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Why some homes survived: Learning from the Fort McMurray wildfire disaster

Preliminary report

By Alan Westhaver, M.Sc.

August 2016

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ICLR's mission is to reduce the loss of life and property caused by severe weather and earthquakes through the identification and support of sustained actions that improve society's capacity to adapt to, anticipate, mitigate, withstand and recover from natural disasters. ICLR is achieving its mission through the development and implementation of its programs *Open for business*, to increase the disaster resilience of small businesses, *Designed for safer living*, which increases the disaster resilience of homes, and *RSVP cities*, to increase the disaster resilience of communities.

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Alan Westhaver holds degrees in forestry and wildlife biology from the University of Montana. He applied that knowledge throughout his 34 year career with Parks Canada, 27 of them as a senior wildland fire manager. Passionate about the wildland/urban interface issue, he served on the Partners in Protection Board of Directors (1992-2012), as a past president, 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, Alan 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 across 1200+ hectares of mechanical and manual forest treatments, and was lauded for its many innovations regarding 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 wildlife and aesthetic concerns of WUI residents – and received a high degree of public support. Since retirement, Alan continues to provide services in the fields of wildland fire behavior, community wildfire protection, FireSmart training, and environmental assessment through his Fernie-based consulting company. He is the author of the 2015 ICLR study 'Risk reduction status of homes reconstructed following wildfire disasters in Canada.'

Executive summary

The wildland/urban interface disaster that struck Fort McMurray, Alberta in May 2016 destroyed more than 2,400 structures. It is the largest ever insured loss in Canada. It will alter the way that governments, communities and industry prepare for, respond to, and recover from future wildfires.

The Institute for Catastrophic Loss Reduction (ICLR) recognized the unprecedented opportunity this event held for firsthand learning towards the ultimate goal of lowering wildfire losses. With that in mind, ICLR dispatched an investigator for the purpose of examining, describing, and interpreting circumstances regarding the survival or destruction of Fort McMurray homes.

The vital question to be answered was: 'Why did some homes survive this wildland/urban interface fire with little or no damage, while others were vulnerable to ignition and destroyed?' Obtaining the answer to this question, and others arising from it, is urgent. Two similar catastrophes of escalating magnitude have occurred since 2003, and there is rising probability of more frequent infernos in the future given present trends in climate change, forest fuel accumulations, and expansion of people and development into wildlands. This unique study[1] was carried out from May 19 to 28, 2016 in urban neighbourhoods at the forested 'interface' fringes of the city, and at forested acreages nearby.

This preliminary report on the investigation has been prepared to provide a sound background on the wildland/urban interface fire problem for non-fire professionals, and to ensure that early lessons from the Fort McMurray catastrophe are expeditiously communicated and incorporated into the post-disaster dialogue. This report is intended to facilitate more fulsome deliberations among public officials regarding policy, regulations, standards, and programs affecting wildfire risk management in the wake of the Fort McMurray fire; and to provide a stronger basis for sound decision making. It is focused on providing insights into the cause of home ignition, the effectiveness of FireSmart risk mitigations in reducing vulnerability to wildfire, and on highlighting trends and conclusions emerging from the broad analyses conducted to date.

On-site visual inspections made from the perimeter of surviving and burned homes provided all the field data necessary for this investigation. Observations were collected from five distinct situations identified within impacted neighbourhoods. Systematic hazard assessments were performed on approximately eighty-five homes and their adjacent properties using recommended FireSmart® guidelines as the criteria. In addition, many other home ignition zones were assessed using less structured methods.

A brief 'backgrounder' is included at the beginning of this report. It describes key concepts and characteristics of the wildland/urban interface fire issue that make it unique from any other type of fire, theory of how homes ignite including the critical role of airborne embers, the fire disaster sequence, and criteria for assessing wildfire

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[1] Scientific and grey literatures contain many examples of well-documented wildland/urban interface disasters from the United States and Australia, but there are few regarding similar events in Canada.

[2] Recommended FireSmart® guidelines (Partners in Protection, 2003) are based on NFPA 1144 standards.

hazard at and around homes. Later sections outline preliminary results, conclusions, and other ongoing analyses and issues that will be addressed in the final report. The unconventional nature of this study resulted in unforeseen opportunities for gaining insights and understanding about home survival.

After evaluating the fire environment and clearances between homes and the forest edge, the investigator discounted direct contact from flames or radiant heat of the forest fire as being significant sources of home ignition at Fort McMurray. Instead, it was concluded that wind-driven embers were the most probable cause for the majority of early home ignitions in the zone where the fire made its transition from forest into urban neighbourhoods. Once established, the fire would have spread from structure to structure as an urban conflagration, accounting for the majority of home losses.

Some of the other early results and conclusions presented in this interim report include:

- On average, surviving homes in urban and country residential areas rated with 'Low' to 'Moderate' hazard using FireSmart® criteria, whereas homes destroyed rated 'High' to 'Extreme' hazard.
- In 89% of the side-by-side comparisons conducted (where one home survived and the other did not), the surviving home rated with substantially lower risk.
- 100% of homes/home groups that survived extreme exposure without igniting rated 'Low' hazard.
- 81% of all assessed homes that survived had a FireSmart rating of 'Low' – 'Moderate' whereas 56% of homes that were destroyed had a FireSmart rating of 'High' to 'Extreme'.
- All of the isolated homes that survived amidst heavily damaged urban neighbourhoods rated with 'Low' hazard when vegetation further than 30m from the home was discounted.
- All of the isolated homes that ignited amidst otherwise undamaged neighbourhoods were either rated with 'Extreme' hazard, or had critical weaknesses making them immediately vulnerable.

From these, and other interim results, some clear patterns and conclusions are already emerging:

- In all neighbourhoods studied, homes whose owners had adopted FireSmart guidelines survived much more frequently than homes where they had not, despite the extraordinarily harsh conditions.
- Recommended FireSmart guidelines work. They are effective in reducing the probability of home ignition and wildfire losses. Home survival does not appear to be random or a matter of luck.
- Home survival depends on conditions in the home ignition zone, for which owners are responsible.
- While low total hazard rating is important, a single critical weakness can lead to home loss.

It was also concluded that this fire fits a pattern widely recognized as the 'wildland/urban interface disaster sequence.' That sequence can be broken, and catastrophic home losses can be prevented; however this depends on widespread adoption of risk mitigations within the home ignition zone. Therefore, it is speculated that if homeowners became more aware of how homes ignite and better understood how and why simple FireSmart measures work, they may be better motivated to correct weaknesses in wildfire defences. A communication tool for raising public understanding is suggested.

The final report will drill further into the data, to determine the spatial distribution of hazard with increasing distance from homes, assess home vulnerability according to each of the rated hazard factors, further evaluate aspects of wildland fire behavior with regards to home ignitions in various neighbourhoods, and test other theories of wildfire risk mitigation.

Recommendations forthcoming in the final report will be strategic, with the goal to prevent or lessen losses from wildland fires – nationally. Therefore, they will be addressed to the broad cross-section of federal, provincial/ territorial, and municipal agencies, as well as to industries with responsibilities for public safety and emergency preparedness across Canada. Recommendations will not pertain specifically to the Fort McMurray disaster, the Regional District of Wood Buffalo, or the City of Fort McMurray.

1. Introduction

Wildland fires that spread into populated or developed areas causing catastrophic losses are called wildland/urban interface[3] fires. They have been a matter of growing concern among wildland fire managers for more than two decades, and now those concerns are stoked by the converging trends of climate change, increasing forest fuels, and expanding residential/industrial development. All reliable indications point to the probability that wildland/urban interface fires will become more frequent, and the occurrence of catastrophes of ascending magnitude in Kelowna (2003/$200 million), Slave Lake, AB (2011, $750 million), and Fort McMurray, AB (2016, $3.6 billion) would seem to bear this prediction out. Thousands more Canadian communities, small and large, continue to be at risk of wildland fires.

With the social and economic impacts of this most recent catastrophe just beginning to be realized and recovery efforts at Fort McMurray barely underway, now is the time to look at this national issue with new eyes and fresh perspectives, and to alter the ways governments, communities and industry prepare for, respond to and recover from wildfire in the future.

The Institute for Catastrophic Loss Reduction (ICLR) appreciates the urgency and importance of addressing the root causes of natural disasters. It also recognizes the unprecedented opportunity that the Fort McMurray fire holds for firsthand learning towards the goal of lowered wildfire losses in the future. With all this in mind, ICLR sought permission to investigate the scene prior to any major recovery efforts. This preliminary report is an early outcome of that investigation.

Consequently, ICLR commissioned a study to investigate the circumstances regarding ignition or survival of Fort McMurray homes. That study was carried out by the author from May 19 to 28, 2016 in urban neighbourhoods at the forested 'interface' fringe of the city, and at forested acreages nearby. While the scientific and grey literatures contain many examples of well-documented wildland/urban interface disasters from the United States and Australia, there are few such studies available from Canada.

Wildland/urban interface fires are neither a traditional forest fire scenario, nor a structural fire scenario. They are a distinct emergency, which carries challenges and dangers not known to other forms of fire. Therefore, distinct solutions matched to the problem are essential. The primary reason for the scale of loss associated with wildland/urban interface fire disasters are conditions within urban areas that allow for the ignition of structures from the flames or embers of the wildland fire. Such conditions are largely preventable, and logically it follows that wildfire losses may also be reduced.

However, success requires that well-known wildfire risk mitigations, collectively known as FireSmart®[4] be applied well in advance by at-risk stakeholders. Hence the problem takes on social and human dimensions aside from technical fire management and engineering aspects.

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[3] Wildland/urban interface: defined as the presence of structures in locations in which topographical features, vegetation fuel types, local weather conditions, and prevailing winds result in the potential for ignition of the structures within the area from flames and firebrands of a wildland fire.

[4] FireSmart' is a term developed by the non-profit Partners in Protection Association and is registered as a trademark to them. The term FireSmart means: actions to reduce wildfire losses.

1.1 Study goal and research questions

The ultimate goal of this investigation is to encourage the application of more effective approaches to wildfire risk mitigation for use by homeowners, planners, policy makers, and public safety and fire managers, based on the Fort McMurray experience. To do this required examination of factors leading to the ignition and destruction of homes during the disaster that occurred in May 2016 at Fort McMurray, Alberta. Most importantly, the study focuses on positive conditions at and around the homes that survived the wildfire with little or no damage.

The primary research question posed by the Institute for Catastrophic Loss Reduction was:

> *'Why did some homes survive this wildland/urban interface fire with little or no damage, while others were vulnerable to ignition and destroyed?'*

Subsequently, a multitude of secondary but more explicit questions about wildfire disasters and risk management arose. Collectively these questions guided the development of a methodology and field investigations at Fort McMurray.

1.2 Purpose of this preliminary report

The purposes of this report are to raise awareness of this ICLR-sponsored investigation, to provide non-fire professionals working in disciplines related to the wildland/urban interface and disaster recovery with a backgrounder to the interface fire problem, and to begin communicating early lessons from the Fort McMurray catastrophe so they may be incorporated into the post-disaster dialogue.

This report is intended to provide early indications of how well homes and home ignition zones were prepared for wildfire, the cause of home ignitions, information about general strengths in terms of fire resistance and weaknesses leading to home destruction, and important insights into the effectiveness of risk mitigations and other topics (expected or otherwise) from the study. Strong trends regarding home survival are emerging from the data analysis – even though it is incomplete at this point. This information should facilitate well-informed deliberations regarding policy, standards, regulations, processes, and practices affecting the future of wildfire risk management.

Most importantly, it is hoped that the information in this interim report will begin raising awareness and understanding among the general public, and for homeowners in particular, about the mechanisms involved in the ignition and destruction of homes during wildland/urban interface fire events – and the effectiveness of actions they can take to prevent wildfire losses and the occurrence of disasters.

Because this investigation is a work in progress, complete analysis of the data has yet to be complete. Therefore, a cautious approach has been taken by the author regarding confidence levels ascribed to initial results and the range of conclusions offered. Nevertheless, the observations and interpretations in this report regarding vulnerability and wildfire-resistance of homes at Fort McMurray are well supported by prevailing research literature and the author's experience.

The final report on the Fort McMurray investigation will provide more rigorous analysis of the data, additional conclusions, and strategic recommendations for a suggested course of action.

2. Backgrounder to the wildland/urban interface and the Fort McMurray fire

2.1 The wildland/urban interface as an emerging issue

Wildland/urban interface fires are now an issue of national concern. Losses incurred from interface disasters are following an exponential curve with the 'worst' event surpassing the previous record by a factor of five to ten times. Catastrophes at Kelowna, BC (2003), Slave Lake, AB (2011) and Fort McMurray, AB (2016) highlight the urgent need for more effective wildfire risk mitigation solutions.[5]

[Photo credit: Troy Palmer]

The increasing frequency and magnitude of wildland/urban interface losses is expected to continue due to expanding urban and industrial development into forested areas, the implications of climate change, and rising availability of forest fuels in some areas. These factors converge to produce a synergistic effect.

2.2 Wildland/urban interface fire characteristics

The wildland/urban interface is generally perceived as a location where the forest meets urban development. More technically, it is not a place but a set of conditions which permit ignition of structures from the flames or embers of a wildland fire, as at Fort McMurray in 2016.

A wildland/urban interface fire occurs when fuel being consumed by a wildland fire begins to include 'urban' fuel, as well as vegetation. Typically, they occur when fire behavior peaks due to low humidity, high wind, and very dry fuel – and fire spreads rapidly with extreme intensity.

It is critical to recognize that they are neither a forest fire nor a structural fire. Wildland/urban interface fires are a distinct type of emergency that requires unique prevention solutions to avoid catastrophic losses.

The complexities that set wildland/urban interface fires apart are as follows:

- Multiple, even hundreds, of homes may ignite within hours, or even minutes.
- The fire 'front' is moving, not stationary.
- There is little warning or time to prepare and respond.
- Human life is at risk, evacuations are ongoing, and firefighter safety concerns are heightened.

[5] In addition, there have been many 'close calls' at other population centres across Canada including Penticton, BC (2004), Salmon Arm, BC (1998), Halifax, NS (2009), Timmins, ON (2012), La Ronge, SK (2015).

2.3. How homes ignite

Structures in the interface can be ignited by burning vegetation, embers, or by other burning structures. Regardless of the heat source, ignition only occurs when sufficient heat is transferred to a vulnerable part of a structure by one or more of these processes:

- Convection: heat transfer through the air by flames or hot gases including direct flame contact.
- Radiation: heat transferred by waves moving from a hot object or flames, to another surface.
- Conduction: heat transferred within a body or between two bodies by direct contact. (WUI Working Team, 2006; Cohen, 2004).

2.3.1 Vegetation to structure ignition

Wildland fire spreads from vegetation to ignite homes directly, due to flames and radiant heat, or indirectly by embers. Only recently are the complexities of the latter mechanism being discovered.[6]

Direct ignition of structures from vegetation

Direct home ignition from heat transferred by radiation or flame contact by the forest fire itself is possible, yet uncommon. For example, 238 homes were lost during the 2003 Kelowna fire storm, but only two were ignited by direct flame contact (Dittaro, 2008). Since the amount of heat transferred to a structure is a function of distance from flames and length of exposure, reducing either of these drastically cuts potential for ignition. Meeting FireSmart fuel treatment standards in Priority Zones 1 and 2 is the best means of increasing structural survival (Walkinshaw et al., 2012; Scott and Reinhardt, 2001).

Indirect structural ignition by embers transported by wildfire

Embers are the most common cause of home ignition. During the 2002 Hayman fire (Cohen and Stratton, 2003), the Cerro Grande fire (Cohen, 2000), and the Angora fire (Safford et al., 2009) nearly equal numbers of homes ignited from firebrands as from direct exposure. At least two thirds of homes (and possibly all) ignited due to embers at the Witch/Guejito fires (Maranghides and Mell, 2009).

Ember densities are greatest within 100m of the fire front but spot fires caused by embers are common at distances of 100-500m, and possible at distances of more than five kilometres (Beverly, 2010). Embers may reach considerable size but are generally <2-3cm in diameter, and may be glowing or flaming. Individual embers are highly efficient ‘ignitors’ and are especially effective when piled by the wind.

Embers included burning cones from distant spruce trees.

[Photo credit: Alan Westhaver]

[6] Cutting edge work at ember-generating test facilities that expose homes and building material to ember showers under controlled conditions by the Insurance Institute for Business & Home Safety and the National Institute of Standards & Technology.

Figure 2-1: Spot fires in the forest, brush, and on rooftops from embers of nearby wildfires.

[Photo Credits: Bill Bereska]

[John Gibbins/U-T San Diego/ZUMA Press]

Under very dry conditions, nearly 100% of embers can ignite spot fires (Forestry Canada Fire Danger Group, 1992). Ember density ranges from fewer than a dozen to several hundred per square metre, and ember showers can last for several hours (WUI Working Team, 2006).

2.3.2 Structure-to-structure ignition

Burning homes can also ignite adjacent homes, because they burn with great intensity, duration, and release abundant embers. When separated by less than five metres, structures can become the principle ignition source for other structures (Cohen, 1995).

Knowledge about home ignition is extensive and tells us that fire spreads according to the rules of combustion, that it can be controlled, and that it is not an irresistible flowing force like lava to engulf everything in its path.

2.4 The wildland/urban interface disaster sequence

Current practice identifies a consistent pattern of events, known as the 'wildland/urban interface fire disaster sequence' (see Figure 2-2). The sequence begins with high fire danger lead and a wildland fire burning in forest, grass, or brush. The wildfire subsequently spreads to an urban area and begins to consume structural fuel, then rapidly expands to involve large numbers of homes via structure-to-structure fire spread resulting in an urban conflagration[7]. This overwhelms any possible fire response, and leads to catastrophic losses and expense.

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[7] An urban conflagration is generally considered to be a large, destructive fire that spreads beyond natural or artificial barriers in an urban environment, causing large monetary losses.

As indicated by the 'X' in panel three of Figure 2-2, the only practical means of breaking the disaster sequence is to block the spread of the wildfire to urban fuels, by making homes more fire resistant. This model has now received widespread acceptance as encapsulating the wildland/urban interface problem and its ultimate solution.

2.5 Measuring susceptibility of homes to ignition by wildfire

Susceptibility of a home to wildfire ignition is evaluated by examining a cadre of sixteen hazard factors relating to characteristics of the structure itself, vegetation, and other combustible objects surrounding the home. Factors are summed to provide an overall rating of wildfire risk to each home. The criteria for evaluating hazards are based on standards, published by the National Fire Protection Association (2013), and reflected in recommended FireSmart guidelines published by Partners in Protection (2003).

The home ignition zone (Figure 2-3) consists of the home and three concentric Priority Zones. Hazard reduction criteria are most stringent closest to the home and become more flexible as distance from the home increases. Priority Zones of one home often overlap with those of others. To reduce, or mitigate, the risk of home ignition requires that deficiencies in meeting the recommended FireSmart guidelines be addressed. Primarily, this is the responsibility of the homeowner.

Figure 2-2: The wildland/urban interface disaster sequence (Calkin et al. 2014)

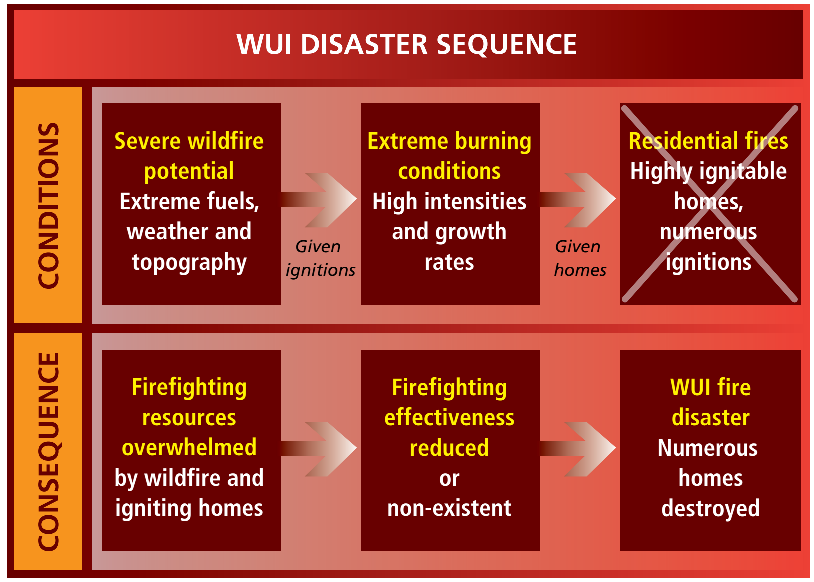
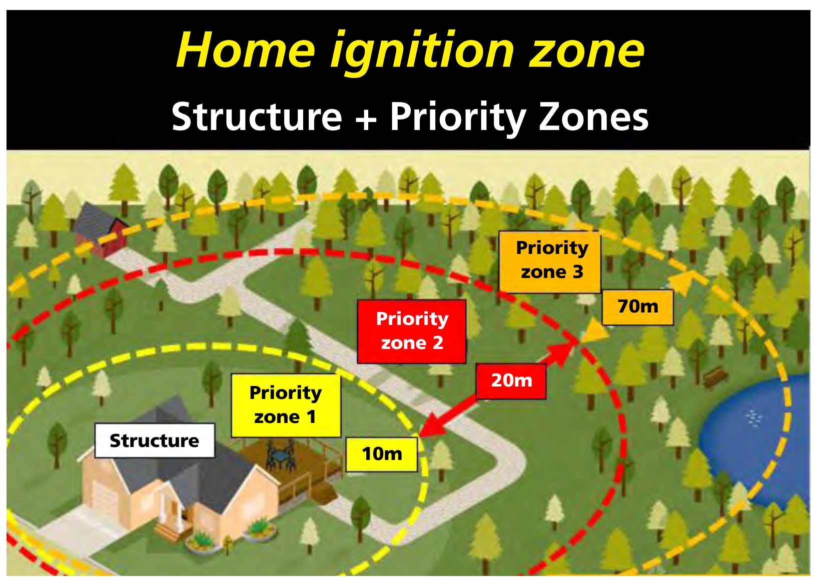


Figure 2-3: The home ignition zone



[Graphic modified with permission from NFPA Wildland Fire Operations Division]

2.6 General fire environment – Fort McMurray, Alberta

The total pattern of fire over the long term is called the fire regime. In boreal forests it is characterized by large to very large wind-driven crown fires and high intensity surface fires occurring at relatively short intervals (e.g. 25 – 100 years) at any given location. Fire activity peaks in spring prior to green-up, and again in summer as fuels dry with sustained heat. Lightning and humans are the main causes of fire.

Intense boreal forest fires typically generate towering convection columns venting gases, smoke and fragments of burning fuel (e.g. cones, bark) thousands of metres into the atmosphere. These burning particles are called embers (a.k.a. firebrands) and are able to ignite spot fires in native vegetation far in advance of the main fire. In urban settings they may also ignite other combustible objects. The 2016 wildfire at Fort McMurray was likely within the range of historical norms.

Figure 2-4: Scenes from the Fort McMurray fire

[Photo credits: Alan Westhaver]

Upper left: Home destroyed at interface between urban area and adjacent forest.
Bottom left: Ember ignition on deck resulted in a rare ‘partial loss’ of a home.
Upper right: Fire spread from home to home towards centre of community (urban conflagration).
Bottom right: FireSmart homes survived even in hard-hit Saprae Creek Estates area.

3. Methods

Being on-scene immediately following the Fort McMurray fire provided unique opportunities to observe and interpret evidence about the spread of fire surrounding homes, fire contact with the home, and eventual ignition of homes. Being able to witness where fire started and stopped, what burned or did not, and the arrangement of man-made and forest fuel allowed invaluable insights to be gained about the survival or loss of homes. Timing of field investigations was critical, and took place before the clues and signs of fire spread disappeared or were obscured by rain, wind, or recovery efforts.

3.1 Study location

The Fort McMurray wildfire disaster provided an unprecedented opportunity to learn firsthand about the survival and ignition of homes. In order to answer the questions posed by this study, it was essential to differentiate between homes destroyed by fire spreading from vegetation-to-home, versus structure-to-structure fire spread. Therefore, care was taken to avoid areas where evidence of home ignition was likely to have been influenced by the confounding effects of burning homes located nearby.

As a result, observations in urban neighbourhoods took place only in situations at or near the ‘front line’ of homes immediately adjacent to forested areas on the urban fringe, where urban areas were first affected by the wildland fire and where it began consuming ‘urban’ fuels. In some neighbourhoods, several rows of apparently fire-resistant homes survived near the forest edge, before homes further into the community began to ignite. Sampling also took place in these situations.

The majority of observations made during this study were within the heavily damaged urban neighbourhoods of Beacon Hill, Abasand, Thickwood, and Timberlea. These neighbourhoods were widely separated from each other. In addition, isolated homes on large lots amidst dense black spruce and mixedwood forests were sampled in the country residential area of Saprae Creek Estates.

3.2 Sampling strategy

Upon arrival in Fort McMurray, an initial reconnaissance was conducted. It revealed several distinct situations of home survival. These situations are referred to as ‘Study Cases’ and described as follows:

I) Study Case I: Urban neighbourhoods sustaining heavy overall losses that allowed paired comparison of adjacent homes exposed to similar ignition forces (one home survived, the other did not).

II) Study Case II: Urban neighbourhoods where individual homes, or groups of homes, received substantial exposure to ignition forces but did not ignite and only sustained minor damages.

III) Study Case III: Isolated homes that ignited and were destroyed well within the perimeter of urban neighbourhoods otherwise not impacted by the wildfire.

IV) Study Case IV: Isolated homes that survived amid urban neighbourhoods destroyed by fire.

V) Study Case V: Country residential homes located on large lots which allowed paired comparison of similar burned and unburned homes.

Other, less common circumstances also provided important perceptions about home survival and loss.


[Photo credit: Alan Westhaver]

3.3 Data Collection

Following an initial reconnaissance of damaged areas of the city and an assessment of the types of data that might be available, it was decided that a dual approach to data collection would be utilized in order to maximize the value of time spent in the field. First, formatted data forms were used to systematically record detailed information from representative home ignition zones. Second, while visiting a larger cross-section of neighbourhoods and home ignition sites within the city, less structured observational techniques were used to gather empirical data, and record it in writing and photographically.

Survival or destruction of a home during a wildfire event is best explained by its degree of resistance to ignition, and the home hazard assessment system of Partners in Protection (see section 2.5) was the optimal tool for obtaining those details. However, for this investigation, hazard assessments would need to be conducted retroactively, after the fire. This is a unique aspect of this study, and one that required improvisational investigative skills. For increased efficiency and utility, the standard assessment format was slightly modified and condensed into a one-page form. A second, two-page form describing aspects of the adjacent forest and fuels, indicators of wildland fire behavior, further characteristics of the home, observations of fire effects on vegetation and other combustibles, ember density, and visible fire pathways was developed for this study, and also completed for each home. Eighty-two home ignition zones were assessed using the resultant three-page data collection form (appended to final report only).

In some cases, supplemental information such as site diagrams was recorded in a notebook, both for homes receiving detailed assessments and for homes evaluated in lesser detail. Field observations took place from May 20 to 28, 2016 while the city was still subject to evacuation and total security lock-down.[8]

Respect for the people whose homes and property were visited during this study was the utmost consideration. Only visual observations were required; no probing or collection of material was necessary to conduct the study. Observations were made remotely by walking on built walk ways, sidewalks, and lawns external to homes, and occasionally by stepping onto a deck or patio. No homes or structures were entered.

[8] Full authorization to conduct the study was received from Incident Command at the Regional Emergency Operations Centre prior to visiting affected neighbourhoods of the city, and continual contact with on-site security personnel was maintained during observation periods.

This placed a minor, but probably insignificant, limitation on efforts to discover causes of home ignition. The Regional Municipality of Wood Buffalo on-line mapping tool featuring 'before and after' aerial photography of every home was helpful to verify and augment field interpretations regarding the pre-fire condition of structures, landscaped and natural vegetation, and prevalence of ignition sites within individual home ignition zones.

Figure 3-1: Typical Study Case sites at Fort McMurray

[Photo credits: Alan Westhaver]

Upper left SC-I: Paired comparison of surviving and burned homes.
Bottom left SC-II: Substantial exposure but no ignition.
Upper right SC-III: Isolated ignition.
Bottom right SC IV: Isolated survivor.

4. Preliminary results

Data analyses and interpretations are ongoing, and progressing from general to more specific. Results discussed here are a mere preview of the final report. They describe cursory findings with regard to general causes of home ignition, preparedness of homes and home ignition zones for wildfire, relative strengths and weaknesses in fire resistance, and the effectiveness of known risk mitigations for reducing wildfire losses. At this early stage new questions are still arising, and apparent anomalies in some of the initial results are prompting other avenues of enquiry. Interest by stakeholders has prompted other threads to be pursued, and novel questions to be explored. Meanwhile, trends and patterns in the data are obvious. Important insights and results have been generated, and are worthy of including in a preliminary report.

4.1 Radiant heat, flames and embers as the proximate cause of home ignitions

Background information on how homes ignite, as well as general information about the process of home ignition by embers is provided in section 2.3.1 of this report.

Observations of the author are that, as a rule, urban Fort McMurray neighbourhoods first impinged by the wildfire (e.g. Beacon Hill, Abasand, Wood Buffalo, Thickwood, etc.) were separated from the surrounding forest by substantial buffer areas. This buffer was made up of 'non-fuel' and 'light-fuel' zones. Non-fuel areas consisted of paved roads, gravelled shoulders, and one or more parallel sidewalks or footpaths incapable of sustaining fire. Light-fuel zones were comprised of contiguous grassy or gravelled verges, grassed or bare ditches, plus boulevards and residential lawns. In some locations the buffer was further augmented by hiking or ski trails, and un-treed park or green spaces that would support low intensity surface fire; non-threatening in terms of direct home ignition by flames or radiant heat.

Generally, the total buffer between the forest and homes was 45 – 55+ metres in width, well beyond the minimum safe clearances established by research for preventing home ignition by direct contact with flames or by radiant heat exposure, even when exposed to extremely intense crown fire burning in upper levels of the wildfire rank system (i.e. rank 5 to rank 6).

Exceptions to these circumstances were noted. For example, in limited areas without benefit of a non-fuel component to the buffer, there was evidence of low intensity, creeping surface fire spread from wild grasses and shrubs onto urban lots along pathways of combustible materials such as flower beds lined with wood mulch, un-greened lawns and wood fences, toward homes.

4.2 Overall FireSmart hazard ratings of homes that survived compared to those that did not

Data describing the overall hazard rating of homes was tabulated and assessed in two ways.

4.2.1 Analysis of pooled FireSmart hazard ratings for pairs of homes

First, when results of the side-by-side comparisons of burned and unburned homes in the urban and country residential areas (i.e. Study Cases I and V) were pooled, it provided some significant insights into home survival among the 36 homes assessed in detail.

This analysis showed that, on average, surviving homes in urban neighbourhoods rated as being at 'Low' risk of wildfire loss, and therefore qualified as being 'FireSmart'. In significant contrast, comparable adjacent homes that were destroyed by the fire rated, on average, as borderline 'High' risk.

Similarly, in country residential areas, surviving homes were assessed as rating 'Moderate' (also FireSmart), on average, whereas adjacent homes destroyed were identified as being at 'Extreme' risk. It is noteworthy that the differential in point ratings between surviving and burned homes was substantial; thereby highlighting the differences in resistance to ignition.

Overall, in 89% of these comparisons, the surviving home was assessed as being 'FireSmart', while its counterpart (destroyed in the fire) was not. The remaining 11% are potential anomalies, and invite further analysis to seek out possible explanations.

From this particular analysis it appears that compliance with recommended FireSmart guidelines results in lowered vulnerability of homes to ignition, and offers homeowners reasonable expectations for home survival. These results also appear to verify efficacy of prescribed risk mitigations (i.e. FireSmart guidelines) within home ignition zones, in both rural and urban situations.

4.2.2 Analysis of FireSmart hazard level for all homes assessed in all study cases

A second type of analysis was performed by tallying the numbers of individual homes receiving 'Low', 'Moderate', 'High', and 'Extreme' hazard ratings across all Study Cases. From this, it was possible to make inferences about home survival in different situations and varied degrees of compliance.

Study Case I: Paired comparisons in urban neighbourhoods

Tabulation by hazard level shows that 92% of paired homes in Study Case I rated as having 'Low' to 'Moderate' hazard survived the wildfire. This yields a very strong positive correlation between compliance with recommended FireSmart guidelines and survival.

Initial results pertaining to hazard levels of homes destroyed was less clear. The number of homes considered to be 'FireSmart' was about equal to the number of homes with 'High' and 'Extreme' hazard levels. This is not an expected result, and suggests that a more critical analysis of grouped and individual hazard factors be undertaken to explore possible explanations.

Study Case II: Substantial exposure but no home ignition (survived)

This Study Case involved sampling at three sites[9] where homes survived extreme exposure to very intense heat from either the adjacent wildfire or from multiple burning homes across the street. All homes were also exposed to intensive ember showers. All homes rated with very 'Low' risk and high compliance with recommended FireSmart guidelines. These results provide more evidence to corroborate the effectiveness of recommended FireSmart guidelines in reducing the risk of wildfire loss.

Study Case III: Isolated ignition of homes in otherwise undamaged neighbourhoods

Five isolated homes that ignited and burned well within neighbourhoods not subject to wildfire losses were the subject of Study Case III. Overall, these had an average hazard rating of 'Extreme'. However, this is misleading since three homes were rated as 'Low' hazard. Cursory assessment of individual hazard factors reveals a possible explanation of why homes rated 'Low' were vulnerable to ignition. That is, each of them had a critical weakness or 'Achilles' heel' that made them immediately susceptible to ember ignitions. Examples of Achilles' heels are a large volume of combustible vegetation located within one metre of a picture window or firewood piled beneath a combustible deck attached to a home.

Study Case IV: Isolated surviving homes

The two most dramatic examples of 'miracle' survivor homes found in the city were both rated with 'Low' hazard. This is as would be expected, since both homes were subject to massive forces of ignition from the adjacent forest and nearby homes. These results strongly validate FireSmart principles.

However, there is also an apparent anomaly among homes in the elite 'isolated survivor' Study Case. That is, two were rated 'High' hazard, and the other rated 'Extreme'. How and why did they survive? Peeking further into the data for these homes reveals that, if vegetation/fuel hazard in Priority Zone III (> 30m from the home) were excluded, then all three of these homes would also have been rated 'Low', or nearly so. This suggests an area for future enquiry by this study: Is vegetation beyond 30m an important consideration with regards to home survival, and what priority should it be given?

Study Case V: Paired comparisons in a country residential neighbourhood

All homes in this Study Case were located in areas of very dense, mature black spruce forest – largely untreated. Results show that four of five surviving homes rated with 'Low' or 'Moderate' hazard levels, with one home barely edging into 'High'. Observations elsewhere revealed that strong FireSmart adoption by owners of surviving homes was the rule throughout the neighbourhood.

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[9] Two other sites representing 15 additional homes are still being assessed.

To the contrary, four of five paired homes that ignited and were destroyed in Case V were rated at 'Extreme' hazard, and the other at 'High'. These homes had fire exposures similar to their surviving counterparts.

To summarize, analysis to date has identified a strong correlation between home survival and high levels of adoption of FireSmart practices. However, when hazard level data from all Study Cases was aggregated, the result was still positive, but less unanimous. That is, while 81% of the surviving homes were rated 'Low' or 'Moderate' (three-quarters rated 'Low') as might be expected, only 56% of the burned homes were rated 'High' to 'Extreme'. This was a somewhat puzzling result. This may be an artefact of improper aggregation, but bolsters the rationale for further data analyses and interpretations.

4.3 Other types of analysis to be performed

A number of additional analyses are ongoing or planned. Results will be presented in the final report. Several of these future analyses, along with the justification for each, are described below:

1. **Home survival in relation to three major hazard categories:** It is expected that breaking the overall hazard rating down into its major components (i.e. structural elements, vegetation/fuel characteristics, and ignition sites) will yield additional insights into their relative importance.

2. **Home survival in relation to vegetation/fuel characteristics by Priority Zone:** Further analysis will be done to determine how vegetation hazard was distributed horizontally and vertically within Priority Zones, as well as the relative impacts of planted versus natural vegetation, on home survival.

3. **Key results regarding individual hazard factors affecting home survival:** The final report will discuss positive attributes of standard hazard factors including roofing, exterior walls, vents, windows, deck construction, landscaping materials, ground cover, fencing styles, and storage sheds.

4. **Other factors associated with home survival:** Incidental observations regarding numerous 'other' aspects of fire resistance such as lot size, property management, pre-evacuation risk mitigation by residents, and embers in relation to wildland fire behavior will be discussed in the final report.

4.4 Future applications of the Fort McMurray data

Data gathered during this investigation could be useful to answer additional inquiries by developers, builders, municipal planners, homeowners, insurers and others. Some of these may be answered by looking only at the database, or by combining it with capabilities of a geographic information system (GIS). Examples of future applications or queries of the data are as follows:

– On average, do older homes rate at higher hazard than newer homes?
– Is there a relationship between lot size and home survival?
– What are the relationships between neighbourhood density and home survival?
– Are different types of homes or home construction styles more or less vulnerable to ignition?
– Is there a relationship between the age of wooden decks and resistance to ember scorch?

4.5 The 'fire pathways' concept as formulated at Fort McMurray

A completely unanticipated result of this investigation could be among its more important outcomes.

Conducting this study required visiting hundreds of properties to discover how fire spread and ignited homes. This required detecting and trailing telltale clues left by fire on its route from ignitor to its eventual terminus. Tracks observed at Fort McMurray were typically initiated by embers and, in total, involved dozens of combustible materials which combined into myriad sequences. In some cases, these terminated short of home ignition because fuel was exhausted or fire intensity was insufficient to ignite an adjacent object but in other cases, the trail ended in destruction of a home. Some tracks were long, complex, and switched freely between vegetation and man-made fuels, while others involved only a single object between ember and home ignition. Some persisted as smoldering fire for days, covering 20 – 30m, while others likely flashed almost instantly.

It struck the investigator that "If people could only see what I was seeing, they would better appreciate how easily fire can spread to their homes," "Wouldn't that increase their motivation to take the simple actions to prevent home loss?" and "Although fire behavior, combustion, and home ignition are complex topics, wouldn't FireSmart solutions be self-evident if all the pieces were laid out as a visual pathway before residents in various fire prevention literature and media?" That is when the concept of illustrating 'fire pathways' schematically was conceived.

Illustrated fire pathways, like the one below, would be innovative and more effective means for raising awareness and understanding of how fire spreads, how homes ignite, and where and how people can take simple actions (or make good decisions) that prevent fire from spreading to their homes. The fictitious fire pathway rendered below is a prototype that demonstrates the potential of this concept. Many other 'real-world problems' could be incorporated by adding icons and operator symbols.

These diagrams could supplement (or provide a flexible and more effective alternative to) technical explanations and justifications presently found in wildfire risk and prevention literature.

It is hoped that the concept will attract the interest required for developing it into a standardized tool for general use by educators in all types of wildfire prevention and risk reduction mediums.

Figure 4-1: Professionally rendered prototype fire pathway depicting ember ignitor to home ignition. This fictional pathway example depicts embers generated by a campfire being carried by wind and igniting dry leaves that spreads flames to nearby juniper shrubs which, in turn, are located near enough to ignite a wooden deck by radiant heat which ultimately spreads fire to a home.

[Used by permission, Alan Westhaver and Book Services]

5. Preliminary conclusions

The following conclusions each address aspects of ICLR's original question: *'Why did some homes survive this wildfire with little or no damage, while others were vulnerable to ignition and destroyed?'*

Conclusions presented in this interim report are a first approximation and pertain only to the portion of the data analysed to date. They are based on careful examination of field data and insights gained during days of field enquiry, grounded in expert opinion and review of scientific literature. Many are also corroborated by scientific models and results of experimental wildfires. They are therefore reliable but are not immune from change, and are appropriately tempered with caution.

5.1 Secondary and proximate causes of home ignitions during the Fort McMurray wildland fire

5.1.1 Direct ignition of homes by radiant heat

It is the author's opinion that, with very few exceptions, radiant heat would not likely have been sufficient to cause sustained ignition of exterior home walls due to the short duration of peak energy production as fuel at the interface burned, and clearance between burning trees and homes.

Given that, it is very unlikely that radiant heat from the forest fire would have ignited many homes (though it did, however, cause substantial damage to homes).

5.1.2 Direct ignition of homes by contact with flames of the forest fire

Cursory analysis of the fire perimeter revealed the breadth of non-fuel and light-fuel buffers located between the forest and homes would have been sufficient in almost all cases to prevent ignition of homes from direct contact with flames of the forest fire.[10]

Given that, it is the author's conclusion that very few homes would have ignited because of direct contact with flames of the forest fire.

5.1.3 Indirect ignition of homes by embers

Given the conditions, it is almost certain that homes at the forest interface would have been subject to an ember storm as the fire front approached causing embers to land and accumulate for a considerable time, and from distances of hundreds, if not thousands, of metres in advance of the fire front. Undoubtedly, ember intensity would have peaked as the fire reached the non-forested buffer.

Considering the above and other evidence gathered[11], the author has concluded that embers generated by the wildland fire were the proximate cause of home ignition among the majority (more probably the large majority) of homes that burned at the urban margins of Fort McMurray and in country residential areas.

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[10] The author observed only one possible situation where direct flame contact was the likely cause of home ignition in urban neighbourhoods and only two to three possible situations in the Saprae Creek Estates country residential area.

[11] For example, maximum ember density measured by the author was 600/M^2

These ignitions would have occurred from embers that landed on ignitable components of the home such as wooden decks or fences, or from embers that accumulated on other combustible objects near the home, such as construction materials, firewood or patio furniture, and initiated fire that spread along pathways that extended to – and ignited – the home.

Efficacy of FireSmart principles and guidelines for reducing the risk of wildfire losses

The Fort McMurray fire was an ultimate test of recommended FireSmart guidelines and principles that have been designed to reduce the risk of wildfire losses. Based on the results of this investigation, the author has concluded that FireSmart mitigations have demonstrated their effectiveness and proven to be valid under the harshest fire conditions and that they can be relied upon with confidence. The author has also concluded that recommended FireSmart guidelines functioned successfully across a wide range of urban and rural situations that occurred within the wildland/urban interface fire.

Consequently, the author concludes that the total number of homes lost at Fort McMurray would have been far fewer if there had been more widespread adoption of FireSmart risk reduction practices by homeowners, within their home ignition zones and neighbourhoods (see Section 5.6).

5.2 Home survival in relation to adoption of recommended FireSmart guidelines

Analyses of detailed assessments of home ignition zones in Fort McMurray neighbourhoods show that:

- 81% of all surviving homes assessed during the study were rated as being within the 'Low' to 'Moderate' hazard levels, three-quarters of these with 'Low' hazard.
- 89% of the time the surviving home in matched (side-by-side) pairs was rated as being 'FireSmart', while its burned counterpart was not.
- All of the isolated homes that survived amidst heavily damaged urban neighbourhoods rated with 'Low' hazard when vegetation further than 30m from the home was discounted.
- All of the isolated homes that ignited amidst otherwise undamaged neighbourhoods were either rated with 'Extreme' hazard, or had critical weaknesses making them immediately vulnerable.

Based on these correlations, the author concludes that compliance with FireSmart guidelines is the logical reason for survival of many homes in the wildland/urban interface at Fort McMurray. Stated another way, homeowners who diligently implemented recommended FireSmart guidelines greatly increased the probability that their homes would survive this wildfire event. It is also the author's observation that home survival is very rarely a random event, nor a matter of luck.

5.3 Home survival with respect to individual hazard factors and categories of hazards

The author concludes that home survival is a 'cumulative' issue whereby it relies on the net effect of compliance with multiple hazard factors that each contribute to a home's resistance to ignition by wildfire.

The author also concludes that there is no single hazard factor, or group of factors (i.e. 'silver bullet'), that can override all others to ensure home survival during a wildfire event. The corollary to this is that a single, critical (i.e. Achilles' heel) weakness can result in home destruction, even though all other FireSmart guidelines may have been adopted, and a home rated with 'Low' hazard.

5.4 The short answer to: 'Why did some homes survive ...?

Quite simply, the homes that survived were those more resistant to ignition by the embers and radiant heat of the wildfire through the actions and decisions of homeowners who had adopted FireSmart measures to a greater degree than the owners of adjacent homes that were destroyed.

5.5 Breaking the WUI fire disaster sequence, preventing urban conflagration, cutting home losses

Based on the author's observations, it is suggested that multiple homes ignited by embers of the forest fire near the forest edge became starting points, or nuclei, for structure-to-structure fire spread.

From these starting points, the fire would have continued to spread downwind, and towards the urban core, with rapidly growing force as fires merged. Massive amounts of radiant heat, flames and firebrands generated from burning homes would have combined with the existing ember train from the wildland fire to initiate an 'urban conflagration' locally dubbed 'The Beast'.

It is the author's conclusion then, that the urban conflagration very likely destroyed far more homes than were initially ignited by wildland embers. However, nearly all home losses could ultimately be traced back to embers emanating from the wildland (forest) fire. This conclusion is consistent with what is widely known and accepted as the 'wildland/urban interface disaster sequence' (Calkin et al. 2014) or, alternatively, as the 'wildfire disaster cycle' (National Wildland/Urban Interface Fire Program, 2006).

Given knowledge of the 'disaster cycle' and observations of discontinuities within the overall pattern of home destruction, locations where groups of fire resistant homes seemed to locally halt or deflect fire spread, and survival of isolated islands of homes; their should be confidence that the disaster sequence could be routinely averted in Canadian interface communities. However, this can only occur if residents and communities consistently adopt FireSmart principles, and homes at the wildland/urban interface become more resistant to ignition by embers.

When the disaster sequence is broken, it is the author's conclusion that rolling urban conflagrations would become far less likely, and that home losses will be reduced to a fraction of present levels.[12]

5.6 The concept of fire pathways as an educational tool

This study provided the investigator with a unique perspective on patterns of fire spread from initial ember strikes, across hundreds of home ignition zones, and to eventual ignition or survival of homes.

This perspective combined with extensive experience (and frustration) as a fire prevention officer/educator, leads to the conclusion that well-illustrated, visual portrayals of 'fire pathways' would become a highly effective educational technique to deepen public awareness of the ways that homes ignite during wildfire events, to enhance general understanding of how and why simple risk mitigation measures are effective, and to motivate people to take actions that will prevent tiny embers from becoming community catastrophes if they were implemented.

5.7 Other considerations associated with home survival

Aside from additional conclusions related to home survival, the final report on this investigation will yield important conclusions relevant to many other FireSmart topics and disciplines including:

- Building codes, municipal planning, and regulatory approaches to community wildfire protection
- Urban landscaping and forest management
- Effectiveness of pre-evacuation measures by residents
- The concept of the community being the fire break
- Assessment of wildland fuel and wildland fire behavior on ember abundance and effects
- Scientific research needs

Overall, these will benefit programs of community wildfire protection and wildfire loss reduction.

[12] Experience from the United States suggests 80 – 85% chance of survival for interface homes with non-combustible roofing and 10m of surrounding property treated to standard.

6. Interim recommendations

There has been a series of increasingly catastrophic wildfire events in recent years including Kelowna, BC (2003), Slave Lake, AB (2011), and now Fort McMurray (2016). Collectively, these have been addressed through a multitude of provincial reviews, expert panels, audits, national working groups, provincial task forces, fire prevention committees, and other remedial efforts. Much has changed, and improvements have been made. Yet the problem remains, and appears to be escalating.

The wildland/urban interface fire problem is large and complex. It is pan-Canadian in its geography, affects a wide array of public, private, and industry stakeholders, and involves trans-jurisdictional responsibilities. To resolve the problem will require that a well-coordinated, multi-disciplinary collaboration be sustained. To be effective and efficient, the solution must be national in its scope, as these catastrophes are not isolated 'one-off' events.

For these reasons, recommendations forthcoming in the final report of this investigation will be strategic. They will be addressed to the broad cross-section of federal, provincial/ territorial, and municipal agencies, and industries, who share responsibility for public safety, emergency preparedness, and most importantly of all, for engaging Canadian homeowners in implementation of wildfire risk mitigations on their own properties.

As such, final report recommendations will not pertain specifically to the Fort McMurray disaster, the Regional District of Wood Buffalo, or the City of Fort McMurray. Their objective will be broader: to prevent or lessen losses from wildland fires in the future.

7. Summary

Interim results and insights stemming from this investigation are already demonstrating the value of on-scene observations within the wildland/urban interface fire disaster zone. This is knowledge that could not otherwise be obtained, or applied. Benefits across the entire spectrum of stakeholders and disciplines concerned with wildfire losses are expected, owing to the foresight shown by the Institute for Catastrophic Loss Reduction by initiating this unique study.

Early benefits of this study include: increased confidence among homeowners and fire prevention specialists that existing standards for reducing wildfire risks are truly effective in preventing home ignitions; an improved understanding of the ways that fire establishes and spreads along predictable pathways within the home ignition zone – causing ignition of the home; clear documentation of the wildland/urban interface disaster sequence unfolding in a Canadian context; and the potential for making refinements to the present hazard assessment system. These, and other positive outcomes from this study will help to shape new programs for community wildfire protection, and improve existing ones, leading towards communities that are more fire resistant and resilient.

Furthermore, first-hand investigations are revealing many nuances and quirks of fire behavior, and strengths and weaknesses in wildfire preparations that were unexpected, and would otherwise go unknown. Many of these insights will eventually make their way into future training and educational programs for homeowners, builders, developers, landscapers and other relevant businesses. Data gathered in the field has potential for many applications and continued learning beyond the scope of the current project.

The final report, anticipated for fourth-quarter of 2016, is expected to cement these interim results and conclusions; to extend study results into other, more detailed, areas of analysis; and, to make strategic recommendations that aid policy and decision-makers in advancing more effective long-term solutions for resolving this urgent national problem.

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