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Risk reduction status of homes reconstructed following wildfire disasters in Canada

By Alan Westhaver, M.Sc.

September 2015

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Alan Westhaver holds degrees in forestry and wildlife biology from the University of Montana. He recently retired following 34 years of service to Parks Canada, 27 of them as a senior wildland fire manager. His passion for the wildland/urban interface runs deep. He is a past president of Partners in Protection, served on its Board of Directors (1992-2012), and co-chaired the working group that developed and published the original FireSmart manual: *Protecting Your Community from Wildfire* in 1999. Between 1999 and 2012, in conjunction with the Foothills Research Institute and the Municipality of Jasper, he planned, managed, and implemented a comprehensive community wildfire protection program for the Town of Jasper, Alberta. The project merged ecological restoration and wildfire protection objectives and involved more than 1,000 hectares of mechanical and manual forest treatments. It was lauded for its many innovations with regards to communications, community engagement, and environmental sensitivity. This real-world experiment resulted in his 2006 M.Sc. thesis which integrated knowledge from wildland fire behavior, forestry, wildlife biology and social sciences to produce ecologically based fuel treatments attuned to the aesthetic concerns of WUI residents - and well supported by the public. Since retirement, Alan continues to provide services in the fields of wildland fire behavior analysis, community wildfire protection, FireSmart training, and environmental impact assessment through his Fernie-based consulting company. Alan and his wife, Lisa, spend much time camping, cycling and exploring, and are beginning to develop a fondness for the desert.

Executive summary

This study looks into an aspect of **wildfire** disaster **mitigation** and recovery that has not been previously investigated. While previous research has focused on wildfire risk mitigations that homeowners should implement, those that they intend on implementing, or their attitudes towards mitigation and risk, this investigation sought to answer the question "To what degree have homeowners actually adopted and implemented FireSmart measures to mitigate the risk of future wildfire losses?"

The two worst **wildland/urban interface (WUI)** fire disasters in modern Canadian history, the 2003 Okanagan Mountain Provincial Park wildfire at Kelowna, British Columbia, and the 2011 Flat Top Complex of wildfires at Slave Lake, Alberta, occurred within a decade of each other. Each was a tragedy of national scale.

However, these catastrophic circumstances also offered a rare occasion to better understand and improve upon the effectiveness of community wildfire protection and risk mitigation/education programs. This study assessed current wildfire hazard at 445 homes reconstructed since these wildfires against recommended FireSmart® guidelines. This comparison created a reliable measure of the degree to which FireSmart guidelines have been accepted and adopted by homeowners.

This study focused on hazard mitigations applied by residents at, or very near to, private homes. It did not assess the broad scale wildfire mitigations being applied by Kelowna or Slave Lake authorities on public lands, such as extensive **fuel** treatments, fire guards, public education initiatives, and other FireSmart activities identified in their progressive Community Wildfire Protection Plans. The latter actions are also important and complementary to mitigations employed in backyards by local residents.

In general, results of this investigation showed that a few FireSmart solutions have been widely adopted by homeowners, others in part, and some very little or not at all. The degree of adoption for known risk mitigations varied between geographic areas, between different categories of wildfire hazards, within categories of related hazard factors, and spatially within the home ignition zone. Equally important, the study revealed similarities among levels of adoption for some risk mitigations. Differences between urban centres and more rural settings were minor. Overall, twice as many wildfire hazard factors received a poor adoption grade, than those that attained an "excellent" rating.

Specifically, the degree to which guidelines have been adopted at private homes was rated good at Slave Lake, but fair to poor at Kelowna study sites. Only conditions at Slave Lake study sites could be confidently rated as "FireSmart." Present conditions at Kelowna study sites could result in a repeat of 2003 events in those neighbourhoods.

Spatial analysis of hazards within the home ignition zone revealed that the greatest degree of hazard, and lowest compliance with guidelines, existed in the most critical area (i.e. the home and the first 10m beyond). Without exception, it was concluded that the lowest levels of compliance pertained to guidelines for mitigating hazards associated with vegetation/fuel conditions in all fuel layers, and in all three FireSmart Priority Zones. Nearly 60% of all wildfire hazards were attributed to deficiencies in vegetation/fuel mitigations, whereas the hazard apportioned to each of the structural, ignition site, and topographic categories of hazards ranged from 17% to 10%.

Altogether, the investigation resulted in sixteen recommendations. These address levels of FireSmart adoption; communication, awareness, and community engagement; vegetation management; home construction and building materials; miscellaneous ignition factors; and the wildfire hazard assessment system itself. The nine "key" recommendations of this study are that:

1. The Federal Government immediately restore momentum to the Canadian Wildland Fire Management Strategy by making a strategic financial investment in the National FireSmart Initiative.

2. The Province of Alberta and the Slave Lake Regional Tri-Council sustain their leading-edge FireSmart communication program to ensure that knowledge and best practices are instilled in newcomers.

3. Government agencies re-examine their communication and fire prevention programs to find ways for improving the degree of adoption of wildfire risk mitigation and increasing public engagement.

4. Partners in Protection/FireSmart Canada upgrade the current FireSmart manual and guidelines to alleviate a serious, documented roadblock to adoption of risk mitigations by developing second-generation **fuel treatment** solutions that are effective, but also address concerns and values of homeowners regarding aesthetics, wildlife habitat, and the ecological health of **WUI** areas.

5. Agencies responsible for FireSmart implementation and education programs adopt the upgraded fuel modification guidelines (noted in #4) in order to expand public support for fuel treatments on public land and to increase the extent of vegetation/fuel management by residents on private lands.

6. Authorities at Kelowna rejuvenate interest, awareness, and citizen engagement in wildfire risk mitigations by formally launching the FireSmart Canada Community Recognition Program in their city, and by creating "demonstration sites" that feature second-generation fuel treatments.

7. Two additional FireSmart “guidebooks” be prepared in order to:
   a) Distribute effective information about FireSmart vegetation management to commercial landscapers, plant nurseries, and garden supply centre personnel.
   b) Develop a FireSmart curriculum module for incorporation into horticulture, arborist, and forestry programs at accredited colleges, technical institutes and universities.
8. The Canadian Home Builders Association be approached for suggestions as to how their industry could become more formally engaged in raising FireSmart awareness among its membership.
9. Further investigations aimed at revealing additional “lessons learned” from the Okanagan Mountain Provincial Park and Flat Top Complex wildfire disasters be undertaken. More specifically, by applying the internationally recognized principles of “forensic disaster investigation” as outlined by Burton (2010) to identify improved and proactive approaches for reducing or preventing future wildfire disasters, and hastening community recovery when they do occur.

While investigation results warrant optimism that persistent programs of wildfire risk education and awareness are making progress to alleviate some important **hazard factors**, it is apparent that we are failing in regard to other hazard factors, including some of the most critical. This study justifies concern that low FireSmart adoption likely prevails in hundreds of other fire-prone communities across Canada.

Wildland/urban interface disasters are expected to become more frequent in the future. Adapting current programs to promote increased adoption of wildfire risk mitigation and to reduce the risk of catastrophic losses should become an urgent priority for insurers, urban planners, municipal administrators, researchers, fire prevention educators and public safety officials at all levels of government.

1. Introduction

1.1 Study objectives

Reducing the risk of losses in communities threatened by **wildfire** requires that appropriate **mitigation**[1] actions be planned and implemented well in advance, at scales that range from landscapes to individual backyards. This requires collaboration by organizations, agencies, and individual residents working together, across jurisdictional boundaries. The Institute for Catastrophic Loss Reduction[2] (ICLR) is one of many active partners in advancing risk mitigations in the wildland/urban interface (WUI). ICLR believes that important lessons can be learned by examining past disasters and has sponsored this investigation.

The purpose of this investigation was to determine the extent to which well-known FireSmart® guidelines[3] for reducing the risk of wildfire losses have been adopted during reconstruction and maintenance of homes and properties destroyed during the two largest wildfire disasters in recent Canadian history – the 2003 Okanagan Mountain Provincial Park Wildfire at Kelowna, British Columbia, and the 2011 Flat Top Wildfire Complex at Slave Lake, Alberta.

Multiple studies have recommended wildfire risk mitigations that residents of the WUI should take. Other studies have polled residents to identify risk mitigations they plan to take, or hazards they perceive to have mitigated already. However, this study is unique in assessing the level of mitigations actually implemented by homeowners during reconstruction of homes destroyed in past wildfire disasters, and the residual level of wildfire hazard that remains.

The ICLR anticipates that results of this investigation will reveal valuable lessons about the effectiveness of past (and present) programs which aim to educate key stakeholders about the dangers of WUI fire and motivate them to adopt FireSmart principles and actions that reduce the risk of wildfire losses.

1.2 The Wildland/Urban Interface fire problem

Wildland fires have burned cyclically for thousands of years, and are essential natural disturbances required to sustain many Canadian ecosystems. Periodic fire provides unique benefits that govern ecosystem renewal, long term forest health, maintenance of plant and wildlife habitat diversity, and the accumulation of fuel. **Wildland fires** burn in all types of natural vegetation. Consequently, communities and homes located within and adjacent to forests, parklands, brush, and grasslands are at risk. Depending on variable weather, topography, and fuel conditions, these landscapes can all experience wildfires that exhibit extreme behavior in terms of **fire intensity**, rates of spread, and difficulty of control. Wildland fires may occur at any time of the

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[1] Terms bolded within the text of this report are defined in the Glossary (Appendix "A").

[2] The Institute for Catastrophic Loss Reduction (ICLR) is a world-class centre for multi-disciplinary disaster prevention research and communication. ICLR was established by Canada's property and casualty insurance industry as an independent, not-for-profit research institute affiliated with Western University.

[3] FireSmart® is a registered trademark held by the **Partners in Protection** Association, and is used here by permission. The term "FireSmart" refers to a set of practices and principles that, when implemented, lead to lowered risk of losses from wildfires. Recommended guidelines for reducing wildfire risk were published by the Association in the 2003 manual FireSmart: Protecting Your Community from Wildfire.

year and are frequent events across the mountain, foothills, boreal, and grassland regions of Canada, from coast to coast.

Benefits aside, wildland fires occasionally threaten people, property or commercial forests. Unwanted fires are called wildfires. If a wildfire event spreads towards human development of any kind (i.e. to an urban, rural, industrial, or agricultural setting) and fuel consumed by the fire begins to include structures, then it becomes a **wildland/urban interface fire** and there is potential for disaster.

Most often, the WUI is described as any area where residential development meets with natural vegetation. This may occur as an abrupt transition from vegetation to a dense urban development, called the "interface", or as an intermingling of buildings within a matrix of native vegetation, called the "intermix." Both situations may occur in the same community, and are equally problematic.

Most usefully, the wildland/urban interface is defined, not as a particular place, but as a set of conditions which result in the potential for ignition of structures from flames or **firebrand**s of a wildfire.

WUI fire disasters are not a new phenomenon in Canada. For example, the Miramichi fire of 1825 in New Brunswick claimed 160 lives; the Great Fernie (BC) Fire of 1908 incinerated that large city in 90 minutes; and the Matheson Disaster in Ontario left 400 dead in 1916 (Alexander, Mutch, & Davis, 2007).

Awareness of how homes ignite is critical to understanding the WUI problem. Traditionally, large flame fronts and intense radiant heat were perceived as the cause of home ignitions. However, a growing body of evidence now proves that embers cause one half to two-thirds of home ignitions on large interface fires (Cohen, 2000; Cohen and Stratton, 2003; Maranghides and Mell, 2009). Embers ignite homes directly by coming into contact with the outside of a structure or entering a home via an opening, or indirectly by igniting combustible materials that eventually spread fire to the home itself.

Figure 1-1: Aerial view of homes destroyed at Kelowna.

[Photo Credit: Government of British Columbia]

Worldwide, experience with WUI fire disasters has demonstrated them to be extraordinarily complex and difficult to control. The unique nature of WUI fire reveals several reasons for this complexity:

- **Structural** and **wildland fuels** are involved, and firefighters must cope with both simultaneously.
- These fires threaten the lives of residents and firefighters; extensive evacuation may be needed.
- WUI fires characteristically develop, spread, and escalate very quickly, with extreme intensity.
- Dozens (or hundreds) of structures may ignite almost simultaneously.
- Effective pre-fire risk mitigation (i.e. FireSmart practices) is often lacking or absent.

Consequently, global experience demonstrates that even the most forceful WUI fire suppression responses are regularly overwhelmed, and that catastrophic losses result. Experience also shows that immediate losses are generally followed by immense, long-lasting social and economic impacts.

Recent Canadian experiences echo the global tendency. Between 1995 and 2005, 250 communities and about 700,000 Canadians have been evacuated due to wildfires (Natural Resources Canada, 2005). During the 2003 fire season more than 100 WUI fires occurred and more than 50,000 people were evacuated from their homes in British Columbia alone. Two communities are still recovering from the most costly fire events in Canada's history: the Kelowna and Slave Lake disasters which occurred within a decade of each other.

Currently, three convergent trends contribute to the disturbing likelihood that more frequent and devastating WUI fire disasters will occur in Canada:

- The WUI footprint is rapidly expanding and more people are exposed to wildfire as populations and development migrate to outlying areas for purposes of country-living, recreation, or work.
- Climate change is resulting in more frequent exposure to extreme wildland fire danger.
- Deteriorating forest health conditions are adding significantly to the amount and continuity of wildland fuels, and to the intensity and difficulty of controlling future wildfires.

Increasingly, Canadians will have to rely on effective risk mitigation measures (i.e. FireSmart) in order to limit future wildfire losses.

1.3 Scale, scope and responsibility for WUI fire loss reduction activities

The task of community wildfire protection transcends many jurisdictional boundaries. Correspondingly, measures to reduce wildfire risk must be implemented at all scales ranging from landscapes or regions, to municipal or community scales and finally, to the scale of individual homes and neighbourhoods.

At the larger scale, the scope of risk mitigation expands to include issues related to extensive fuel treatments, construction of fireguards, and improvements to water supply, road access, disaster response service, equipment, training, and land use planning. At the smaller and arguably most important scale, homeowners need to take FireSmart actions which limit the ignition potential of their individual homes. The hazard factors that contribute to overall wildfire risk to homes, the means to assess them, and solutions to address them are well-described in the FireSmart manual (Partners in Protection, 2003).

Responsibility for risk mitigation at larger scales, usually on public lands, most often lies with various levels of government or corporations, and it can be contentious. In contrast, homeowners living in the WUI bear sole responsibility for taking FireSmart actions on their property (i.e. private lands).

While this study focuses on residents and their uptake of FireSmart practices, it also reflects upon the important risk reduction contributions that government agencies and industry can make. For example, they can play key roles in facilitating education and information programs that motivate and/or assist homeowners, or mitigate fuel hazards on public land adjacent to homes.

1.4 Evolving standards, policy, and programs for wildfire loss reduction in the WUI

The framework for wildfire suppression and loss reduction in the wildland/urban interface has evolved dramatically over the past 150 years.

1.4.1 Early influences on development of North American WUI standards

The foundation for Canada's FireSmart guidelines for reducing wildfire loss was laid following a series of fire disasters in 1871. The Peshtigo (Wisconsin) and Great Chicago fires led insurance and sprinkler interests to convene in Boston and, eventually, to formation of the National Fire Protection Association (NFPA) in 1896. NFPA has since become the leading North American authority on fire prevention and has published hundreds of "standards" and codes[4] pertaining to protection of people and property from fire of all types. The first NFPA code pertaining to the WUI was published in 1935, and has been continually amended or replaced. It now exists as NFPA-1144: the Standard for Reducing Structure Ignition Hazards from Wildland Fire (2013).

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[4] The NFPA does not independently test, evaluate or verify information used or the soundness of any judgments contained in its codes and standards. The Association also carefully disclaims liability for personal injury, property or other damages resulting from use or reliance on its documents. Although the NFPA does not have power to enforce compliance with its "standards", members are free to adopt NFPA "standards" as guidelines, or provide them with legal status by enacting local laws and regulations.

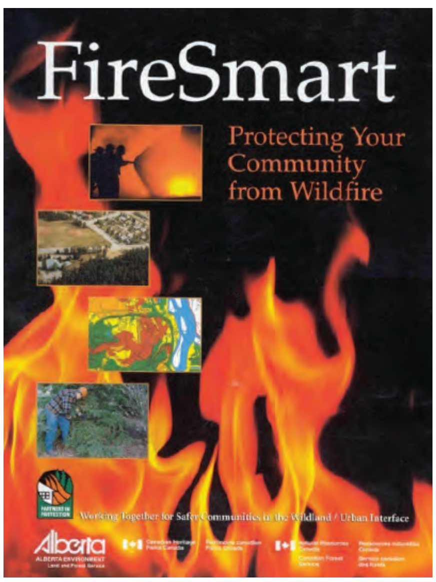
Catastrophes spurred development of American WUI policies and programs. The disastrous 1985 fire season (44 lives lost and 1,400+ homes destroyed) gave rise to a joint effort by the NFPA and the U.S. Department of Agriculture (Forest Service) to create the National Wildland/Urban Interface Program. More recently, the 1991 Oakland-Berkeley Hills, California, conflagration resulted in the loss of 25 lives and 2,500 homes; it galvanized public and political interests resulting in re-organization of wildland fire management agencies, and development of the U.S. Firewise program, headquartered at the NFPA.

Regardless of the above, catastrophic WUI fires have continued to occur almost annually in the United States, Europe, Australia, and Canada. These regularly eclipse previous benchmarks for wildland/urban fire losses, and further underline the seriousness of this issue.

1.4.2 Establishment of Canadian FireSmart guidelines for loss reduction in the WUI

In Canada, public safety and wildland fire officials also began to worry that wildfire could strike close to home. They had also begun to recognize that the outcome of WUI fires is more likely to be determined by the degree of disaster risk reduction undertaken in advance of the fire event, than by the force of the subsequent fire response. In addition, various analyses were demonstrating that escalating fire suppression efforts in an attempt to eliminate all wildland fires would be ineffective, unwise, and economically unsustainable.

In about 1990, Provincial fire officials initiated the first formal effort towards risk reduction in the wildland/urban interface. Notable among these was the publication of two manuals dealing with WUI planning and risk communications in the Province of British Columbia.



Concurrently, an Alberta-based non-profit association called **Partners in Protection** Association (PIP) sprang up. It was comprised of fire professionals and municipal officials, and dedicated itself to raising awareness, providing information, and facilitating forums to encourage proactive, community-based initiatives in the WUI. From the onset, PIP has championed the twin concepts that the WUI fire problem requires a range of coordinated solutions, and that responsibility for implementing these actions is shared by many stakeholders. Since then, PIP has become the national leader for WUI risk reduction.

In 1999 PIP published the first edition of *FireSmart: Protecting Your Community from Wildfire*. It contained comprehensive information pertaining to seven key FireSmart disciplines. These were: communication and public awareness; hazard evaluation; structural and infrastructure risk mitigations; vegetation/fuel treatment strategies; emergency response; training; and land use planning. PIP's approach to hazard evaluation and guidelines for risk mitigation were based closely on NFPA standards, and augmented by Forestry Canada research (Hirsch, 1991).

Since the second edition in 2003, the FireSmart manual has been supported and adopted by virtually every Canadian province and territory, and has become the "defacto" Canadian standard for risk mitigation in the WUI. More than 35,000 copies are now in circulation. It is also available in CD and bilingual (i.e. "Intelli-feu") formats, and online.

1.4.3 National wildland/urban interface policy and programs

In the ensuing years, some provincial and territorial wildland fire agencies developed dedicated "FireSmart" positions to advance WUI issues and nearly all have incorporated FireSmart into existing fire prevention programs. Subsequently, myriad provincial and municipal WUI information products have been produced. These have often been mediated or facilitated by Partners in Protection.

Most significantly, the Canadian Council of Forest Ministers with the support of all federal, provincial and territorial wildland fire management agencies, tabled a consensus report titled *The Canadian Wildland Fire Strategy: A Vision for an Innovative and Integrated Approach to Managing Risks* (CCFM, 2005). Among its four strategic objectives, two were directly associated with solving the WUI problem:

1. Enable change through increased awareness of wildland fire risks and appropriate responses at all levels.

2. Foster immediate action towards more resilient communities by implementing a "Canadian FireSmart Initiative" that minimizes risk to public safety and property.

That document marked the first formally sanctioned step towards a well-coordinated and funded national program for proactively mitigating growing wildfire risks to Canadian communities.

The strategy had two positive outcomes: an existing working group of the Canadian Interagency Forest Fire Centre (CIFFC) was re-structured in 2010 to incorporate WUI issues, and a task force struck within it to further develop the details for expansion of FireSmart community protection initiatives. Furthermore, Partners in Protection advanced proposals to the federal government, and others, for a FireSmart Canada Initiative. Unfortunately, funding for the Canadian Wildland Fire Strategy has not materialized as envisioned, and the strategy appears to have lost momentum.

Despite these setbacks, Partners in Protection (with support from the Canadian Wildland Fire Management Working Group and the Institute for Catastrophic Loss Reduction) developed and launched two major elements of the proposed FireSmart Canada Initiative. The FireSmart Communications Program was launched in 2012 with the advent of the FireSmartCanada.ca website. In 2014, this was joined by the FireSmart Canada Community Recognition Program which was created to promote formation of self-organized groups of residents to take the lead in implementing FireSmart solutions in their own neighbourhoods and backyards. To date, fifteen Local FireSmart Representative workshops to facilitate implementation of the Community Recognition Program have been held in British Columbia, Northwest Territories, Alberta, Saskatchewan, Ontario and Quebec. Many neighbourhoods have now received or are working towards formal FireSmart recognition.

1.4.4 Current status of the WUI issue in Canada

By about 2005, it had become obvious that a strong disconnect existed between the clear understanding of WUI issues and solutions held by subject matter experts and the low level of compliance with FireSmart practices by the general public, planners, and other WUI stakeholders.

During the past decade scientists and managers subsequently conducted research to better understand why these stakeholders have been resistant to accept and slow to implement FireSmart measures, especially in the face of such overwhelming consequences (Boura, 1996; McCaffrey, 2004; Winter et al., 2004; Brenkert et al., 2005).

As a result of this research, a solid body of social science is now available to help understand the competing values and concerns of residents regarding FireSmart mitigations, to help develop more effective risk communication, and to overcome previous roadblocks to implementing risk mitigations (Graham, 2003; McGee et al. 2005; McCaffrey, 2004b; Winter et al., 2002).

Currently, the potential for future WUI disasters remains high across much of Canada and is trending upwards. There is widespread concern that progress in implementing risk reduction is too slow. Many experts perceive the issue, once again, to be resting at a tipping point where we are equally poised for success, or apt to plunge back into another cycle of apathy and catastrophic loss.

1.5 Two essential FireSmart concepts

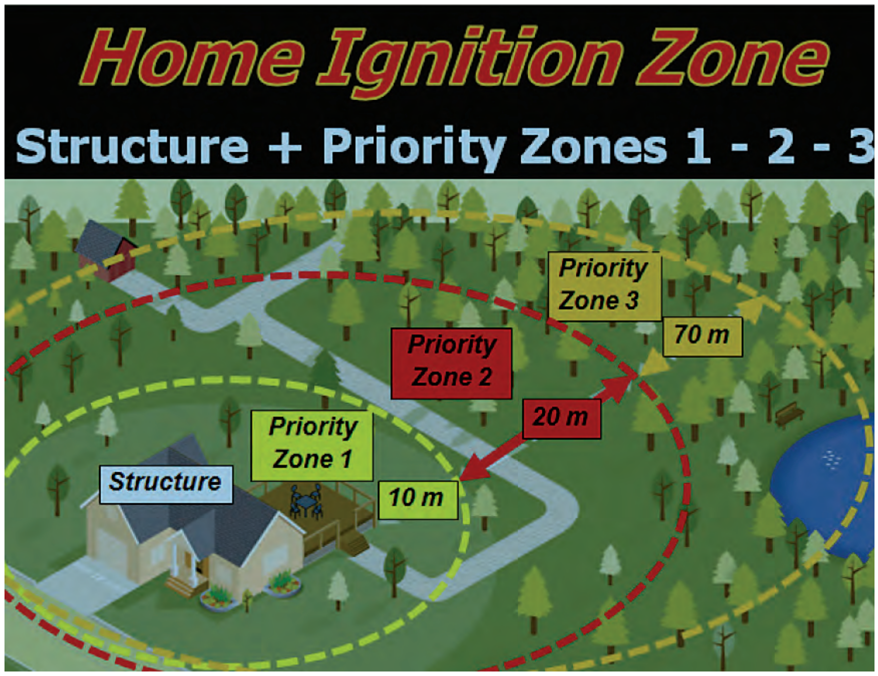
It is important to understand two key concepts that play prominent roles in FireSmart principles. They are central to establishment of the **Recommended Firesmart Guidelines** and to interpreting results of this investigation.

The first concept outlines the home ignition zone, which consists of the home itself, and three concentric Priority Zones that surround it. This is the most critical area for homeowners to implement risk mitigation activities. Accordingly, hazard factors within the home ignition zone are the focus of detailed hazard assessments and subject of recommended FireSmart guidelines. Figure 1-2 illustrates the home ignition zone and dimensions of Priority Zones 1, 2, and 3.

The second critical concept explains that urban wildfire disasters evolve through a series of predictable stages (see Figure 1-3). Given that high fire danger will develop and wildfires are inevitable, this second concept is based on evidence that if more home ignitions can be prevented, then fire suppression resources will not be overwhelmed - and disaster can be averted.

This model is known as the Wildfire Disaster Cycle. It emphasizes that the only logical and effective means of breaking the cycle is at the point where a wildfire begins the transition from consuming vegetation to feeding on **structural fuels** and homes begin to ignite. Simply put, if homes or structures do not ignite, a wildfire event cannot become an urban disaster. In this way, communities located in wildfire prone environments become adapted to wildland fire, and are more resilient to its negative effects.

Figure 1-2: Oblique view of the home ignition zone with priority zone dimensions.



[Image courtesy of Partners in Protection]

Figure 1-3: Breaking the wildfire disaster cycle.

[Image courtesy of Partners in Protection]

FireSmart benefits accrue in two ways that help break the wildfire disaster cycle:

- First, by following FireSmart principles, a homeowner greatly reduces the potential intensity of fire if it were to burn on their property. In turn, this lowers the probability that their home will ignite. It follows then, that the potential for fire spread from that home to neighbouring homes is reduced.

- Second, when clusters of homes exhibit FireSmart characteristics and become resistant to ignition, the entire neighbourhood becomes increasingly resistant to the spread of wildfire through urban fuels, and to heavy losses.

1.6 A new approach to disaster investigation: Maximizing lessons learned

The scope of the current study is limited to assessing and drawing conclusions regarding post-fire conditions apparent during the recovery stage of two major wildfire disasters. However, a broader and more detailed forensic type of investigation that would examine the myriad decisions, conditions, and actions leading up to these fire disasters has been proposed; it could reach beyond the present analysis, thus yielding constructive insights potentially valuable in identifying, rectifying, and avoiding the pre-cursors of future wildfire disasters. For additional details, see Appendix D.

2. Background

2.1 Kelowna and Slave Lake wildfire disaster scenarios

The communities chosen for this investigation were the location of the two most catastrophic WUI fire disasters in modern Canadian history. These were the City of Kelowna, British Columbia, which was struck by the Okanagan Mountain Provincial Park wildfire in 2003, and the Town of Slave Lake, Alberta, and surrounding hamlets that were overrun by the Flat Top Complex of wildfires in 2011. In both cases homes situated within high density urban areas, as well as homes situated on outlying acreages, were destroyed.

At Kelowna, the wildfire spread through a number of outlying rural acreages along Lakeshore Road on the outskirts of the city before impinging directly upon the recently developed subdivisions of Crawford, Mission Hills, and Mission Estates within the city limits. In contrast, the Flat Top Complex near Slave Lake was comprised of two separate, but nearly simultaneous, wildfires. One advanced through the rural acreages of Poplar Estates before spreading to the Town of Slave Lake, through older and newer neighbourhoods, and into the downtown core. The other wildfire spread through the nearby hamlets of Widewater and Canyon Creek along the south shore of Lesser Slave Lake.

2.1.1 Description of the Okanagan Mountain Provincial Park wildfire

The OMPP wildfire began on August 16, 2003, was ignited by overnight lightning, and grew to a final area of 26,600 hectares before being extinguished nearly 30 days later. Most home losses occurred within the first seven days.

An unprecedented number of wildfires and area burned occurred in British Columbia during the 2003 fire season; at least 50 fires threatened urbanized areas. Many large fires were burning in the interior of the province at the time of the Kelowna disaster. Fire danger was rated at extreme on August 16, 2003.

2.1.1.1 Fire and urban environments of the Okanagan Mountain Provincial Park wildfire

Kelowna is located in one of the hottest and driest areas of BC. Terrain within the fire perimeter was gullied, with rolling hills and multiple drainages. The affected private properties at Kelowna were located on gentle to moderately steep (i.e. 10% – 20%) northwest facing slopes that rise from the eastern shores of Okanagan Lake to the highlands above.

Native vegetation near Kelowna is dominated by dry grasslands and open ponderosa pine forest. Denser Douglas-fir/pine forest occurs at upper elevations and in shaded drainages. Often, mature forest is underlain by dense thickets of young conifers and shrubs. At the time of the fire, virtually all grass was fully cured. The area had suffered from an unprecedented three-year drought, compounded by the lowest June - August rainfall since 1899. Maximum temperatures during the multi-day disaster ranged from 25 - 30º C. while humidity varied from 17 - 38% with winds at 7 - 33 km/h. These conditions produced extreme wildfire intensity and rates of spread. High winds pushed fire through Kelowna neighbourhoods on August 22.

The subdivisions of Crawford, Mission Hills, and Mission Estates are located on the outer southeast margin of Kelowna. They were new, still developing, and mostly bounded by natural grassland and open forest. Thus, the classic interface and intermix situations were both present at the time of the fire.

Figure 2-1: Aerial view of the southwest quadrant of Kelowna impacted by the OMPP wildfire.

[Photo Credit: Government of British Columbia]

In 2014, these subdivisions still contained pockets of undeveloped housing land, enclaves of natural vegetation in community reserves and parks, and areas of undevelopable land comprised of steep terrain and gullies with dense natural vegetation. Outlying acreages ranged from very large, isolated homes to small clusters of five to ten homes on adjacent 0.25^{+} acre lots. Virtually all private homes in the Kelowna study sites appeared to be single family homes, and of middle to upper class stature.

2.1.1.2 Residential losses during the Okanagan Mountain Provincial Park wildfire

A total number of 238 private homes were destroyed in the City of Kelowna and on nearby acreages during the 2003 wildfire. Within the city, the majority of these losses occurred in a few, relatively large clusters of homes as the wildfire spread to the northeast and across the slopes above Okanagan Lake.

2.1.2 Description of the Flat Top Complex wildfires

The Flat Top Complex of wildfires (three separate fires) began on the afternoon of May 14, 2011 and were human-caused. Within 31 hours, two of these fires had destroyed 484 single family homes, and many other structures. The first of these wildfires burned west through Poplar Estates and entered the Town of Slave Lake. The second wildfire burned along the south shore of Lesser Slave Lake, impinging on the hamlets of Widewater and Canyon Creek. Collectively, these fires burned 22,000 hectares.

In the spring of 2011 the Province of Alberta faced an extreme wildfire situation. Between May 11 and 15 alone, Provincial wildfire personnel responded to 189 wildfires; 23 of these threatened communities. Fire danger was extreme in the Slave Lake region and 52 wildfires were reported during this period.

2.1.2.1 Fire and urban environments of the Flat Top Complex wildfire

These wildfires occurred in the central mixedwood sub-region of the boreal forest. The flat to gently undulating landscape consists of a patchwork of low-lying wetlands and dryer uplands. Upland areas are dominated by a mixedwood of aspen and spruce, and jackpine forest. Black spruce bogs prevail in low-lying areas. Dense shrub/grass layers are common in forested areas, as are deep organic layers. Small patches of previously harvested forest and/or agriculture-disturbed lands are scattered through the forest matrix.

Figure 2-2: Aerial view of fire #SWF-065 as it encroached on the Town of Slave Lake, AB.

[Photo credit: Mark Missal]

Following snowmelt, but prior to spring green-up, a brief period of extreme fire danger is common. This was the situation in May of 2011. Wildfires spread quickly on May 14, abated somewhat overnight in response to aggressive attack, then surged once more on the afternoon of May 15 as heavy, sustained winds of 70-100$^+$km/h pushed them from the southeast towards and into urban areas.

The Town of Slave Lake is located on the southeast shore of Lesser Slave Lake. There is a sharp interface between the town and forested lands to the east, being separated only by provincial highway #88. Neighbourhoods in the southeastern, most heavily impacted, quadrant of the town were well-established (i.e. built between the 1960s and 1980s) and fully developed with few vacant lots and very little native vegetation. These consisted of average to small urban lots arranged along linear or concentric street patterns, with alleys.

Newer neighbourhoods located just to the north, across the CN Rail right-of-way, were also impacted. Sawridge Creek meanders among these neighbourhoods and the downtown core to the west, and is bordered by a number of parks and forested enclaves.

The outlying areas that suffered home destruction ranged from isolated acreages, to small clusters of rural homes on large lots, to the low-density hamlets of Poplar

Estates, Widewater, and Canyon Creek. In all cases, native forest vegetation was prominent and these areas exhibited a distinct intermix situation.

2.1.2.2 Residential losses during the Flat Top Complex wildfires

The wildfires destroyed 428 single family homes in the Town of Slave Lake as the fire spread through the southeast quadrant of the town, into the downtown core. In addition, 56 single-family dwellings were destroyed in Poplar Estates, Widewater, and Canyon Creek. This represented the largest loss of private homes from a single natural catastrophe in modern Canadian history.

2.1.3 Current large-scale wildfire mitigation programs at Slave Lake and Kelowna

Both the Slave Lake and Kelowna jurisdictions have prepared very progressive Community Wildfire Protection Plans. These plans are guiding the systematic implementation of a wide range of wildfire protection measures on public lands. In both jurisdictions, targeted provincial funding has been utilized very effectively to prioritize and conduct treatments that reduce the intensity of wildland fires and their ability to spread, on hundreds of hectares of forest surrounding these urban centres.

As well, demonstration projects and other communication programs have been initiated to raise public awareness and promote FireSmart ideals. In Kelowna, a pilot program to implement the FireSmart Canada Community Recognition Program is now underway in two neighbourhoods located within the city but beyond the study areas; these neighbourhoods are expected to attain FireSmart recognition in the near future.

3. Methods

3.1 Study area

The Kelowna and Slave Lake WUI fire situations and study areas encompassed a wide range of biophysical, urban development, and administrative conditions. These included:

- Important differences in the climatic and topographic conditions that influence **wildfire behavior**.
- Differences between the fire/fuel environments surrounding rural homes versus that of homes situated in urban centres (e.g. structural versus native vegetation fuels; density of vegetation in Priority Zones 2 and 3).
- Jurisdictional differences with respect to regulatory, administrative, and public education/awareness programs relevant to FireSmart principles.

As a result of these differences, it was decided from the onset to divide the study area into four "study sites" for the purpose of analysis. These sites were designated as: 1) Kelowna – Urban; 2) Kelowna – Rural; 3) Slave Lake – Urban; and 4) Slave Lake – Rural.

Homes in and around the rural hamlets of Canyon Creek, Wagner, Widewater, and Poplar Estates were grouped together as the "Slave Lake – Rural" study site. Homes on the southeast outskirts of Kelowna and along the south shore of Okanagan Lake comprised the "Kelowna – Rural" study site.

3.2 Field orientation and data collection

Detailed fire damage maps, civic address maps, and remote imagery of each study site were obtained from internet sources or from municipal service centres in order to identify and locate homes destroyed and re-built since the wildfires. These were enlarged, augmented with information from published street maps, and then subdivided into neighbourhood areas to simplify field navigation.

Agency reports (Flat Top Complex Wildfire Review Committee, 2012; BC Ministry of Forests, Lands and Natural Resource Operations, 2014) record that a total of 722 homes were destroyed or damaged by these two WUI fires. Formal hazard assessments were performed on a total of 445 single-family residences during this study. The remaining 277 homes were either inaccessible, incomplete, or had not been re-built.

Table 3-1: Location of homes assessed and sample size

Study style	Number of homes destroyed	Number of homes assessed
Slave Lake - Rural	56	31
Slave Lake – Urban	428	226
Kelowna - Rural	35	18
Kelowna - Urban	203	170
Totals	**722**	**445**

Assessments were conducted by the author in the Kelowna area August 18 – 22, 2014 and in the Slave Lake area September 16 - 21, 2014. Initial investigation of each neighbourhood was undertaken prior to completing individual home assessments in order to gather general information about the local fire environment, become familiar with hazard factors shared by multiple residences and to verify addresses of newly reconstructed homes. Streets in each neighbourhood were then systematically driven to obtain progressive views of the side and frontal aspects of subject homes on the opposite side of the street. Several stops were made at varied distances from each home.

Observations of each hazard factor were recorded at this time and revised if required during a duplicate drive-by. Wherever possible, alleys or adjacent streets were driven to obtain alternate views of conditions at the rear of private homes; however, the layout of sub-divisions in Kelowna made this very difficult.

To complete the data collection process, streets were walked to clarify uncertainties and to view landscaping features, building materials, and construction features more closely. Abundant field notes and photographs were taken to augment form-based data.

3.3 Rapid residential wildfire hazard assessment technique

In order to systematically measure the degree to which FireSmart principles had been adopted by study area residents, homes re-built following the two wildfire catastrophes were assessed against the FireSmart guidelines recommended by Partners in Protection (2003). These guidelines set out best practices applicable to the home and three concentric "Priority Zones" surrounding it (i.e. the home ignition zone). By 2003, those guidelines had been adopted by the wildland fire management agencies of British Columbia and Alberta.

Residential wildfire hazard assessments are usually conducted by walking repeatedly around the home and property while closely examining a multitude of hazard factors related to structural, vegetation/fuel, topographic, and other characteristics that affect the ignition potential of the home. This requires close homeowner cooperation. Due to constraints inherent in this study it was not feasible to meet with each homeowner, yet it was essential to respect the privacy of residents. Therefore, a less intrusive assessment process was devised: the "rapid residential wildfire hazard assessment technique."

The field form used for rapid assessment of each property is included in Appendix B. It encapsulates all standard FireSmart hazard factors contained in the Structure and Site and Area hazard assessment forms of the Wildfire Hazard Assessment System (Partners in Protection, 2003). In that system, hazard factors are weighted in direct relation to the degree of risk they contribute to the overall ignition potential of a home. Critical fail point rating allocates immediate failure (30 points) to the most critical factors, and fewer points to less significant factors.

The rapid assessment system incorporates one additional hazard factor not identified in the 2003 system. That factor is labelled 'Ember accumulator features'. It assesses the abundance of locations on, under, or connected to a home that would capture accumulations of wind driven embers, promote smoldering **combustion**, and potentially result in ignition of the home itself. This factor was added because of research that places increased emphasis on airborne firebrands as causes of home ignitions.

The twenty individual hazard factors evaluated at each home are listed in Table 3-2. Hazard factors were grouped into four major categories that respectively evaluate the structural, vegetation/fuel, topographic, and other ignition characteristics that affect the overall vulnerability of a home to ignition by wildfire.

Table 3-2: Distribution of hazard factors (20) within major hazard categories

Hazard factors grouped into major hazard categories							
Structural		Vegetation/Fuel		Topographic		Ignition sites	
1	Roofing material	6	Surface fuel in PZ-1	15	Setback from slope	18	Roof cleanliness
2	Building exterior	7	Ladder fuel in PZ-1	16	Slope percent	19	Location of combustibles
3	Eaves, vents, openings	8	Canopy fuel in PZ-1	17	Slope position	20	Ember accumulators
4	Balcony, deck, porch	9	Surface fuel in PZ-2				
5	Windows and doors	10	Ladder fuel in PZ-2				
		11	Canopy fuel in PZ-2				
		12	Surface fuel in PZ-3				
		13	Ladder fuel in PZ-3				
		14	Canopy fuel in PZ-3				

3.4 Data analysis

Baseline data from all 445 assessed homes were input, by study area, to separate Excel 2010 spreadsheets. This allowed the hazard level for each home to be tabulated and facilitated simple calculations and analysis regarding individual hazard factors and groupings of hazard factors.

3.5 Study limitations

Results of the home hazard assessments were potentially affected by the variable time elapsed between the two wildfire events and the date of data collection, and by constraints on the study methodology. It was important to recognize these effects and, if possible, quantify and compensate for them.

3.5.1 Temporal and jurisdictional limitations

The time elapsed since the respective wildfire events and conducting the 2014 hazard assessments varied between 11 years at Kelowna and three years at Slave Lake. This temporal gap caused two important differences to post-fire reconstruction efforts, and subsequent hazard ratings.

First, there was significantly more time for post-fire landscaping efforts by residents and for establishment and growth of native vegetation in Kelowna, than in Slave Lake. In order to avoid a bias in this regard, all vegetation on and around urban and rural properties at Slave Lake was assessed as though its size, density and **fuel load** had increased by eight to ten years of additional growth.

Second, between 2003 and 2011, there was rising awareness and concern about "high intensity residential fires" in Alberta (Alberta Municipal Affairs and Housing, 2007). This type of fire originates at a single building then spreads very rapidly to many adjacent structures, resulting in urban conflagration. These concerns led to revisions in the Alberta Building Code which required application of fire resistant ply board beneath the side exposures of vinyl-sided homes. Front and rear exposures remain exempt. As a result, Slave Lake homes with vinyl siding are rated as being less vulnerable than vinyl-clad homes in Kelowna. See Appendix C for details.

3.5.2 Limitations of the methodology

The importance of respecting property and homeowner privacy during this study precluded the standard 360° "walk-around" performed by WUI hazard assessors. This restriction somewhat limited the assessor's ability to view and thoroughly examine certain hazard factors contributing to overall wildfire vulnerability, particularly those located at the rear of the home. Therefore, observation of hazards related to decks, balconies, outbuildings and building attachments, miscellaneous combustibles, and vegetation were incomplete. Incomplete access may also have constrained the ability to ascertain hazardous conditions related to windows, vents, openings, and siding materials.

In most cases, the lack of access at Slave Lake was overcome by driving or walking back alleys or viewing backyards from a distance, then updating the assessments. However, due to subdivision design, the absence of back alleys, and topographic constraints it was not possible to obtain adequate views of hazard factors in back yards and some side yards at the urban Kelowna study site. This limitation resulted in a systematic bias that underestimated wildfire hazards. Based on a sample of homes that were fully visible, the actual hazard ratings for urban homes at Kelowna are estimated to be 20% higher than assessed on the field forms. To correct for this bias, and because of its significance, the hazard ratings presented in this report for homes in urban Kelowna have been adjusted upwards by 20%.

3.6 Study assumptions

Several assumptions were made at the outset of this investigation. Most significantly, it was assumed that the measured results obtained from each home hazard assessment are a proxy for the level of adoption of FireSmart wildfire risk mitigations by each homeowner. That is, achieving a low hazard point rating is synonymous with an excellent degree of adopting (or compliance with) recommended FireSmart guidelines for mitigating wildfire risk. (See Section 3.7 and Table 3-3 below).

Second, due to the aforementioned amendment to the Alberta Building Code, the assumption was made that all builders and homeowners using vinyl siding have complied with this requirement. Hence, the rated hazard associated with vinyl siding at Slave Lake is systematically lower than at Kelowna[5].

Third, because of the limited access to property, it was necessary to assume that the screening in the external vents of new homes consisted of fine, non-combustible wire mesh, as recommended.

3.7 FireSmart hazard levels and degrees of FireSmart adoption

The maximum theoretical hazard rating for all factors pertaining to an individual home in this study was 294 points. The point ratings corresponding to recognized FireSmart hazard levels are as follows:

Table 3-3: Point ratings associated with FireSmart hazard levels and degrees of adoption

	FireSmart hazard point values			
Hazard point range	**0 - 42**	**43 - 58**	**59 - 70**	**>70**
FireSmart hazard level	Low	Moderate	High	Extreme
Degree of FireSmart adoption	Excellent	Good	Fair	Poor

Note that only a rating of "Low" or "Moderate" are considered by Partners in Protection (2003) to be FireSmart.

[5] Homes meeting the new Alberta code requirement remain highly vulnerable to structure ignition from external heat sources on their front and rear exposures.

4. Results and discussions

Section 4.0 presents results of the various analyses of data collected at the four study sites. The analysis progresses from overall hazard ratings (4.1), to an analysis of the four major hazard categories (4.2) and finally, to more detailed breakdowns of the twenty individual hazard factors.

4.1 Overall FireSmart hazard rating and degree of FireSmart adoption by study site

The overall results of the residential wildfire hazard assessments are summarized in Table 4-1.

Table 4-1: Average FireSmart hazard and adoption levels for each study site

Study site	Number of homes sampled	Average wildfire hazard and FireSmart adoption		
		Points	Hazard level	FS Adoption
Slave Lake Rural	31	34.5	LOW	Excellent
Slave Lake Urban	226	35	LOW	Excellent
Kelowna Rural	18	67	HIGH	Poor
Kelowna Urban[6]	170	58	MODERATE + *	Fair to Poor

* Note that the boundary between "Moderate" and "Low" hazard levels is 58 points, and 70 points between "High" and "Extreme."

Key results:

Overall, the analysis of wildfire hazard and FireSmart adoption demonstrated that:

– Although Kelowna and Slave Lake were impacted by similar wildfire disasters, it is clear from Table 4-1 that there are significant differences between the current levels of hazard and degrees of FireSmart adoption by residents in the two geographic areas.

– Overall, the implementation of FireSmart wildfire risk mitigations by urban and rural residents of Slave Lake was substantially greater than by residents of urban and rural Kelowna. Consequently, FireSmart hazard levels were lower at Slave Lake than at Kelowna.

– In the reconstructed urban areas of Kelowna, hazard levels measured at individual homes by this study are rated at "moderate+" but are verging on "high". Similarly, the outlying rural areas near Kelowna are verging on "extreme". FireSmart hazard levels in the urban and rural areas of Slave Lake were rated at "low", and compliance as "excellent". FireSmart adoption rates were "poor to fair" at Kelowna, and "excellent" at Slave Lake.

– While sample sizes for rural homes are relatively small, the data reveal a slight tendency for rural homes to be less compliant with FireSmart guidelines than their urban counterparts.

[6] Due to limitations of the methodology, as noted in Section 3.5.2, the value shown here represents the actual hazard rating in urban Kelowna, and is 20% higher than assessed on field forms.

Figure 4-1: Typical low hazard home with good adoption of FireSmart guidelines.

[Photo credit: Alan Westhaver]

Figure 4-2: Typical high hazard home with poor adoption of FireSmart guidelines.

[Photo credit: Alan Westhaver]

4.2 Residential wildfire hazard rating by major category

The overall FireSmart hazard rating for each study site is further broken down in Table 4-2. This analysis illustrates the average number and percentage of hazard points allocated to each category of hazard at each of the study sites.

Table 4-2: Average hazard points and percentages allocated to homes by hazard category

	Major hazard categories							
Study site	**Structural (max. 52 points)**		**Vegetation/Fuel (max. 205 points)**		**Topography (max. 21 points)**		**Ignition sites (max. 16 points)**	
	Points[7]	**%[8]**	**Points[7]**	**%[8]**	**Points[7]**	**%[8]**	**Points[7]**	**%[8]**
Slave Lake Rural	6.5	18.9	22.2	64.4	1.2	3.5	4.6	13.2
Slave Lake Urban	5.0	39.4	4.0	31.7	.03	0.2	3.6	28.7
Kelowna Rural	4.0	5.9	42.6	63.3	14.5	21.5	6.3	9.3
Kelowna Urban	2.5	5.5	35.1	73.0	7.0	14.5	3.5	7.1
Overall Average	**4.5**	**17.4**	**26.0**	**58.1**	**5.5**	**9.9**	**4.5**	**14.6**

Key results:

Overall, the analysis of major hazard categories indicates that:

- Newer homes built with modern techniques and materials accumulated very few hazard points and a low proportion of total hazard due to structural hazard factors. In particular, it is significant that no homes were given a critical fail point rating for having a combustible roof, a notorious problem in older neighbourhoods.

- On average, vegetation/fuel is by far the most significant hazard category contributing to overall residential wildfire hazards (58%), followed distantly by structural (17%), and ignition hazards (15%).

- When data from all Kelowna homes was combined, more than 70% of all hazard was attributed to non-conforming vegetation/fuel factors on private property.

Figure 4-3: Non-conforming vegetation/fuel accounted for 58% of all wildfire hazards.

[Photo credit: Alan Westhaver]

[7] Average number of hazard points allocated to homes in this study site.

[8] Percentage shown here is the average hazard rating for homes in this study area.

– At Kelowna, it was incidentally observed that the majority of hazard points attributed to vegetation/fuel were due to the presence of planted landscaping materials on private property, and a minority to adjacent forest or grassland fuel.

– There appeared to be a tendency for rural areas to accumulate a greater proportion of vegetation/fuel points, than in urban areas.

– At the Slave Lake - Urban study site, where the degree of FireSmart adoption was excellent and hazard levels low, the proportion (i.e. percentage) of hazard was evenly distributed among structural, vegetation, and ignition categories. Due to level terrain, the contribution of topographic factors was negligible.

– Topographic hazards are inherent to the geographic area, and make it more difficult to attain FireSmart status once the decision to locate in steep terrain is made by the homeowner, regardless of FireSmart adoption rates pertaining to other hazards.

– All sites exhibited good overall compliance with guidelines pertaining to miscellaneous ignition sites.

4.3 Hazards related to structural characteristics of homes

Data pertaining to structural hazards were further broken down to assess the relative importance of the building materials and building features sub-category (see Table 4-3) and individual contributions of the five structural hazard factors (see Tables 4-4 and 4-5).

4.3.1 Grouped results for hazard attributed to building materials and features.

Table 4-3: Relative hazard contributions of building materials and building features

	Structural sub-categories			
Study site	**Building materials (max. 40 points)**		**Building features (max. 12 points)**	
	Points[7]	**%[8]**	**Points[7]**	**%[8]**
Slave Lake Rural	3.5	10.1	3.0	8.8
Slave Lake Urban	3.1	24.4	1.9	14.9
Kelowna Rural	1.9	2.9	2.1	3.0
Kelowna Urban	1.3	2.9	1.2	2.6
Overall Average	**2.5**	**10.1**	**2.0**	**7.3**

Key results:

- In newly reconstructed homes across all study sites, guideline compliance level applicable to structural hazards is high, and the relative amount of hazard ascribed to building materials or features is low.

- There was no significant difference between the cumulative point ratings pertaining to building materials and features between study sites or geographic areas. Neither sub-category made a substantial contribution to overall wildfire hazard at any study site.

Figure 4-4: Stuctural features reflected good to excellent adoption of FireSmart guidelines.

[Photo credit: Alan Westhaver]

4.3.2 Hazard attributed to building material factors

The vulnerability of building materials located on exterior surfaces of homes to heat produced by flames, radiant energy, or embers are important hazard factors. Guidelines pertaining to building materials promote the use of non-flammable materials on the roof, fire resistant exterior siding, and smaller, multi-pane windows that are resistant to heat breakage and collapse.

Table 4-4: Hazard contributions of building materials by study site

	Building materials					
Study site	**Roofing (max. 30 points)**		**Exterior siding (max. 6 points)**		**Windows (max. 4 points)**	
	Points[7]	**%[8]**	**Points[7]**	**%[8]**	**Points[7]**	**%[8]**
Slave Lake Rural	0	0	2.5	7.2	1.0	2.9
Slave Lake Urban	0	0	2.0	16.1	1.0	8.2
Kelowna Rural	0	0	0.6	0.9	1.3	2.0
Kelowna Urban	0.1	0.3	0.1	0.1	1.1	2.5
Overall Average	**0**	**0**	**1.3**	**6.1**	**1.1**	**3.9**

Key results:

Adoption levels for recommended guidelines pertaining to building materials were good to excellent at reconstructed rural and urban residences in Slave Lake and Kelowna. Consequently, there was a low proportion of hazard and few hazard rating points allocated to the roofing, exterior siding, and window hazard factors. On average, exterior siding accounted for 6% of material-related hazards, followed by windows (4%), and roofing materials (0%).

Roofing:

- Most notably, none of the re-constructed homes in any jurisdiction featured combustible wood roofing material. This represents 100% compliance with FireSmart guidelines, and is an important breakthrough for WUI risk reduction efforts.

- The vast majority of homes at all study sites were roofed with asphalt shingles.

- Two methods of installing curved (i.e. Spanish style) roofing tiles were observed at private homes in Kelowna. One method ensured that the openings of the lowest, overhanging tiles were sealed to prevent possible entry by embers; and another left large gaps where embers could enter and accumulate on the combustible wood surfaces beneath.

Exterior siding:

- Adoption of FireSmart guidelines for building materials was good to excellent in all reconstructed neighbourhoods, with the exception noted below. With one exception, building materials were not a significant source of hazard in reconstructed neighbourhoods.

- About 50% of all residents opted for modern, fire resistant exterior siding options. These options included cement fiber board, feature walls of brick, river stone and other masonry products, stucco, or vinyl siding backed by fire resistant ply board. These materials were applied either as features on lower portions of exterior walls or on the entire exterior.

- The major exception referenced above were homes at Slave Lake where vinyl siding was not backed by fire resistant ply board[9] on all exposures of the home.

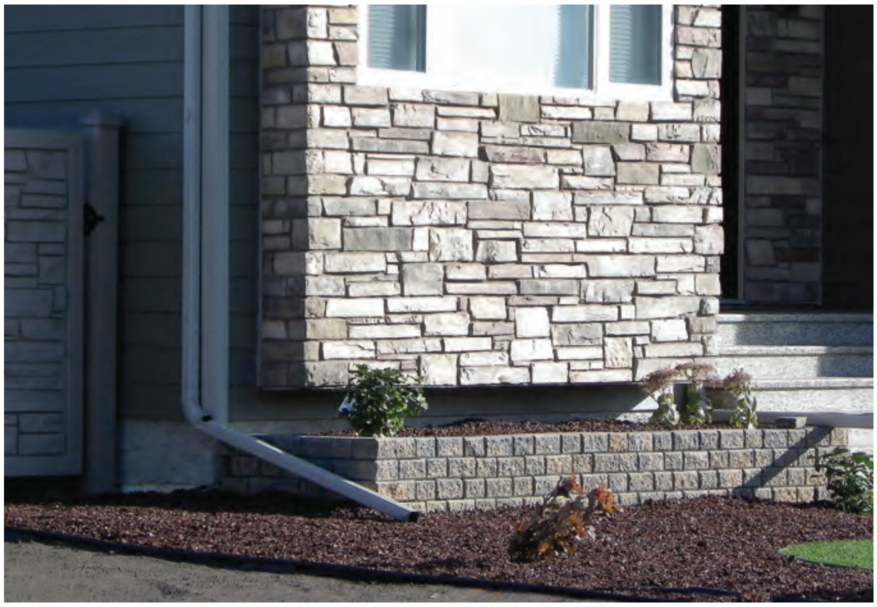
[9] Municipal officials interviewed at Slave Lake speculated that, due to costs, few residents extended fire resistant ply board onto all exposures of their homes; it is mandatory only on side exposures to adjacent homes.

Windows:

- Compliance with FireSmart guidelines pertaining to windows appeared to be almost universal. Reconstructed homes generally incorporated double-glazed windows with smaller or sub-divided surfaces that are more fire-resistant than older window styles.

- Unless combustible materials like shrubbery or window boxes had been placed beneath or directly in front of windows, the vast majority of homes assessed received very low hazard ratings.

Figure 4-5: Fire resistant siding and windows reduced wildfire hazard.



[Photo credit: Alan Westhaver]

4.3.3 Hazard attributed to building feature factors

Guidelines for building features focus on ensuring that essential openings in a home are properly covered to prevent penetration by wind-driven embers, to prevent fire from spreading from overhanging structures such as decks, porches and balconies to the home, and to promote construction of attached features with non-combustible or fire resistant materials.

Table 4-5: Hazard contributions of building features by study site

	Building features			
Study site	**Eaves, vents, openings (max. 6 points)**		**Balcony, deck, porch (max. 6 points)**	
	Points[7]	**%[8]**	**Points[7]**	**%[8]**
Slave Lake Rural	0.2	0.6	2.8	8.2
Slave Lake Urban	0	0	1.9	14.9
Kelowna Rural	0	0	2.1	3.1
Kelowna Urban	.05	0.2	1.2	2.4
Overall Average	**0.1**	**0.2**	**2.0**	**7.1**

Key results:

Overall, building features were marginally less hazardous (7%) than building materials (10%), and in good compliance. Balconies and decks accounted for the largest proportion of hazard (7%), and eaves and vents with less than 1%. Homeowners (and home builders) displayed good to excellent degrees of adoption of guidelines related to building features at all four study sites.

***Eaves, vents, and openings*:**

- Compliance with FireSmart guidelines that require adequate screening of eaves and vents and sealing of non-essential openings in homes was excellent and levels of associated hazard were therefore negligible. When inadequately screened vents were observed, they were generally located on attached garages or outbuildings only.

New home designs, construction methods, and/or ventilation requirements appear to have resulted in greatly reduced numbers of exterior openings and unregulated vents relative to older homes. Similarly, fewer openings in eaves and soffits were observed. The net result has been to reduce potential entry points for embers, and to lower home ignition potential.

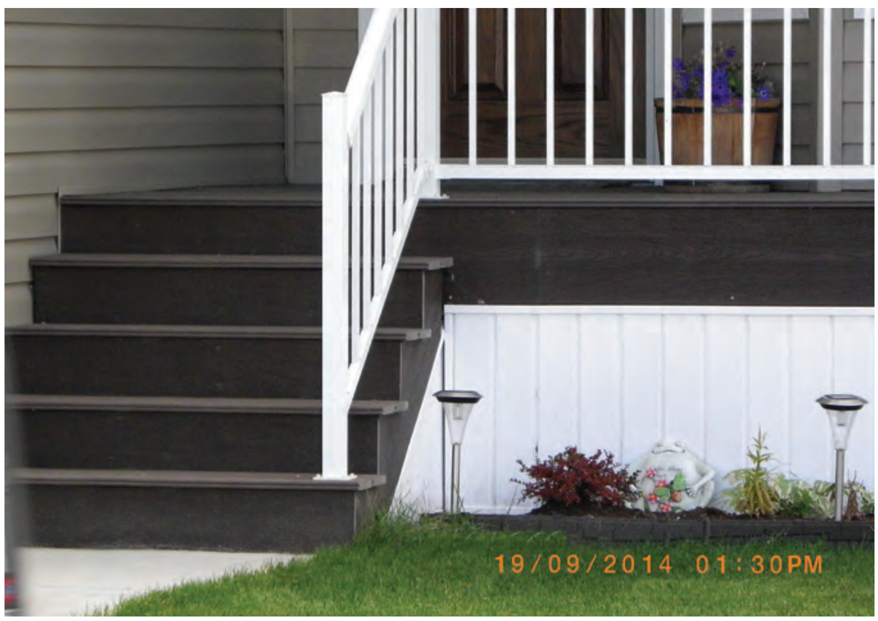
Balconies, decks, and porches:

- Modest point ratings for decks, balconies and porches indicate that residents and home builders are achieving good compliance with FireSmart guidelines in this regard.

- Based on past experience, the frequency of decks that were fully enclosed to prevent **ember** entry was greater than expected in this study. In addition, while combustible wood decking still prevails on most decks and balconies, it appeared that less flammable composite decking had been used at 10 – 20% of homes. Both are examples of increasing adoption of FireSmart principles.

- Relative to other communities studied by the author, it was observed that steps to front porches, doorways, and low decks were more frequently constructed of stone, masonry or other non-combustible materials, and that stair stringers were more likely to be constructed of metal. These construction features also contribute to lower hazard ratings for attached decks and porches, and simultaneously eliminate sites for ember accumulation and fire "wicking" potential.

Figure 4-6 FireSmart building features potential for home ingnition by embers.



[Photo credit: Alan Westhaver]

4.4 Hazards related to vegetation/fuel conditions surrounding homes

Natural and landscaped vegetation provides many of the valued amenities of living in a WUI community. At the same time, vegetation provides fuel that makes it possible for wildfires to spread into and though urban areas. FireSmart guidelines identify treatments to modify the location, amount, composition, and burning characteristics of vegetation fuels. In particular, the horizontal and vertical continuity of fuel dictates wildfire behavior. Collectively, these treatments promote lowered fire intensity and greatly reduce the potential for homes to ignite if they are implemented.

4.4.1 Contribution of vegetation/fuel hazard by FireSmart Priority Zone

In order to achieve risk reduction objectives, maintaining FireSmart vegetation guidelines in each of the three concentric Priority Zones is essential. Guidelines become progressively more stringent as the distance to the home decreases.

Table 4-6: Hazard points and percentage of vegetation/fuel hazard attributed to Priority Zones

	Priority Zone vegetation/fuel					
Study site	**Priority Zone 1 (max. 80 points)**		**Priority Zone 2 (max. 70 points)**		**Priority Zone 3 (max. 55 points)**	
	Points[7]	**%[10]**	**Points[7]**	**%[10]**	**Points[7]**	**%[10]**
Slave Lake Rural	3.1	14.1	8.5	38.4	10.5	47.5
Slave Lake Urban	2.3	56	1.1	26.7	0.7	17.3
Kelowna Rural	16.3	38.3	14.4	33.9	11.8	27.8
Kelowna Urban	17.3	49	10.5	30	7.4	21
Overall Average	**9.7**	**40**	**8.6**	**32**	**7.6**	**28**

Key results:

By far, vegetation was the leading contributor to critically high levels of wildfire hazard at private residences studied in Kelowna, and levels of FireSmart adoption were very poor. In contrast, the degree of FireSmart compliance by homeowners was excellent at Slave Lake, and vegetation related hazards low. In urban areas, vegetation conditions closest to the home consistently accounted for the majority of fuel hazards.

Priority Zone-1:

Priority Zone-1 extends outwards for a distance of 10m from the outer walls of a structure. It is the most critical zone for treating vegetation to reduce home ignition potential. In the dense urban settings of Slave Lake and Kelowna it was common for the Priority Zone-1s of adjacent homes to overlap. Recommended guidelines focus on removal, reduction, and conversion of vegetation in this zone.

[10] Percent of the total hazard attributed to vegetation/fuel in Priority Zones 1, 2, and 3.

- Vegetation/fuel accounted for almost 60% of all WUI hazard identified in this study (see Table 4.2). This analysis showed that almost half of that occurred within Priority Zone-1. Therefore, vegetation management in Priority Zone-1 emerged as a critical issue within this study.

- Overall, study results in urban and rural Slave Lake demonstrated good to excellent adoption rates and low allocations of hazard points due to positive vegetation management practices within Priority Zone-1:

  > The volume and density of vegetation in Slave Lake study sites was extremely low, even when vegetation was hypothetically advanced in age and size to equate it with older vegetation on private lots in Kelowna. Most notably, very little landscaping vegetation had been added to properties since 2011.

  > Although much of the mature native vegetation was destroyed by the fire, remaining native vegetation has since been removed or appropriately treated by residents or municipal authorities.

  > The selection of fire resistant landscaping species and plant types in Priority Zone-1 and, for the most part, maintenance of proper clearances between flammable vegetation and structures reflected strong awareness of FireSmart principles by residents.

- Conversely, study results for urban and rural Kelowna indicate that resident adoption rates pertaining to vegetation management were very low, and hazards due to vegetation/fuel were high.

- Two high-risk situations were observed during assessment of vegetation/fuel within Priority Zone-1. These create critical vulnerabilities likely to result in major home losses in all study sites:

  > About 5% of homes were compromised by improper placement of one or more dense, coniferous shrubs in contact with, or very close to, windows. In these situations, it is expected that intense, sustained flames from ignited shrubbery would impinge directly onto the window and cause it to fracture and fall away, allowing fire to enter the home. Even at homes rated "very low" this situation is considered to be an "Achilles Heel" that would make home destruction possible, if not probable.

  > At 20 – 25% of private homes in urban Kelowna mature cedars and/or junipers (planted individually, in clusters, or in hedge-rows) were observed to be in contact with the home, located beneath overhanging eaves and balconies, or in very close proximity to the home. It is reasonable to expect that these configurations would almost certainly result in home ignitions if they were to burn, which is almost certain during a WUI fire.

Priority Zone-2:
Priority Zone-2 consists of the area extending in all directions from 10 to 30m from the outer walls of a home. Due to small lot sizes, Priority Zone-2s in urban areas almost always overlap with neighbouring properties or adjacent municipal lands. FireSmart guidelines here focus on reduction and conversion of vegetation.

- With the exception of urban Slave Lake, the adoption of FireSmart guidelines by WUI residents was low for Priority Zone-2. As a result, non-conforming Priority Zone-2 fuels made significant contributions to the overall wildfire hazard at both the rural and urban Kelowna sites, and to the Slave Lake – Rural study area.

- Overall, untreated vegetation in Priority Zone-2 accounted for about 30% of the hazard attributable to vegetation/fuel in this study, thus illustrating the opportunity for increased diligence.

Priority Zone-3:
Priority Zone- 3 extends from 30m to at least 100m from the structure. Recommended FireSmart guidelines here focus on reduction and conversion of vegetation to less flammable species or forms. In urban settings, virtually all of this Zone is likely to be located on adjacent properties or municipal land.

- Overall, 28% of all hazard attributable to vegetation/fuel across this study occurred within Priority Zone-3. Proportionately, this was somewhat less than the vegetation/fuel hazards in other Priority Zones at Kelowna and urban Slave Lake, but it is still significant.

- Hazard point ratings indicate that the degree of compliance with guidelines for Priority Zone-3 vegetation were low in the rural and urban Kelowna study areas, and the rural Slave Lake area.

- The proportion of hazard attributable to vegetation in Priority Zone-3 within the rural Slave Lake study area was exceptionally high (i.e. 47.5%). This was largely due to the unique nature of the surrounding boreal forest.

Figure 4-7: Concentration of vegetation/fuel close to homes multiplied wildfire vulnerability.

[Photo credit: Alan Westhaver]

As an incidental observation it appears that the vegetation management practices being implemented by Slave Lake residents during this study align well with their FireSmart “intentions” as surveyed by McGee, McFarlane, Harris and Faulker (2009).

4.4.2 Contribution of vegetation/fuel hazard by vertical fuel layers

Vertical **fuel arrangement** regulates fires' ability to spread upwards, increase in intensity, and ignite nearby structures. To address fuel located on the ground surface, in the tree-tops, and in the critical layer between (i.e. **ladder fuels**) recommended guidelines have been developed. Continuous vertical fuel allows easily controlled low-intensity surface fire to evolve into high-intensity crown fire. Guidelines call for treatments to reduce, relocate, re-arrange or separate vegetative fuel in these layers.

Table 4-7: Proportion and percent of vegetation/fuel hazard assessed to vertical fuel layers

	Vertical fuel layers					
Study site	**Surface fuel (max. 75 points)**		**Ladder fuel (max. 40 points)**		**Overstory fuel (max. 90 points)**	
	Points[7]	**%[11]**	**Points[7]**	**%[11]**	**Points[7]**	**%[11]**
Slave Lake Rural	9.1	41.2	2.1	9.5	10.9	49.3
Slave Lake Urban	2.6	65	0.8	20	0.6	15
Kelowna Rural	19.9	46.7	8.8	20.6	13.9	32.7
Kelowna Urban	10.37	30	7.0	20	17.7	50
Overall Average	**10.5**	**46**	**4.7**	**17**	**10.8**	**37**

Key results:

Surface vegetation/fuel:

Surface fuels are comprised of fuel found on or near the ground surface. Examples include combustible coarse wood chip or bark mulches, **fine fuels** such as cured tall grasses, weeds, and needles or leaves. These dry out quickly, are easily ignited, and quickly spread fire in vertical and horizontal dimensions.

– The Slave Lake – Urban study site exhibited good FireSmart adoption and subsequent low risk in terms of surface vegetation. Ground cover consisted predominantly of well-manicured lawns. Decorative flower beds were relatively rare, were mostly planted with low-hazard species of ground cover, low-growing perennials, and deciduous shrubbery, and were located near the property perimeter. Flower bed mulch and xeriscaping ground cover consisted almost exclusively of non-combustible rock, gravel, or river-stone cobble. Wood-based mulches were rare.

– In contrast, high levels of hazard and poor adoption of guidelines were documented at private properties in Kelowna. Manicured lawns were also common. However, flower beds or rockeries were abundant in lawns and on terraces. Placement of beds under taller vegetation or close to structures and the flammable nature of vegetation contributed significantly to wildfire risk and were non-conforming with recommended FireSmart guidelines in three ways:

[11] Percentage of total hazard attributed to vegetation/fuel in all layers at a given study site.

> Combustible bark and wood chip mulching material, 5–15cm in depth, predominated as the ground cover of choice in flower beds. These organic mulches are a predictable[12] source of fuel. It would sustain spot fire ignitions by embers, propagate the spread of flaming or smoldering fire along the ground and/or upwards into flammable vegetation, and eventually lead to ignition of vulnerable structural elements of the home itself.

> A small proportion of flowerbeds at Kelowna homes were planted with perennial flowers or ground-hugging species with low flammability. However, most were dominated by a volatile mix of deciduous and coniferous shrubs or by coniferous shrubs alone (i.e. juniper, cedar and ground pine). The latter combinations were assessed as being capable of spreading fire to adjacent vegetation or igniting the adjacent home via heat or ember transfer.

> Flowerbeds seemed to be evenly distributed about properties including locations immediately adjacent to vulnerable decks, windows, and other combustible vegetation.

– Within the footprint of both the 2003 Kelowna and 2011 Slave Lake wildfires, it was observed that abundant surface vegetation (e.g. tall grasses, weeds) had regrown on many abandoned or undeveloped lots adjacent to new homes.

– In the case of Kelowna, **surface fuel** was heavily augmented by needle accumulations beneath mature or regenerating ponderosa pine. Fine surface fuel is subject to rapid drying and seasonal curing, contributes substantially to the probability of successful ember ignitions, and quickly spreads fire towards homes or other susceptible fuel sources like fences, wood piles, shrubbery, and vehicles.

– An upward trend in the use of tall (up to 2m) perennial bunch grasses as decorative landscape features was noted. When dormant and dry, these features add to overall surface fuel hazards and could potentially act as ladders spreading fire upwards into adjacent shrubbery and trees.

Ladder fuel:
Ladder fuels connect fuel on the ground surface to fuels above, like tree crowns. Most often **ladder fuels** are comprised of woody fuels located within 2m of the ground. Examples include the lower branches of mature conifers, coniferous shrubs, and thickets of evergreen seedlings. Even man-made fuels like combustible patio furniture, window boxes, or recycling bins can act as fuel ladders.

– In Slave Lake, coniferous shrubbery (e.g. juniper, ground pine, etc.) was almost absent in Priority Zones 1 and 2, and in conformance with FireSmart guidelines.

– At Kelowna homes, highly volatile coniferous species of juniper, cedar, and ground pines contributed greatly to rated hazards in Priority Zones 1 and 2, and within all three vertical fuel layers. These flammable plants were the most frequently chosen and spatially abundant landscaping species.

[12] Under windy, low humidity, high temperature and/or sustained drought conditions that accompany wildfires.

– Although generally low-growing in form, some species of cedars and juniper attained heights of 5 to 8+m. Frequently, plantings occurred in dense rows or clusters, and were positioned beneath taller mature conifers or structural features of the home (i.e. balconies, eaves), thus becoming very effective ladder fuels.

– Also at Kelowna homes, dense thickets of regenerating ponderosa pine were observed to be proliferating in areas burned over in 2003. These provide very effective vertical pathways for fire, thus increasing the probability of candling and ember transport to nearby homes. This phenomenon was particularly evident on steep terrain and in ravines[13] or gullies and on public parklands, vacant properties, as well as on community reserves. Untreated forest vegetation is contrary to FireSmart principles.

Overstory fuel:

Overstory fuel is comprised primarily of mature needle-bearing trees and tall shrubs like cedars. They are capable of spreading very intense fire through the forest canopy and showering surrounding areas with embers. Deciduous trees rarely contribute to this problem.

Figure 4-8: Vertical arrangement of vegetation/fuel exacerbates potential for homes to ignite.

[Photo credit: Alan Westhaver]

– In the urban areas of Slave Lake, most of the **forest overstory** was either consumed by the fire, survived and is now properly pruned according to FireSmart guidelines, or has been subject to post-fire removal. Therefore, overstory fuel made negligible contribution to current hazard levels.

– It was also observed that a high proportion of trees chosen for new plantings (i.e. the future overstory) on Slave Lake residential lots were deciduous, and in conformance with guidelines (e.g. birch, poplar, mountain ash, or individual conifers well-separated from buildings).

– Non-conforming coniferous overstory vegetation/fuel contributed 33–50% of all vegetation hazard in the urban and rural areas of Kelowna, and in the rural Slave Lake study site.

– At Kelowna homes, the majority of hazardous overstory vegetation was in the form of tall (i.e. 5–8+m) cedars planted for landscaping purposes but too close to homes and other major sources of structural/infrastructure fuel. Tall native ponderosa pine (at Kelowna homes) and boreal spruce/pine (at Slave Lake homes) were but minor contributors to home ignition potential.

[13] These features represent "terrain traps" or "chimneys" that would funnel extremely intense fire upwards toward homes located in the upper zones of these drainages, and along their edges.

4.5 Hazards related to topographic conditions

Topographic hazards arise from inadequate setback of a structure from the top of a slope or ridge, the steepness of the slope, and the position of a structure in relation to the slope. The contributions of each of these topographic hazards are summarized in Table 4-8. Once a home has been constructed at a given location, topographic hazards become an inherent risk of living there. FireSmart guidelines were established to encourage low-risk home locations at the planning stage. Once a home is built, there are no guidelines to directly mitigate topographic hazards, other than to compensate by more stringent application of guidelines pertaining to the structure, vegetation, and infrastructure.

Table 4-8: Summary of topographic hazards by study site

	Topographic hazard factors					
Study site	**Setback from edge of slope (max. 6 points)**		**Slope steepness (max. 10 points)**		**Slope position (max. 5 points)**	
	Points[7]	**%[8]**	**Points[7]**	**%[8]**	**Points[7]**	**%[8]**
Slave Lake Rural	0.1	0.2	0.7	2.0	0.5	1.4
Slave Lake Urban	.03	0.2	0	0	0	0
Kelowna Rural	4.5	6.8	6.3	9.3	3.7	5.4
Kelowna Urban	2.1	4.3	3.0	6.2	1.9	4.0
Overall Average	**1.7**	**3**	**2.5**	**4**	**1.5**	**2.7**

Key results:

– The net contribution of topographic factors was almost negligible at Slave Lake due to the level nature of the boreal terrain.

– In contrast, topography in the Kelowna area ranged from level to steep and the landscape is deeply dissected by linear erosional features that vary from gently angled drainages less than 5m across to steep sided canyons 100+ m wide which cut through entire neighbourhoods. Consequently, topographic hazard factors contribute 14–20% to the overall hazard at many Kelowna urban residences, and to almost all rural homes.

Setback from edge of slope:

– At Kelowna, several neighbourhoods featured homes on lots positioned at the top of steep slopes, or on ridge-crests. In most cases, these homes are located above expanses of undevelopable, but heavily vegetated land. This combination of topographic and fuel conditions result in significantly elevated hazard levels.

– In other Kelowna locations, homes on extremely steep slopes (i.e. up to 30%) are positioned on streets located one above the other, such that ignition of the lower home would almost certainly result in ignition of homes above.

– In about 2% of the homes assessed in urban Kelowna, it was observed that the combined effects of steep slope, undulating terrain, and small lot size has conspired to create a situation where a low-lying home (e.g. located in a depression) would, almost certainly, provide the fuel source to ignite adjacent homes located on higher ground.

Slope steepness:

– The steepness of slopes, measured in degrees or percent, affected the hazard level of almost all homes in urban Kelowna and virtually every home in rural Kelowna. Risk mitigation is possible by extending the zone of treated vegetation elliptically and further downslope than for level terrain, and by exceeding other FireSmart guidelines.

Slope position:

– Almost all homes in rural and urban Kelowna are positioned at least mid-slope, or on the upper slopes of minor prominences. Consequently, they acquired 2–3 additional hazard points.

4.6 Hazards related to miscellaneous ignition sites

In acknowledgment of embers as a leading cause of home ignitions (see Section 1.2), FireSmart guidelines have been developed to reduce the number of sites and situations that are vulnerable to this problem.

More specifically, guidelines address the accumulation of fine fuels on the roof surface and scattered combustibles located close to the home. In addition, this study quantified features called "ember accumulators" that create suitable "nooks and crannies" for wind-driven embers to pile up and ignite combustible elements of the home. Vegetation vulnerable to ember ignition is accounted for elsewhere, and not included in this category.

Figure 4-9: Topography compounds other hazards and is difficult to mitigate.

[Photo credit: Alan Westhaver]

Table 4-9: Summary of ignition site hazard factors by study site

	Miscellaneous ignition sites					
Study site	**Roof cleanliness (max. 3 points)**		**Miscellaneous combustibles (max. 6 points)**		**Ember accumulators (max. 10 points)**	
	Points[7]	**%[8]**	**Points[7]**	**%[8]**	**Points[7]**	**%[8]**
Slave Lake Rural	0	0	2.4	6.8	2.3	6.5
Slave Lake Urban	0	0	2.1	17	1.5	11.7
Kelowna Rural	0	0	2.1	3.1	4.2	6.3
Kelowna Urban	.01	0.2	1.2	2.6	2.2	4.5
Overall Average	**0**	**0**	**1.95**	**7**	**2.6**	**7**

Key results:

Roof cleanliness:

– Roof cleanliness was not a significant factor in this study. This was likely due to a combination of homeowner diligence and low densities of mature trees within the study sites.

Miscellaneous combustibles:

– Overall, the adoption of FireSmart Guidelines that aim to reduce the occurrence of miscellaneous combustibles and ensure adequate clearances was fair to good in all study sites, with a noted tendency for urban residents to be somewhat more diligent than rural homeowners. It appeared that many residents had developed covered or indoor storage options for most combustibles.

– The most common (and significant) sources of miscellaneous combustibles were firewood piles, fencing, all-terrain and recreational vehicles, barbecues, LPG or liquid fuel storage containers, recycling storage areas, compost piles, and stored construction materials. Many of these were potential sources of intense, long-lasting heat that could readily ignite a home.

– Combustible wood panel fencing posed an additional problem since it was usually attached directly to the home, often contiguous with combustible vegetation, and occasionally connected adjacent homes to each other. It was observed at the majority of Slave Lake homes, and at many homes in Kelowna. Combustible fencing contributes to home ignition potential by acting as a “wick” which allows fire to spread from remote areas into direct contact with structures[14].

[14] As an alternative to combustible wooden fencing, and to solve the “wicking” problem, Slave Lake residents had installed pre-fabricated vinyl fencing panels around their homes, or utilized a section of wire fencing as a “fire break” between their home and sections of wooden fencing.

Ember accumulators:

- Although formal guidelines pertaining to ember accumulator sites have not yet been established, it appeared that residents were being quite attentive to limiting the number of ember accumulator sites, at all but the rural Kelowna area.
- Based on the author's prior experience with home assessment and informal comparison of nearby unburned (i.e. older) homes versus newly re-constructed homes, it appears that modern styles of building design[15] are helping to mitigate this particular risk. That is, new designs appear to provide cleaner roof lines and fewer attachments and "nooks and crannies" for embers to accumulate in. It could also be the case that the number of ember accumulation sites will increase over time.

Figure 4-10: Miscellaneous ignition sites contribute to the spread of fire near homes.

[Photo credit: Alan Westhaver]

[15] Some design changes are possibly motivated by concern for wildfire vulnerability but more likely by energy efficiency, style preferences, and aesthetic values.

4.7 Proportion of individual homes rated at various FireSmart levels

The percentage of homes assessed to be at each FireSmart hazard level provides yet another informative measure of the acceptance of FireSmart solutions by WUI residents. Table 4-10 provides a breakdown of homes (sample size of 445) in each of the four study areas that were assessed to be FireSmart. Only homes at the "low" and "moderate" levels are considered to qualify.

Table 4-10: Number of homes at each hazard level by study site (N=445)

	FireSmart hazard levels			
Study site	**Low (0 - 42 points)**	**Moderate (43 - 58 points)**	**High (59 - 70 points)**	**Extreme (70+ points)**
	% homes	**% homes**	**% homes**	**% homes**
Slave Lake Rural	68	23	9	0
Slave Lake Urban	97	2	0	1
Kelowna Rural	22	44	6	28
Kelowna Urban	45	19	14	23
Overall Average	**72%**	**12%**	**6%**	**10%**

Key results:

- In urban Slave Lake, this analysis validates the overall "low" hazard rating assessed in Table 4-1 by means of averaging, since nearly every home received that same individual rating. A similar but less pronounced trend occurred with rural Slave Lake homes.

- In contrast, at both the rural and urban Kelowna study sites (which received respective hazard ratings in the upper reaches of "high" and "moderate" by means of averaging) this breakdown illustrates a more even distribution of ratings for individual homes.

- In urban Kelowna, it was noted that 23% of homes (i.e. 39 individual homes) are rated at "extreme" hazard.

4.8 Summary of adoption rates for specific FireSmart mitigations

All observations from the Slave Lake and Kelowna study sites were pooled in this analysis in order to provide an overview of the net degree to which residents have adopted recommended FireSmart guidelines.[16]

Table 4-11: Adoption rates for specific FireSmart mitigations

Resident adoption of FireSmart mitigations for WUI hazard factors		
Poor	**Fair-Good**	**Excellent**
Surface fuel in Priority Zone-1	Building exterior	Roofing material
Ladder fuel in Priority Zone-1	Balcony, deck, porch	Eaves, vents, openings
Canopy fuel in Priority Zone-1	Location of combustibles	Windows and doors
Surface fuel in Priority Zone-2	Ember accumulators	Roof cleanliness
Ladder fuel in Priority Zone-2	Surface fuel in Priority Zone-3	
Canopy fuel in Priority Zone-2		
Ladder fuel in Priority Zone-3		
Canopy fuel in Priority Zone-3		

Key results:

- Overall, results show that efforts to encourage Canadian homeowners to adopt FireSmart mitigations that reduce wildfire losses are making progress, but are far from being fully successful.
- At this time, and within the study area, more FireSmart hazard mitigations are experiencing a "poor" rate of adoption by homeowners than those with an "excellent" rate of adoption.
- All hazard mitigations for which adoption rates are "poor" are related to the management of vegetation/fuel, and are primarily the responsibility of homeowners to implement.
- Three of four hazard mitigations for which adoption rates are "excellent" (i.e. roofing material, eaves/vents, and windows/ doors) are structural mitigations largely pre-determined and implemented by the home builder, and not necessarily the result of direct action by homeowners.
- Three of five hazard mitigations for which adoption rates are "fair to good" (i.e. building exterior, balcony/deck/porch, and ember accumulators) are within the discretion and capability of homeowners to mitigate, but are also positively influenced by building design, style preferences, and construction materials selected by the home builder.
- All three hazard mitigations for reducing miscellaneous ignition sites (i.e. roof cleanliness, location of combustibles, and ember accumulators) are rated in the "good" to "excellent" levels of adoption, thus indicating diligence by area residents.

Figure 4-11: The level of adoption for 9 out of 10 vegetation/fuel guidelines was poor.

[Photo credit: Alan Westhaver]

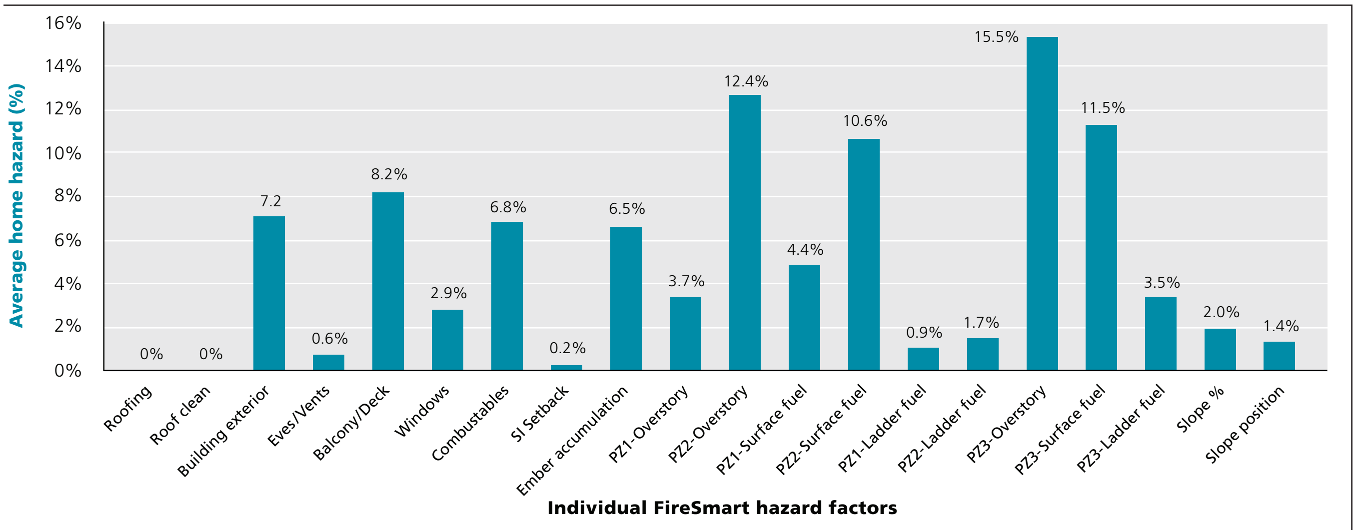
[16] Slope steepness, position, and setback are legitimate hazard factors but have not been included here. This is because they are not considered to be within the ability of residents to voluntarily mitigate.

4.9 Profiles of FireSmart hazard factors at Kelowna and Slave Lake study sites

As a final analysis, the percent of total FireSmart hazard assessed to each of the 20 hazard factors was plotted for each of the four study areas. The resulting bar charts form profiles which illustrate the relative contribution of each hazard factor within each study area. The profiles have limitations due to the nature of percentages.

Figure 4-12 sketches the profile for 31 rural Slave Lake homes. Similar to urban Slave Lake, this profile is also erratic and points to issues with building exteriors and ignition sources. It also highlights hazards from forest overstory fuels further from homes.

Figure 4-12: Distribution of FireSmart hazard: Slave Lake – Rural (N=31)



The profile for 226 homes in urban Slave Lake shown in **Figure 4-13** reflects the very low level of FireSmart hazard rating attained by residents and is remarkable for the number of hazard factors that have been well-mitigated, particularly those relating to vegetation/fuel. Spikes are exaggerated by the nature of percentages, but also serve to highlight weaknesses deserving additional attention such as miscellaneous combustibles, ignition sites, and ember accumulators.

Figure 4-13: Distribution of FireSmart hazard: Slave Lake – Urban (N=226)

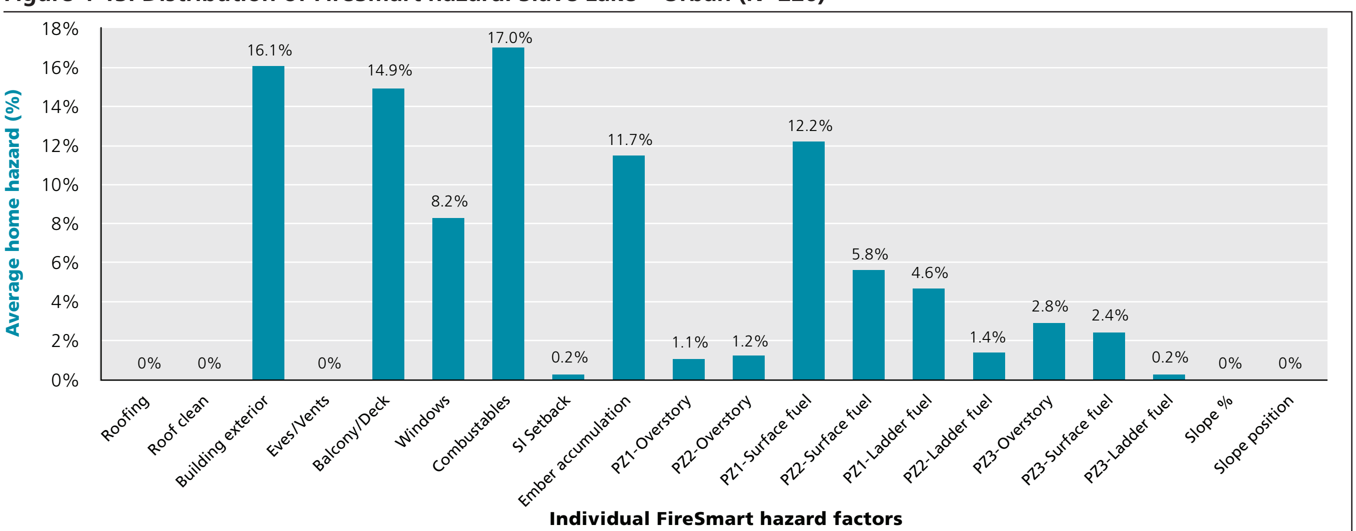
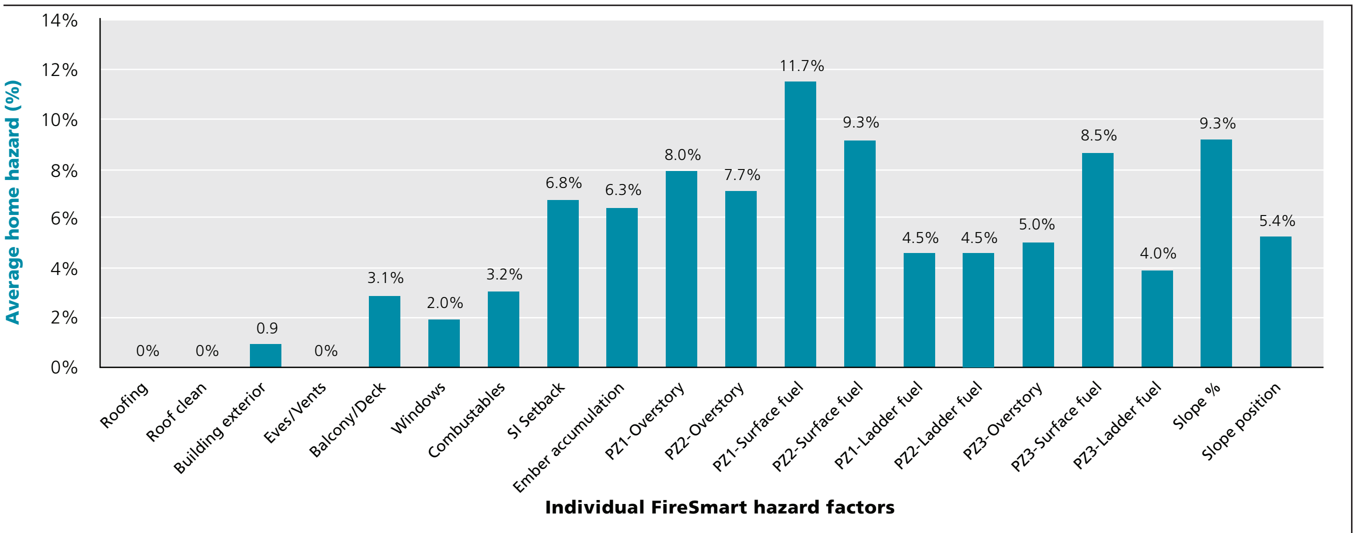


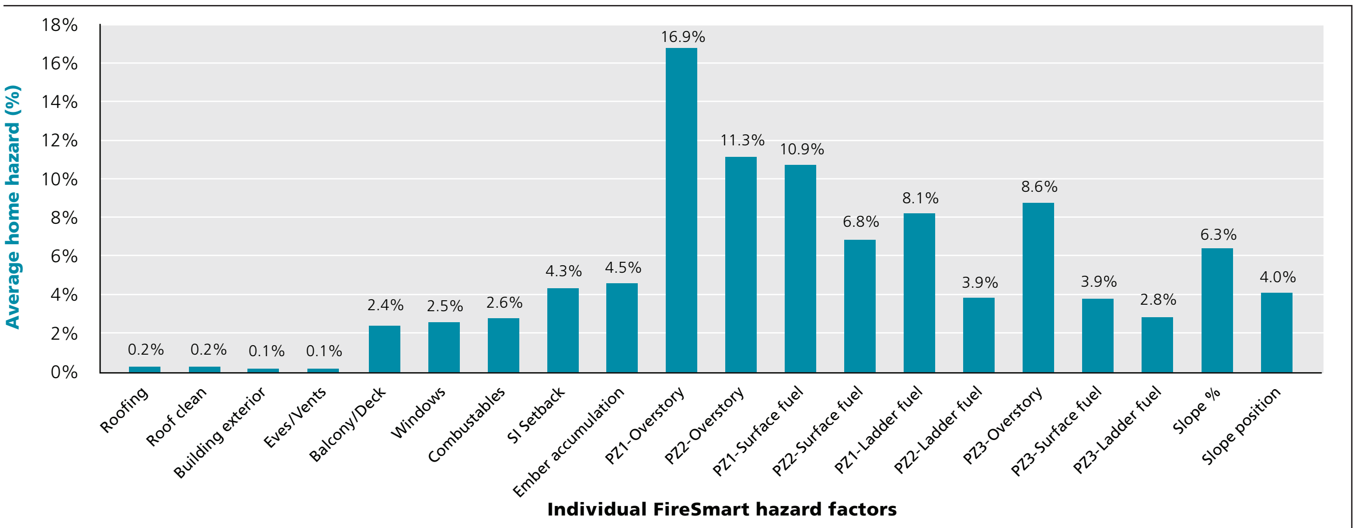
Figure 4-14 profiles hazards at 18 rural Kelowna homes. The profile illustrates low hazard due to structural factors but quickly plateaus reflecting high relative hazards across-the-board, especially for surface and overstory fuels. Hazards due to the steeper terrain are most dramatic at this study site.

Figure 4-14: Distribution of FireSmart hazard: Kelowna – Rural (N=18)



From left to right the profile of 170 urban Kelowna homes in **Figure 4-15** portrays very low hazard due to structural factors, the rising but minor contributions of ignition factors, and sharp spikes due to high contributions of vegetation/fuel factors - particularly those closest to homes. The profile then tails off gradually with more moderate hazard contributions by topographic factors.

Figure 4-15: Distribution of FireSmart hazard: Kelowna – Urban (N=170)



4.10 Spatial distribution of hazard within the home ignition zone

To complete this investigation, an analysis of the spatial distribution of wildfire hazards within the home ignition zones was undertaken at each of the study locations. Recall that the home ignition zone is comprised of four entities: the home itself and three concentric Priority Zones. The numbers shown in Table 4-12 represent the average number of hazard points allocated to each of these four entities when data for all homes in each study site was pooled.

Table 4-12: Spatial distribution of hazard within the home ignition zone

	Spatial distribution of wildfire hazard in the home ignition Zone (HIZ)				
Study site	**Average total hazard points in HIZ**	**Home + all associated factors**	**Priority zone-1 vegetation**	**Priority zone-2 vegetation**	**Priority zone-3 vegetation**
Slave Lake Rural	34	12	3	8	11
Slave Lake Urban	13	9	2	1	1
Kelowna Rural	67	24	17	14	12
Kelowna Urban	58	16	21	12	9

Key results:

– In general, the spatial distribution of hazard is focused on the structure itself and tends to taper off quickly as distance from the structure increases. This effect is stronger in urban areas than in areas of rural acreages where remnants of mature forests still exist.

– Overall, about two-thirds of all hazard points are generated by the home and within Priority Zone-1. That is, within 10m of the home and largely within the responsibility of the homeowner.

Figure 4-16: Two-thirds of all hazard originates with the home and vegetation within 10 metres.

[Photo credit: Alan Westhaver]

5. Conclusions

The broad scope of this investigation leads to a diverse array of conclusions. Generally, these conclusions fall within the scope of the major FireSmart disciplines (Partners in Protection, 2003).

Adoption of FireSmart practices

1. Upon conducting WUI hazard assessments at 445 homes within four areas tragically impacted by recent wildfire disasters, the author has concluded that a wide disparity existed in the degree to which recommended FireSmart guidelines had been adopted by homeowners in the rural and urban areas of Slave Lake, and Kelowna. Consequently, the author has determined that only the urban and rural study sites at Slave Lake could be confidently rated as being "FireSmart" in terms of current wildfire hazard levels.

2. Regarding the urban and rural study sites at Kelowna, the author has concluded that the level of wildfire hazard at private homes has risen since re-construction to the extent that a future wildfire threat could, quite possibly, trigger a repeat of the 2003 disaster.

3. A spatial analysis of the distribution of wildfire hazards within the home ignition zone reinforced the basic FireSmart principle that the greatest amount of attention to wildfire risk mitigations should be focussed closest to homes, in order to be most effective and efficient. As a corollary to this and other analyses, the author has concluded that homeowner attentiveness to FireSmart risk mitigations often appears to be least where it matters the most (i.e. at the home itself and within 10m outwards).

Figure 5-1: Kelowna study sites were not considered to be "FireSmart" due to low FireSmart adoption.

[Photo credit: Alan Westhaver]

4. Several analyses within this study converged to produce the conclusion that, without exception, the lowest levels of compliance with recommended FireSmart guidelines were those pertaining to mitigation treatment of vegetation/fuels. This was true regarding fuels in each of the three recognized vertical layers, as well as in all three concentric Priority Zones that surround the home.

5. Topographic hazards aside, the author concludes that the majority of existing wildfire hazards (i.e. those linked to vegetation/fuel, structural, and miscellaneous ignition conditions) are well within the authority and responsibility of homeowners and local land managers to mitigate.

6. The author has also concluded that the low level of FireSmart adoption by residents, and correspondingly high levels of hazard, in communities so greatly devastated by wildfires justifies concern that low FireSmart adoption rates probably prevail in hundreds of fire-prone communities across Canada.

Communications, public awareness, and community engagement

1. From this study the author has concluded that persistent FireSmart communications are raising public awareness and making progress to alleviate some important wildfire hazard factors. Furthermore, fire prevention and public safety officials have reason to be optimistic that similar success can be achieved with regard to other hazard factors that continue to be in non-compliance.

2. It is clear that home builders, residents, and other stakeholders at Slave Lake have been very attentive to FireSmart guidelines and principles since re-construction of homes began in 2011. While the importance of risk aversion as a motivating force is unknown, the author has concluded that residents and other stakeholders in the community benefitted immensely from the extraordinary, highly innovative program of effective FireSmart communications conducted there. That program arose from close collaboration between the provincial FireSmart Unit of Alberta Environment and Sustainable Resource Development, members of the Slave Lake Regional Tri-Council, and the FireSmart Regional Action team.

Figure 5-2: Study results create doubt about the effectiveness of current FireSmart communications.

[Photo credit: Alan Westhaver]

3. With the exception of Slave Lake, the author has concluded that there are sound reasons to doubt the overall effectiveness of past and present FireSmart (i.e. WUI risk reduction) communication programs. While low adoption of FireSmart practices may be the result of not enough messages about wildfire risks and FireSmart solutions, it seems more likely that present messages and risk reduction guidelines are ineffective, being rejected, or simply ignored by wildland/urban interface residents.

4. It is the author's conclusion that there is an immediate need for increased understanding by Kelowna homeowners, builders, commercial landscapers, and municipal managers regarding basic fire behavior principles (i.e. what constitutes fuel, how fire spreads, how homes catch fire) and simple FireSmart solutions (i.e. **fuel modification**, clearances, reducing ignition sites and ignition potential of structures) before urgently needed gains in mitigating WUI fire risks can be made.

5. After conducting nearly 450 home assessments and a cursory examination of the pattern of home destruction in the two urban centres, it has become apparent that wildfire hazard at the level of an individual home is not a mutually exclusive situation. The vulnerability and ignition of one home greatly affects the ignition

potential and survival chances of surrounding homes. From this, the author has concluded that resolving the WUI fire problem requires increased emphasis on programs of communication and public engagement that motivate residents to work together with their neighbours to implement FireSmart practices collectively, across entire neighbourhoods[17].

6. It is also concluded that insights obtained by this study into the differential adoption of various FireSmart practices by residents of these two communities could be useful in guiding development of future FireSmart communications programs and targeted projects.

Vegetation management, landscaping, and fuel modification

1. Overall, this study concluded that hazard factors related to vegetation/fuel accounted for 58% of the total wildfire hazard assessed in the study area. This ranged from 32% in urban Slave Lake, to 64% in rural Slave Lake, 73% in urban Kelowna, and 63% in rural Kelowna. Thus, vegetation/fuel was, by far, the largest single contributor to the risk of home losses to wildfire. This translates to poor or very poor adoption of FireSmart practices by interface residents.

2. By deduction then, it was concluded that the greatest potential for reduction to future WUI fire losses in urban and rural Kelowna and, to a lesser extent, in rural Slave Lake areas lies with increased actions by residents and managers of adjacent undeveloped lands to implement recommended FireSmart guidelines for vegetation/fuel treatments on private and public property.

3. Taking a wildfire behavior perspective, an analysis of the spatial distribution of hazards stemming from vegetation/fuel conditions resulted in two important conclusions:

   – In the horizontal dimension, vegetation/fuel conditions in Priority Zone-1 accounted for the most hazard (40%), followed by Priority Zone-2 (32%), and Priority Zone-3 (28%).

   – In the vertical dimension, vegetation/fuel conditions on and near the ground accounted for the majority of hazards (46%), followed by fuels in the canopy (37%), and ladder fuels (17.5%).

4. After examining the large discrepancy between "low" hazard levels in the urban areas of Slave Lake and the borderline "high" to "extreme" levels at Kelowna homes more closely, the author has concluded that about 75% of that difference was due to non-compliance pertaining to vegetation/fuel guidelines.

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[17] The fledgling FireSmart Canada Community Recognition Program was developed to encourage self-organized groups of neighbours to work together to implement FireSmart practices, and is based on this principle.

Figure 5-3: The greatest potential to reduce wildfire losses is by increasing adoption of vegetation/fuel guidelines.

[Photo credit: Alan Westhaver]

5. Specific to the Kelowna study sites, this investigation identified current conditions that result in substantial wildfire risk to homes. These conditions lead to several important conclusions:

   – The abundance and density of easily ignited and highly volatile trees, shrubs, and ground cover planted in close proximity to or in contact with homes have placed a significant proportion of Kelowna homes at extreme risk of destruction during a wildfire event.

   – Flammable bark and wood chip mulches predominate in flower beds located on private property within the urban Kelowna study site. These provide a receptive fuel bed for ember ignitions, would promote horizontal spread and vertical growth of fire, and contribute significantly to the potential for igniting nearby homes.

- The space between homes was frequently crowded with highly volatile coniferous vegetation, in addition to other sources of fuel such as fences, stored vehicles, firewood, and other combustibles. This creates a situation which further promotes the spread of fire from home to home, and development of an urban conflagration.

- The Kelowna subdivisions studied are typical of the urban "intermix." Enclaves of mostly natural vegetation flourish on community reserves, riparian corridors, vacant lots, and in undeveloped gullies located between and within blocks of homes. Most enclaves were not treated to FireSmart standards. Therefore, the author has concluded that these areas are highly susceptible to ignition during a wildfire event, and would encourage rapid fire spread towards homes.

The upshot of these conclusions is that many Kelowna homes rebuilt following the 2003 wildfire disaster are now at high to extreme risk of igniting, and that the combination of abundant, nearly continuous man-made and natural fuels will promote **extreme fire behavior** and the likelihood of large-scale home destruction during a future WUI fire event.

6. Specific to Slave Lake, residents have demonstrated strong adoption of FireSmart vegetation/fuel management practices. The author has concluded that:

   - Residents of Slave Lake exercised strong selection in favour of fire resistant deciduous species over more combustible coniferous tree species and highly volatile wood shrubs when making decisions regarding residential landscaping.

   - Flowerbeds and rockeries were less common than on private property in Kelowna but those present were most commonly surfaced with non-combustible mulch.

Considering the above, the author strongly suspects that residents of Slave Lake have received effective information, and have accepted the advice to choose "FireSmart" vegetation and configurations when making landscaping decisions in the post-fire era[18].

7. The author has concluded that results of this study are in close agreement with many recent publications which identify weaknesses in current guidelines for managing vegetation and fuel in the WUI as chief reasons why residents fail to adopt them. Studies point to the failure of FireSmart guidelines to accommodate other values that residents attach to planted or natural vegetation surrounding their homes. For example, vegetation is viewed as being important to preserve aesthetic appeal, privacy, wildlife habitat and viewing opportunities and to provide shade, sound buffers, and other services.

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[18] Since 2011, the Province of Alberta and the Slave Lake Regional Tri-Council created following the Flat Top Wildfire Complex have undertaken an extensive array of communication initiatives to encourage wildfire risk mitigations.

Home construction and building materials

1. From study results, the author has concluded that, overall, hazard factors related to building structures account for only 17% of the total wildfire hazard in the rural and urban study sites at Slave Lake and Kelowna, a distant second place in comparison to hazards attributed to vegetation/fuel factors.

2. Compliance with FireSmart guidelines with respect to structural aspects of new homes (e.g. building materials, vents, etc.) was good to excellent, and higher than expected. While some of this strong performance is certainly due to acceptance of guidelines by residents, the author has concluded that a significant proportion of this improved performance is more likely to be an incidental benefit resulting from:

   – Home builder initiatives to increase the energy efficiency and attractiveness of new homes.

   – Consumer preferences for modern design features.

   – Availability of an increasing array of stylish, fire-resistant building materials.

   The trend towards increased use of cement fiber board and masonry combinations on exterior walls is favourable to WUI risk reduction where these options are available, and affordable.

Figure 5-4: Homeowners hold jurisdiction over most wildfire hazards.

[Photo credit: Alan Westhaver]

3. Overall, building materials (e.g. roofing, exterior siding, windows) and building features (e.g. decks, balconies, vents) contributed almost equally to wildfire hazards in the home ignition zone.

4. Recent (2006) changes to the Alberta Building Code require the installation of fire-resistant ply board beneath vinyl siding on side lot exposures (only) when adjacent homes are present. This is a significant step in combatting structure-to-structure fire spread. However, the author has concluded that this represents only a "half-measure" with regards to WUI fires, since code-compliant homes remain vulnerable to ignition on rear and front exposures from radiant, conducted and convective heat sources. In fact, the revised code spawns concern that the use of vinyl siding may be encouraged, thus leading to an overall increase in wildfire risk.

5. The author also has concluded that the hazard reduction advantages provided by structural advances in newer homes are most likely to be overwhelmed by hazards posed by volumes of combustible landscaping material.

Home ignition potential

1. Overall, the author has concluded that hazard factors associated with miscellaneous ignition sites accounted for about 15% of the total hazard, making these the third most significant category of hazards. Compliance with these guidelines varied widely, but was fair to good overall.

2. Breaking the data on ignition sites down further resulted in conclusions about the relative hazard contributions of its component hazard factors:

   – Roof cleanliness was not a significant factor in any study site, and only registered in the urban Kelowna study site (0.2%).

   – Miscellaneous combustibles and ember accumulator sites were in fair compliance, each accounting for 7% of the cumulative hazard.

3. A consistent spatial pattern of home losses was observed in the urban areas of Slave Lake and Kelowna. Specifically, the majority of home losses occurred in large, nearly continuous blocks consisting of 6 to 70 homes. Far fewer home losses occurred in small groups or as single, isolated occurrences. From this cursory examination, and knowledge that a burning home is an extremely intense long-lasting source of heat, it seems logical that wildfire hazards at an individual home were not a mutually exclusive situation. That is, the vulnerability and ignition of one home greatly affected the ignition potential of surrounding homes.

   This apparent pattern of clumped home losses gives rise to speculation that highly vulnerable homes that do ignite may act as "nuclei" or "flashpoints" to initiate zones of continuous home destruction in dense urban neighbourhoods. If this is true, it can also be concluded that there is elevated risk to

Figure 5-5: This study raises concerns about house-to-house fire spread.

[Photo credit: Alan Westhaver]

neighbourhoods where multiple homes were found to have “high” or “extreme” hazard ratings.

The FireSmart hazard assessment system

1. Performing nearly 450 FireSmart home assessments turned out to be a unique opportunity to consider strengths and weaknesses of the current hazard assessment system (Partners in Protection, 2003). Although the functionality and comprehensiveness of this quantitative system are excellent, the author has concluded that minor modifications would be beneficial to improve its operational value to community wildfire protection personnel and its educational/motivational values to WUI residents:

    – Increase the overall emphasis on embers as main sources of home ignition by incorporating a hazard factor that assesses the abundance of ember accumulator sites at the home and in PZ-1.

    – Develop criteria for rating the risk of structure-to-structure fire spread at individual homes.[19]

    – Add a “wildcard” factor to highlight seemingly minor FireSmart infractions that create sure potential for structure ignition and destruction, even at homes otherwise rated “low”.

[19] Examples of this type of hazard factor are: a robust juniper bush positioned against a basement or living room window; a household recycling station on a second-floor balcony; several tall cedars placed directly beneath the corner eaves of a home. Any of these would almost assure home destruction by wind-driven embers.

6. Recommendations

The following recommendations are offered in the interests of increasing the adoption of wildfire risk mitigations (i.e. FireSmart practices) by residents of the wildland/urban interface in the short term, and reducing wildfire losses and accelerating recovery by fire-impacted communities in the longer term.

It is recommended that:

Adoption of FireSmart practices

1. The Federal Government immediately restore momentum to the Canadian Wildland Fire Management Strategy and its working partnership with organizations and agencies dedicated to reducing wildfire losses in the wildland/urban interface. It could do this by making a strategic financial investment in a national FireSmart initiative and to operationalize programs to break the wildfire disaster cycle.

2. The Province of Alberta and the Slave Lake Regional Tri-Council continue their leading edge FireSmart communication efforts at Slave Lake in order to sustain existing high levels of understanding and FireSmart adoption among long-time residents, and to instill this knowledge and practices in newcomers. As residents turn their focus from home construction to landscaping initiatives, ongoing effort to promote FireSmart vegetation management options is critical.

3. Key government agencies (i.e. Provincial Offices of the Fire Commissioner, Public Safety Canada, provincial wildland fire management branches, provincial departments of municipal affairs, and municipal fire departments, etc.) carefully re-examine their current communication and fire prevention programs to find opportunities for increasing the effectiveness of wildfire risk reduction messages being delivered within their jurisdictions, then partner with FireSmart Canada/ Partners in Protection to implement improvements.

Figure 6-1: Agencies are challenged to increase their investment in residential WUI risk mitigation programs.

[Photo credit: Alan Westhaver]

Communications, public awareness, and community engagement

4. Municipal authorities in Kelowna are urged to kick-start renewed interest, awareness, and implementation of WUI risk mitigations at Kelowna by sponsoring a two-day "Local FireSmart Representative Workshop" in 2015-2016 and providing the necessary support to formally launch the FireSmart Canada Community Recognition Program in their city, which will lead to citizen-led FireSmart initiatives at the neighbourhood level.

5. Provincial wildland fire managers in Alberta build on the success of public communication efforts that followed the 2011 Slave Lake disaster by preparing guidebooks for WUI residents and commercial landscapers describing upgraded FireSmart vegetation/fuel treatments that also accommodate concerns for environmental, wildlife, and aesthetic values.

6. In co-operation with a willing community college or other post-secondary educational institution, a pilot FireSmart training module be prepared for incorporation into the curriculums of existing horticulture, arborist, and forest technician programs. The self-contained module will target future WUI vegetation managers with information to raise awareness about WUI fire issues and basic principles of fire behavior, and provide first-hand familiarity with upgraded FireSmart guidelines (see Recommendations #3 and #5) that mitigate wildfire risks in ways that recognize the environmental concerns and values of residents. This knowledge will change future business practices. The module should include instructional aids and a student manual.

Vegetation management, landscaping, and fuel modification

7. Partners in Protection/FireSmart Canada make it a priority to revise and augment the current FireSmart manual and recommended FireSmart guidelines for vegetation/fuel management in order to provide a range of second-generation solutions that are effective in risk reduction but also address known concerns of residents and their values regarding aesthetics, wildlife, and ecological health of WUI areas. Upgraded guidelines will resolve a critical roadblock to adopting FireSmart practices and reducing wildfire risks by incorporating lessons learned from research about human dimensions of the WUI, as well as technical and ecological advances in vegetation management.

8. Agencies responsible for FireSmart implementation and education programs quickly adopt the upgraded fuel modification guidelines (as noted in #7) in order to expand public support for fuel treatments on public land and to increase the extent of vegetation/fuel management activity by residents on private land. Integrating ecological and aesthetic considerations into existing vegetation/fuel treatments will resolve the dilemma faced by residents who feel that current guidelines clash with their personal values regarding forest vegetation, a major current barrier to implementation of wildfire risk mitigations.

9. Municipal governments, the Regional District, and corporate owners with land management responsibilities at Kelowna ensure that enclaves of hazardous natural vegetation fuel within or at the perimeter of urbanized areas are treated[20] immediately, and regularly maintained to resolve threatening wildfire situations. Two options for achieving this are possible:

   – Locally initiating the FireSmart Canada Community Recognition program which, in turn, will trigger resident-organized fuel treatments via "FireSmart Events" (see Recommendation #4).

   – Deploying agency resources to develop a series of FireSmart demonstration sites at high-visibility locations adjacent to fire-prone neighbourhoods in ways that create models for fuel modified areas that are effective, visually attractive, and ecologically appropriate.

10. Building on leading edge communications following the Slave Lake disaster, program collaborators are encouraged to initiate a new pilot program by spring 2016. The pilot should specifically target local commercial landscapers, and personnel at plant nurseries and garden supply outlets with information to raise wildfire awareness and techniques for FireSmart vegetation management and landscaping. Following a trial year, the materials should be made available across Canada.

Figure 6-2: Incorporating aesthetic and ecological values into FireSmart guidelines will accelerate adoption levels.

[Photo credit: Alan Westhaver]

[20] Until FireSmart guidelines are formally revised, it is strongly recommended that "interim guidelines" be developed to promote conservation of watershed, wildlife habitats and visual considerations in these sensitive, high profile areas, while satisfying FireSmart fuel reduction criteria.

Home construction and building materials

11. The Canadian Home Builders Association be invited to come forward with suggestions as to how their industry could become more effectively engaged in raising awareness among its membership regarding wildfire risks and risk mitigations, and implementing changes that would continue to further reduce the risk of future wildfire losses.

12. An informative pamphlet be prepared for national distribution to home builders, suppliers of home improvement products and services, municipal planners, and others in order to better inform them of the WUI problem; recommended FireSmart guidelines pertaining to building design, home features, and building materials; and suggest ways that they can make positive contributions to reducing wildfire losses and breaking the wildfire disaster cycle by helping to educate their clients.

The FireSmart hazard assessment system

13. The Partners in Protection Association address recommendations made in this report for improvements to the existing wildfire home hazard assessment system (Partners in Protection, 2003).

Research, regulations, and planning

14. Conduct further investigations aimed at revealing additional "lessons learned" from the Okanagan Mountain Provincial Park and Flat Top Complex wildfire disasters by:

    - Applying the internationally recognized principles of forensic disaster investigation as outlined by Burton (2010) to identify improved, proactive approaches to reducing or preventing future wildfire disasters and hastening recovery when they do occur (see Appendix D).

    - Systematically compiling and analysing existing information pertinent to the immediate pre- and post-fire conditions of structures, vegetation/fuel, and the surrounding urban and natural environments in and adjacent to the Kelowna and Slave Lake WUI fires; assessing these in relation to known home losses, cases of home survival, and patterns of multi-structure loss; then identifying explanations for these phenomenon and conditions that either increased or reduced losses. Results would be valuable in guiding future programs of wildfire loss reduction.

– Conducting additional social science research to assess the current knowledge and perceptions of Kelowna residents about wildfire, examine influences on their attitudes and actions toward adoption of FireSmart risk reduction measures, and comparing these results to similar social science investigations from Canada, the United States, and Australia.

– Compiling existing information and, if necessary, conducting additional investigations to better understand the phenomenon variously known as "structure-to-structure" fire spread, "urban conflagration", and "high intensity residential fire" and to investigate the theory advanced in this study that vulnerable homes in a community are potential "nuclei" that ignite and, in turn, trigger the destruction of multiple homes surrounding them.

15. Municipal planners and other managers apply increased diligence to developing block plans and community design features that maximize clearance between homes, enacting regulations that favor fire-resistant building materials and design features on all exposures, and providing regulatory or educational tools encouraging residents to utilize non-combustible vegetation when landscaping.

16. Authorities with responsibility for reviewing and revising current building and fire codes promote the use of fire resistant exterior siding options on all home exposures in the wildland/urban interface.

Figure 6-3: Maximizing lessons learned from wildfire disasters is essential to limiting future losses.

[Photo credit: Alan Westhaver]

7. Summary: Looking back, looking forward

"To what degree have communities that are rebuilding and recovering after a catastrophic wildfire adopted known principles and practices to reduce the probability of wildfire losses in the future?"

That is the thoughtful question that motivated this investigation. The method used in this study is new, but the concept of learning lessons from wildfire disasters of the past is not. The words of city founder William Fernie, as he gazed upon the smoldering ruins[21] of what had been the bustling City of Fernie, British Columbia, and home to 5,000 people just hours before, may have been prophetic:

> *"In my opinion it is because Fernie was situated in the heart of a thickly timbered area that the disaster fell upon it with such crushing fury. One of the most important things to be remembered by all interested in the building of a town is the necessity of clearing away much of the timber and underbrush close to the place."*
>
> William Fernie, City Founder (1908)

Figure 7-1: Main Street in Fernie, British Columbia, on the evening of August 01, 1908.

[Photo credit: Fernie Historical Society]

Two of the worst wildfire disasters in Canadian history occurred within a decade of each other, and thus provided the unfortunate opportunity to investigate this question. The answer is, "it depends."

The results of this investigation show that some FireSmart solutions have been widely adopted by homeowners, others only in part, and some very little or not at all. The level of adoption for known risk mitigations also varied between geographic areas, within the home ignition zone, between different categories of wildfire hazards, within categories of similar hazard factors, and with increasing time since the fires. Equally important, the study also revealed similarities in the level of adoption for some risk mitigations across study sites.

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[21] Early on August 01, 1908, a small forest fire that had been smoldering upwind of the City of Fernie in southeastern British Columbia was whipped by high winds and spread suddenly to city outskirts. In the brief span of 90 minutes all but 37 structures within the city were incinerated. The disaster caused a number of fatalities and left 5,000+ people without homes, infrastructure, or commerce.

It is possible that differences in the degree of adoption arose due to differing levels of public awareness and education about risk mitigations in the two jurisdictions but determining reasons for these differences was not part of this study, and remains a topic for speculation and further research.

Because of the very wide range of hazardous factors that contribute to wildfire risk and the complex array of mitigations recommended to reduce those risks, many conclusions regarding these factors emanate from this investigation: these include levels of FireSmart adoption; communication, awareness, and community engagement; vegetation, landscaping and fuel modification; home construction and building materials; miscellaneous ignition sites on residential properties; and the wildfire hazard assessment system itself.

Sixteen recommendations are subsequently offered to suggest future actions by responsible agencies and organizations to increase the effectiveness of wildfire risk mitigations, and the degree to which they are accepted and implemented by residents of the wildland/urban interface in the future.

Can we, will we, learn lessons from past wildland/urban disasters and break the wildfire disaster cycle?

The author doesn't know the answer to that question, but does know that all stakeholders must work together and keep trying.

Figure 7-2: Greater collaboration among fire authorities is required to increase adoption of wildfire mitigation by residents and municipalities.

[Photo credit: Alan Westhaver]

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Appendix A: Glossary of key terms[22]

Available fuel: The quantity of fuel that would be consumed if a fire were to occur under specified conditions (eg. some fuel may be too moist to burn).

Candling: When the foliage of a single tree or small clump of trees ignites from below, and flares up completely (synonymous with "torching").

Combustion: A process where oxygen is rapidly combined with another substance to produce heat and light.

Crown fuel: Well elevated combustible forest components not in direct contact with the ground (i.e. foliage, twigs, branches, cones) that are only consumed during crown fires.

Duff: Compacted layers of partially or fully decayed organic matter found below the more recent and looser litter layer, but above the mineral soil.

Drought Code (DC): A numerical rating of the average moisture content of deep, compact, organic layers. Within the Canadian Fire Weather Index, it is an indication of seasonal drought effects on forest fuels, and the amount of smoldering in deep duff layers and large logs.

Ember: A piece of flaming or smoldering material capable of acting as an ignition source, usually lofted or transported by the wind or convection heating. Synonymous with firebrand.

Extreme fire behavior: A level of fire behavior that often precludes fire suppression action. It usually involves one or more of the following characteristics: high rate of spread and frontal fire intensity, crowning, prolific spotting, presence of large fire whirls, and a well-established convection column. Fires exhibiting such phenomena often behave in an erratic, sometimes dangerous, manner.

Fine fuel: Fuel of very small diameter (e.g. less than 1cm) that dries and gains moisture in a matter of hours, is very easily ignited, and characteristically burns very rapidly (i.e. flashy) with great intensity and rates of spread. Examples include cured grass, coniferous needles, dead leaves and small twigs.

Firebrand: A piece of flaming or smoldering material capable of acting as an ignition source, usually lofted or transported by the wind or convection heating. Synonymous with ember.

Fire behavior: The manner in which fuel ignites, flame develops, fire spreads and exhibits other related phenomena as determined by the interaction of fuels, weather, and topography (i.e. fire environment).

[22] Unless otherwise cited, the majority of these definitions have been drawn from the 2003 Glossary of Forest Fire Terms published by the Canadian Interagency Forest Fire Centre.

Fire behavior triangle: An equilateral triangle representing fuel, topography and weather as the three essential influences that govern behavior of wildland fire.

Fire intensity: The rate at which heat is released from a fire. Intensity is measured in kilowatts per metre at the flame front. There is a direct relationship between flame length and fire intensity.

Fire regime: The total pattern of fires in vegetation over time, characteristic of a natural region or ecosystem including variation in the characteristics of fire frequency, fire intensity, fire severity, fire size, and the season and sources of fire ignition.

Fire severity: The depth and degree to which heat from fire penetrates downwards into the organic layers of soil. High severity fires can be persistent, are difficult to extinguish, and have significant impacts on vegetation and soils due to high root mortality and combustion of soil organic matter.

Forest overstory: Layer of tallest or dominant trees in the forest, generally mature trees.

Fuel: Any living or dead organic or manmade material located in, on, or above the ground that contributes to fire. This includes "urban" fuels (i.e. homes, businesses, and industrial structures), and their associated combustible surroundings. More technically, fuel is the physical characteristics of live and dead biomass that contribute to wildland fire.

Fuel arrangement: The horizontal and vertical distribution of all combustible materials within a particular fuel type or complex.

Fuel complex: A three-dimensional array of fuel over a given area.

Fuel load: A technical term referring to the measured dry weight or mass of fuels in a given area; usually expressed in kilograms per square metre (kg/m^2).

Fuel modification: Any manipulation or modification of fuels to reduce the likelihood of ignition or the resistance to fire control (NFPA).

Fuel treatment: Manipulation of living or dead forest fuels to diminish the likelihood of a fire starting, and to lessen the potential rate of spread and resistance to control. (Synonymous with Hazard Reduction, Hazard Abatement, Fuel Modification).

Ground fuel: All combustible fuel below the litter layer of the forest floor that normally supports smoldering or glowing combustion (i.e. rotting logs; compacted, partially decayed organic matter).

Hazard factors: 20 elements of home and surroundings assessed to determine WUI hazard level.

High-Intensity Residential Fire (HIRF): Fires involving rapid heat release and fire spread beyond the point of origin that usually involve adjacent buildings. These fires also typically include the early exposure of large amounts of combustible materials and can occur in groupings of occupied residential buildings, unoccupied residential buildings under construction, or a mix of both. (Alberta Municipal Affairs and Housing, 2007).

Interface: A shortened term for Wildland/Urban Interface.

Intermix: An area where homes or structures and wildland fuels (native vegetation) are intermingled, with no well-defined boundary.

Ladder fuel: Fuels that provide vertical continuity between surface fuels and crown fuels in a forest stand or WUI situation. Fuel ladders contribute to the vertical spread of fire leading to torching or candling, and crowning. Typical ladder fuels include dense grasses beneath overhanging conifer branches, young conifers, highly flammable shrubs like junipers, flaky bark, and tree lichens.

Mitigation: An action that limits the severity of fire hazard or risks (NFPA), and applied in a proactive, sustained manner.

Partners in Protection: A national Association of professionals dedicated to creating awareness and information programs to reduce the risk of wildfire losses in the wildland/urban interface across Canada.

Recommended FireSmart Guidelines: These are criteria established and published by Partners in Protection (2003) to mitigate individual WUI hazards related to structural, vegetation, infrastructure, and other elements of a home and its surroundings. The FireSmart guidelines are founded in standards developed by the National Fire Protection Association, supplemented by research by the Canadian Forest Service.

Spotting: A process of heat transfer resulting from firebrands (i.e. burning embers) being transported ahead of a fire by the wind, or being carried aloft in the convection column, or by a fire whirl.

Structural fuel: Fuels composed of combustible building components and man-made materials.

Surface fuel: All combustible materials located above the decomposing duff layer eg. freshly cast needles, grass and other living vegetation close to the ground, downed woody debris, low shrubs, seedlings, and stumps) that help propagate surface fire.

Wildfire: An unplanned or unwanted natural or human-caused fire.

Wildland fire behavior: The manner in which fuel ignites, flame develops, fire spreads, and exhibits other related phenomena as determined by the interaction of fuels, weather, and topography (i.e. the fire environment).

Wildland fuel: Fuels composed of vegetation from forests, grasslands, shrub lands or other natural plant communities.

Wildland/Urban Interface: The presence of structures in locations in which authorities determine that topographical features, vegetation fuel types, local weather conditions and prevailing winds result in the potential for ignition of the structures in that area from flames and firebrands of a wildland fire (NFPA).

Classic WUI definition: An area where homes or structures and wildland fuels (native vegetation) meet. At a well-defined boundary = interface; where structural and wildland fuels are intermingled = intermix.

Wildland/Urban Intermix: An area where homes or structures and wildland fuels (native vegetation) are intermingled, with no well-defined boundary. (See Intermix).

Wildland/Urban Interface fire: Fire that involves buildings and wildland fuels or vegetation simultaneously. Wildland/Urban Interface fires can ignite within a building and spread to nearby forests, or more commonly, spread from burning vegetation to engulf homes, farms or industrial developments.

WUI: Abbreviation for wildland/urban interface.

Appendix B: "Rapid" Residential Wildfire Hazard Assessment Form

Map#:

I.C.L.R. HOME RE-ASSESSMENT PROJECT

FIRESMART: RAPID RESIDENTIAL HAZARD ASSESSMENT FORM. ALW_V3 09/14/2014

Town/District: Street Name(s):

	FACTOR	CHARACTERISTICS AND POINT RATINGS					S.A.	S.A.	S.A.	S.A.	S.A.	S.A.	S.A.	S.A.
	STRUCTURE													
1	Roofing material	Metal, tile, asphalt, ULC rated shakes; non-combustible			Unrated wood shakes									
		0			30									
2	Roof cleanliness	No combustible material	Scattered material <1cm		Clogged >1cm deep									
		0	2		3									
3	Building exterior	Non-combust.	Log, heavy timber		Wood, vinyl, shakes									
		0	1		6									
4	Eaves, vents and openings	Closed; screened	Closed; not screened		Open; unscreened; debris									
		0	1		6									
5	Balcony, deck or porch	N/A; fire resistant/closed	Combustible/closed in		Combustible; not closed									
		0	2		6									
6	Window and door glazing	Tempered	Double pane		Single pane									
			Sm/med	Large	Sm/med	Large								
		0	1	2	2	4								
7	Location of combustibles	None or >10m from structure			<10m from structures									
		0			6									
8	Setback from edge of slope	Adequate			Inadequate									
		0			6									
8a	Ember accumulators*	None to few	Moderate		Abundant									
		0	5		10									
	PRIORITY ZONE 1 (0 – 10m) and PRIORITY ZONE 2 (10 – 30m)													
9	Forest Overstory	Deciduous	Mixedwood		Coniferous									
					Separated	Continuous								
	PZ-1	0	30		30	30								
	PZ-2	0	10		10	30								
10	Surface Vegetation	Lawn; non-combust.	Wild grass or shrubs		Dead/down woody									
					Scattered	Abundant								
	PZ-1	0	30		30	30								
	PZ-2	0	5		5	30								
11	Ladder Fuel	Absent	Scattered		Abundant									
	PZ-1*	0	10		20									
	PZ-2	0	5		10									
	PRIORITY ZONE 3 (30+m)													
12	Forest overstory	Deciduous	Mixedwood		Conifer									
					Separated	Continuous								
		0	15		15	30								
13	Surface Vegetation	Lawn; non-combust.	Wild grass or shrubs		Dead/down woody									
					Scattered	Abundant								
		0	5		5	15								
14	Ladder fuel	Absent	Scattered		Abundant									
		0	5		10									
15	Slope	0-10%	10-25%		>25%									
			Even	Gullied	Even	Gullied								
		0	4	5	8	10								
16	Slope position	Valley bot.m/lower	Mid-slope		Upper slope									
		0	3		5									
	Hazard Levels: LOW = 0-42 MOD = 43-58 HIGH = 59-70 EXTREME = 70+													

Appendix C: Adapted vinyl siding hazard ratings for Alberta

Recent changes to the Alberta Building Code require installation of fire-resistant ply board beneath vinyl siding on side lot exposures (only) when adjacent homes are located close by. This amendment partially reduces structural ignition potential during WUI fires.

Therefore, for the purposes of this study only, the FireSmart (Partners in Protection, 2003) wildfire hazard assessment system was adapted accordingly. This adaption recognizes this step forward, but also that the front and rear exposures of vinyl-sided homes in the WUI remain vulnerable to wildfire ignition from radiant, conducted, and convective heat sources.

The following table summarizes the allocation of hazard points for vinyl-sided homes in Alberta by this investigation.

Adapted Hazard Rating: Vinyl sided homes with ply board on side exposures	
Condition	**Rating**
Vinyl siding + any combustible shrubs/trees @ front or rear in Priority Zone-1	6
Vinyl siding + bldg. attachments[a] + combustible veg layers[b] in Priority Zone-2 @ front or rear	4
Brick/stone/stucco on lower ½ of front/rear; vinyl siding applied above; tall fuel yes	4
Vinyl siding + combustible vegetation layers @ front/rear in Priority Zone-2	3
Vinyl siding but NO combustible vegetation in Priority Zones-1 and 2 @ front or rear	2
Brick/stone/stucco on lower ½ of front/rear; vinyl siding applied above; no tall fuel	2

a Building attachments = combustible porch, steps, deck, fence, etc.
b Combust. veg layers = 2 or more fuel types present (e.g. surface, ladder, canopy fuel)

Appendix D: Background on the Forensic Disaster Investigation Technique

The Forensic Disaster Investigation technique is a recent concept developed by Dr. Ian Burton of University of Toronto, and a group of his international colleagues. It challenges persons and agencies charged with the responsibility of responding to natural disasters to look more deeply and dispassionately at the root causes of disasters, than in the past.

The goal of a Forensic Disaster Investigation case study is to ensure that when comparable events occur in the future, there will be a reduction in loss of life, fewer people will be adversely impacted, and wiser choices will be made by governments, the private sector, and civil society (Burton, 2010). Simply put, Forensic Disaster Investigations seek to maximize lessons learned from the past.

This technique is a recently developed approach for dissecting the web-like history of human actions and decisions that cause large natural disturbance events (e.g. floods, landslides, earthquakes, wildland fires) to transition into disasters (Integrated Research on Disaster Reduction, 2011). Rather than critiquing the disaster response and seeking blame or a locus of culpability, this technique seeks to identify fundamental factors contributing to the longer range build-up of conditions that enabled a disaster.

Forensic Disaster Investigations are carried out independently, at arms-length from government but with widespread input and support. The methodology of the forensic approach relies on asking a series of probing questions about disaster risk management. In turn, these are based on hypotheses regarding risk reduction, integration, clarity of responsibility, and communication, as well as in several complementary modes of analyses. These allow flaws in current disaster risk management to be identified, and give rise to opportunities for fundamental improvements.

Wildland/urban interface fire disasters are an excellent candidate for applying such an approach. Whereas wildland fire is an inevitable and essential natural process in virtually all ecosystems that surround the majority of Canadian urban developments, known risk mitigations are available to prevent them from becoming disasters.

Similar to many other types of natural hazards (Kovacs & Sandink, 2013), there is a belief that future wildfire losses can be limited by applying current and emerging knowledge.

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