning ignited several small fires in southwestern Oregon in July 2002, which eventually merged and became the Biscuit Fire. The fire burned 202,000 ha of Douglas-fir dominated forest until it was finally extinguished by rain in November 2002. The fire burned into 6 plots established by the USDA for its Long-Term Ecosystem Productivity study in Siskiyou National Forest. Treatment plots were 6-8 ha in size; three were mechanically thinned, one was thinned then underburned, two were untreated plots. Thinning operations (8m spacing) were completed in 1996, and underburning was completed in 2001.

On the day the sites burned, the maximum temperature was recorded at 26 °C, relative humidity was 8%, the 10 h fuel moisture was 4%, and the average wind speed was 4 km/hr. Soil moisture deficiency, which was measured on a scale of 0 to 800, was 663. Expected fire behaviour was recorded as severe.

The Biscuit Fire burned through the thinned and untreated plots as intense surface fire but stopped at the edge of the thinned-underburned plot, unable to spread through the sparse surface fuels.

**Black Mountain II Fire** *(Fites and Henson 2004)*

The Black Mountain II Fire burned in the Douglas-fir dominated forests of Lolo National Park, Montana. The fire burned into an area with an open stand (700 stems/ha) that resembled a thinning treatment, and an adjacent stand that was dense (1200 stems/ha) with heavy surface fuels. Crown fire behaviour was observed in both the open and the dense stand. Rate of spread was calculated at 73m/min in the dense stand and 31m/min in the open stand. The fireline intensity was calculated to be 1.4 times higher in the dense site. Although area size of the dense stand and the open stand were not given, the researchers concluded that the open stand was a fairly small patch within the larger area of dense Douglas-fir and could have been overwhelmed by fire in the adjacent stands resulting in the complete consumption of the crown fuels.

**Cascade Complex Fire** *(Graham et al. 2009)*

Between 1996 and 2006, nearly 4,000 ha of land in the Warm Lake Basin, Idaho had been treated mechanically and/or prescribed burns. Spacing between tree boles was increased to approximately 3-5m and the lower limbs of the residual trees were pruned to a height of 1.5m. Harvesting material was piled and burned on site. The treatments were designed to improve the protection of the numerous summer homes and other structures around Warm Lake, and to affect wildfire behavior on 4,000 to 5,000 ha.
At the time the Monumental and North Fork Fires were burning, the fuels in the Warm Lake vicinity were extremely dry. Dead 1000 hr fuel moisture averaged 9%, dead 100 hr fuel averaged less than 6%, as did the moisture of the 10 hr fuels. Similarly, live fuel moisture were also extremely low and reminiscent of moisture concentrations of late fall when conifers enter dormancy. Wind gusts were recorded at over 50 km/hr, humidity readings were below 10% and temperatures exceeded 27°C. These conditions caused considerable crowning as the fire moved through the Warm Lake Basin. The Monumental Fire burned with such intensity (30-60m flame lengths), that spot fires were ignited over a mile away.

On more than one occasion during the Monumental and North Fork Fires, the fuel treatments and their resulting forest structures and compositions modified fire behavior compared to areas where the fuels were not treated. The fuel treatments did not, however, stop the progression of either fire and when combined, the fires burned over 60,000 ha. Wildfire spread rates were not lower in areas where the fuels were treated compared to areas where they were not. The Monumental fire burned easily through a 1996 prescribed burn area and a 1989 wildfire area with very high intensity. This outcome illustrates the necessity to revisit and, if necessary, retreat forests to maintain fuel conditions that produce the desired wildfire intensity and burn severity.

By modifying the fires’ behavior, the fuel treatments presented suppression opportunities that otherwise may not have been available. The mechanical fuel treatments were very effective in creating conditions where surface fires dominated. Because of the lower intensity observed in some of these areas, they often provided safe zones for firefighters. The fire crews were able to re-burn prescribed burn areas from 2000/2002 in advance of the Monumental Fire; to use existing fuelbreaks as anchor points for burning non-treated fuels; and easily spot and extinguish spot fires in treated areas.

**Cavity Lake Fire** *(Neitzke 2007)*

The Superior National Forest in Northeastern Minnesota is dominated by boreal forest, combining aspen, paper birch, balsam fir, white and black spruce, jack pine, red pine, and white pine. In 1999, a massive blowdown event affected 193,000 ha in the Boundary Waters Canoe Area Wilderness (BWCAW) within the Superior National Forest. Fuel loadings in the damaged areas increased from an average of 23 tonnes/ha to more than 246 tonnes/ha. Dr. Mark Finney with the USDA Forest Service developed a theory for treatment within the BWCAW where patches of prescribed fire would connect to bodies of water (i.e. strategic placement of treatments (SPOTS)). The concept was to interrupt the fuel bed to slow a fire and allow an opportunity for control measures to be used. Research suggested that while a crown fire will stop its major movement when the wind stops blowing, a blowdown fire will continue to spread until it runs out of blowdown fuels. By the end of 2005, approximately 13,000 ha of complex blowdown burning to create the spatially located treatment units had been completed.
The Cavity Lake Fire was reported in July 2006. The fire was in some of the heaviest blowdown fuels and upwind of several homes, businesses, a heavily used campground, and a youth camp located within the Gunflint Trail corridor. Although the fuel reduction plan had not been fully implemented at this point, there was a significant buffer of prescribed fire between the Cavity Lake Fire and the values at risk. Extreme winds (60-80 km/hr) in late evening drove the fire into the treatment areas. The fire had spotted into the prescribed fire patches and was smoking at up to a half mile into the burns.

The treatments had taken enough energy out of the fire to halt the spread toward the homes and fire specialists were able to use a combination of lakes and the prescribed burn areas to anchor control tactics that included burnout operations.

**Cone Fire  (Maleki 2007; Skinner et al. 2004)**

In September 2002, the Cone Fire burned approximately 800 ha in the Blacks Mountain Experimental Forest where a long-term, large-scale project was underway to study ecological responses to contrasting stand structure. The experimental forest had the following stand and fuel conditions when the Cone Fire occurred:

- untreated stands with multiple canopy layers, dense clumps
- high diversity structure with prescribed fire
- high diversity without prescribed fire
- low diversity structure with prescribed fire
- low diversity structure without prescribed fire

High diversity (HiD) structure was achieved by thinning from below, retaining larger trees and removing most of the ladder fuels to simulate more historical conditions of mature forests. Low
diversity (LoD) structure was achieved by removing larger trees from the overstory and smaller trees from the understory, leaving mostly intermediate trees. The forest in this area is dominated by Ponderosa pine and the fire regime is of frequent, low-to moderate severity fires.

The Cone Fire burned into 3 treatment units: two LoD units, one with prescribed fire and one without; and one HiD unit with prescribed fire. Although winds were moderate (16 km/hr) humidity was very low (down to single digits, even during the night) and fuel moisture was at 8% (critical levels are 12% or less) so fire conditions were considered severe.

Where the Cone Fire encountered thinned and burned stands, the fire went out or could be safely suppressed. Where it encountered thinned stands without prescribed fire, with fuels left after harvest, the fire burned as a surface fire with patches of scorched tree crowns in the stand. Although both the HiD and LoD treatments with prescribed fire worked well in halting the high intensity fire, there were differences. The fire stopped at the edge of the LoD treatments, whereas it continued as a very low intensity surface fire for approximately 100m before self-extinguishing.

The fire burned with much greater severity and resulted in significantly higher tree mortality outside the treatment areas. Tree mortality inside treatment units seemed mostly driven by an “edge effect”– trees on the inside boundary of the treated units were scorched by the extremely intense fire burning immediately adjacent in the untreated areas. The lowest fire impact was evident in the stands that had been treated with both thinning and prescribed burning. In these stands, there was almost no tree mortality.

Fontainebleau Fire  (Martinson and Omi 2008)

The study site was located on and adjacent to the Fontainebleau Unit of the Mississippi Sandhill Crane National Wildlife Refuge. Topography is flat throughout at an elevation of 6m. Slash pine is dominant in the forest canopy. Management of the Refuge included extensive use of prescribed fire to reduce hazardous fuels and restore the open structure of pine savannahs. One such prescribed fire became the Fontainebleau wildfire in April 1999.

On the day of the Fontainebleau Fire, wind speed was 12 km/hr, temperature 22°C, and relative humidity was 28%. 1-hr moisture content was 6%; 10-hr moisture content was 7% and 100-hr moisture content was 15%. At 1430, the prescribed burn spotted across a railroad and onto private property containing untreated fuels. The wildfire exhibited extreme behaviour and at 1600 hours spotted back across the railroad and into a stand that Refuge managers had burned in 1988, 1992, and 1998. The Fontainebleau fire grew to a final size of 142 ha including 36.5 ha on Refuge lands last treated in 1998.

The forest treated with repeated prescribed fires had significantly different fuel profiles than the adjacent unmanaged private forest. The untreated forest had 2500 stems/ha, whereas the treated stands had 400 stems/ha. Trees in the untreated stands were substantially smaller in diameter and height. Height to crown in the treated stands was 11m, and 7m in the untreated stands. There was no significant difference in shrub density between the two sampled areas.
The two areas with distinctly different fuel profiles were observed to have experienced distinctly different wildfire severity. Average height of needle scorch was nearly twice as high in the untreated plots. With very few exceptions, crown volume scorch in the untreated plots was 100% and significantly greater than in the treated plots. Ground char was light in all the treated plots, but somewhat deeper in the untreated plots.

**Grass Valley Fire** *(Rogers et al. 2008)*

The Grass Valley fire started in October 2007 in the mountains of San Bernardino National Forest in Southern California. The layers of vegetation in untreated forests created a continuous fuel ladder from surface into the canopy. In untreated areas there were approximately 2000 stems/ha. The largest treated unit within the fire perimeter was the Tunnel 2 fuel treatment which was approximately 100 ha. Treatment in this area included removal of dead, dying and diseased trees, thinning, pruning, reduction of surface litter and woody fuel loading as well as ladder fuels. More conifers were removed than deciduous which left a widely spaced deciduous dominated woodland with discontinuous surface fuels. Stand density was 250 stems/ha and surface fuel loading was light to moderate. The Tunnel 2 treatment did not seek to stop fire spread but rather reduce crowning potential and ember production.

Slopes within the fire perimeter ranged from gentle (<10%) to steep (>60%). Fuels were unusually dry for that time of year; large dead fuel moisture was 8%, live woody fuel moistures 56% and the relative humidity was 8%. Wind speeds were recorded at 30-55 km/hr with gusts in excess of 65 km/hr.

When the fire moved into the Tunnel 2 treatment area, the fire behaviour shifted to a low intensity surface fire. Fire behaviour exhibited lower flame lengths (<1m), slower rate of spread, less transition to crown fire and less spotting. Fire personnel noted that the reduced fire behaviour allowed fire resources to concentrate on the protection of structures and evacuations. A post-fire examination revealed incomplete litter and duff consumption, patches of unburned fuel and low scorch heights, which supported firefighters’ accounts.

**Hayman Fire** *(Graham 2003)*

The Hayman Fire started in June 2002 between Denver and Colorado Springs and impacted more than 56,000 ha of Ponderosa pine and Douglas-fir stands along the Colorado Front Range. The potential for extreme fire behavior was predisposed by continuous surface and crown fuel structure, both horizontally and vertically, and by drought. Below normal precipitation in the past several years and the acute drought in 2002 brought about exceptionally low moisture contents of live foliage, duff, and dead fuels of all size classes. Extreme weather conditions consisted of high winds (30 to 80 km/hr) and low humidity (5%).

The Hayman Fire encountered most of the fuel treatments, prescribed burns, and previous wildfires within the perimeter when the weather was extreme. Extreme wind, weather, and fuel moisture and the large size of the Hayman Fire that developed overwhelmed most fuel treatments in areas burned by the heading fire, this included almost all treatment methods including prescribed burning and thinning. Fuelbreaks and treatments were breached by massive spotting and intense surface fires.
There were some exceptions: The Polhemus prescribed burn (2001), the Schoonover wildfire (2002), and the Platte Springs wildfire (2002) had occurred less than 1 year earlier. These areas did actually appear to stop the fire locally; illustrating that removal of surface fuels alone (irrespective of thinning or changes to canopy fuels) can dramatically alter fire behavior within 1 year of treatment. Fire behavior was modified but not stopped by stand thinning operations conducted at Manitou Experimental Forest. The operations apparently moderated fire behavior and effects during extreme weather; however, a fortuitous shift in winds also contributed to the changes in fire behavior at this location.

Large areas such as the Polhemus prescribed burn (approximately 3,200 ha) were more effective than small fuelbreaks (Cheesman Ridge, 21 ha) in changing the fire progress. Under extreme conditions, spotting easily breached narrow treatments and the rapid movement of the fire circumvented small units.

No fuel treatments were encountered when the fire was small. The fire had time and space to develop a broad front and generate a large convection column before encountering most treatment units. Fuel treatments may have been more effective in changing fire behavior if they were encountered earlier in the progression of the fire before mass ignition was possible. The high degree of continuity in age and patch structure of fuels and vegetation facilitated fire growth that, in turn, limited the effectiveness of isolated treatment units.

Suppression efforts had little benefit from fuel modifications within the Hayman Fire. Exceptions include the Polhemus prescribed fire (2001), two previous wildfires (Schoonover 2002 and Big Turkey 1998), and thinning operations at Manitou Experimental Forest.

**Wheeler Fire** *(Fites et al. 2007)*

The Wheeler Fire started in July 2007 and burned through dense mixed conifer forest in the Plumas National Forest, California. Within the fire perimeter there were a number of treatment areas designed and implemented for hazardous fuel reduction and to aid potential suppression actions.

The main fire was exhibiting high intensity, rapid spread and column development when it encountered several treatment areas. The fire was an intense crown fire but when it moved into the treated areas, it transitioning from a crown fire to a surface fire. While tree crowns were scorched in most of the treated areas, they were totally consumed in the surrounding untreated areas. The fire moved through the treated areas as a surface fire but jumped back into the crown once in untreated fuels again. The authors believe that had the treated expanse been larger, it might have sustained its transition to a surface fire.

Although treated areas resulted in reduced fire behaviour and effects, there were still severe effects when the fire gained momentum and burned through these areas, or when weather conditions were hotter, windier, or drier. These treatments were designed to work under high weather conditions not severe weather conditions that occurred during the Wheeler Fire. Observations during the first two days suggest that large untreated areas allowed the fire to build
momentum and contributed to increased rate of spread and intensity that overwhelmed some treated areas and reduced their effectiveness.

The treated areas allowed suppression forces to safely launch both direct and indirect attacks on the fire along several flanks of the active fire and spot fires were easily contained or went out on their own in treated units.
Appendix F – Challenged Fuelbreak Incidents in Canada

Crutwell Fire (Braaten 2002)

In June 2002, the Crutwell Fire was observed at approximately 14:30 HRS and quickly grew to Rank 5 in mature Jack pine. On the second day, suppression crews were dispatched to contain the Crutwell Fire at an old linear fuelbreak, between 500-800m wide constructed between 1980 and 1982. It consisted of grass (O-1 fuel type) and scattered juvenile deciduous underbrush. Control lines were to put in to tie the river to the old fuelbreak and along the east side. Back-burning from the fuelbreak was also conducted. When the Crutwell fire encountered this old fuelbreak, it was Rank 4-5.

Through the use of timely and aggressive suppression action along the fuelbreak, the Crutwell Fire was successfully stopped. One small spot fire was noticed smoldering outside of the fuelbreak (#1 in Figure 4). The fire burned up to the retardant line that was placed on the eastern edge of the fuelbreak and stopped (#2 in Figure 4). The fire burned around the north edge of the fuelbreak and had continued burning on the east side of the fuelbreak (#3 in Figure 4). Retardant drops were observed to be extremely effective in the grassy fuel type of the fuelbreak.

Prior to the fire reaching this old fuelbreak, suppression crews made three unsuccessful attempts to control the fire at three separate locations; a gravel road (30m wide), the main highway (75-100m wide) and an old highway (30m wide).

Figure 4. Map of the Crutwell Fire perimeter.
This fuelbreak protected important values-at-risk, including numerous residences. It was the opinion of Mr. Braaten and his colleagues, that there would have been significant control issues and losses had the fuelbreak not been present.

**Morrison Coulee Fire**  (*Pengelly 2009*)

A fuelbreak in the Morrison Coulee in Banff National Park was created in March 2003, using a feller-buncher to thin the stand to 5m average spacing. The piles were burned in April. The fuelbreak was linear and between 25-100m wide in flat terrain. The wildfire fire started in August that same year in extreme fire weather conditions with an ISI recorded at 21. The head fire intensity was recorded as >10,000 kW/m when it approached the fuelbreak and spotting was observed to be between 100m to 500m. There was no suppression action initiated along this fuelbreak.

The fuelbreak was breached with no observed change in fire behaviour. Radiant heat from the un-thinned forest upwind of the thinned stand is believed to be the primary cause of failure. The narrowness of the fuelbreak is also believed to have been a factor.

**Moose River Fire**  (*Blackwell 2009*)

In Mount Robson Provincial Park, a prescribed burn had been conducted in 2004 on the slopes along Moose River to create a landscape level fuelbreak. The fuelbreak area, tied into Moose River was greater than 100 ha. Within days of that prescribed burn, a wildfire ignited from a lightening strike up the valley. Fire weather conditions were noted as high and the head fire intensity was 4000-10000 kW/m. Spotting was observed to be >500m.

This fuelbreak effectively prevented the wildfire from moving into the main Robson Valley. Crown fire behaviour was suppressed as it encountered the previously burned surface fuels and the wildfire was not able to spot over the large area of the prescribed burn.
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