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BRITISH COLUMBIA FireSmart™

An examination of the Lytton, British Columbia wildland-urban fire destruction

Summary Report to the British Columbia FireSmart™ Committee

Prepared by:
Jack D. Cohen, PhD., Research Physical Scientist, Missoula, MT.
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Explanation for using the term "wildland-urban"

The term "wildland-urban interface" is a geographic classification that implies a geographic determination of community wildfire destruction. However, as we will later explain, the community location – the "interface," "intermix," or other classification – does not determine structure ignition vulnerability during an extreme wildfire. "Wildland" references wildfire, and specifically extreme wildfire, as the unique source of simultaneous ignitions across wide areas of the community. "Urban" references burning structures as a principal source of community fire spread and the resulting destruction of numerous community structures where people live and do business. Thus, we use the term "wildland-urban" (WU) fire without "interface" as a more appropriate reference to how W-U fire disasters occur, assessing community ignition vulnerabilities contributing to disastrous fire destruction and importantly, how to effectively create ignition resistant communities for preventing WU fire disasters.

Acknowledgements

We thank the British Columbia, FireSmart™ Committee for sponsorship of the Lytton wildland-urban (WU) fire examination. We are particularly grateful to Ms. Kelsey Winter, BC Wildfire Service and Chair of the Committee for championing this project, making arrangements for site access and facilitating our work at every stage. We also appreciate assistance from:

- Chief and Council of Lytton First Nation (LFN) who welcomed us onto their land and into their community.
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- Officials of the Village of Lytton, the Thompson Nicola Regional District, Emergency Management BC and the British Columbia Wildfire Service for arranging access.
- Those who lived the fire and agreed to provide interviews to help us better understand the June 30th, 2021 Lytton WU fire disaster.
- Kelly Johnston of FireSmart Canada and Brenden Mercer of the First Nations Emergency Services Society (FNESS) for assistance during the field examination, and technical support and critical thinking throughout.
- Cheryl Evans, Larry Price, Dean Colthorp, Mark Ackerman and others for their review of report drafts.
- The BC FireSmart Committee acknowledges the Institute for Catastrophic Loss Reduction for ongoing support for improved understanding of community and structure vulnerability to wildfire, including this examination.

Dedication

Speaking on the nationally broadcast CBC radio show "As it Happens" in early July 2021, Councillor John Hogan of the Lytton First Nation spoke about the disaster:

> ***" We want the whole country to be able to learn from this because hotter things are coming… We have to get ourselves ready; we have to have things in place that are going to really assist communities in being able to resist wildfire threats and disasters that are going to be on a continual basis from here on in. We really want people to be cognizant, you just can't be dismissive of science and weather, and we have to really educate ourselves as best we can on how to help our climate, our environment and our fellow human beings."***

We dedicate this report in the spirit of good will, with honor and respect for First Nations people and all Lytton residents enduring impacts of the fire and now faced with recovery. Our intention is to improve the understanding of how this community ignited and burned, what contributed to these losses, and to assist with recommendations for re-building in ways that can prevent a re-occurrence. We also hope this report will assist other communities to effectively prepare for and survive inevitable future wildfires.

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Executive Summary

The British Columbia FireSmart Committee initiated this examination of the Lytton Wildland-Urban (WU) fire disaster for the purpose of:

- Understanding the relationship between the wildfire conditions and how homes and businesses ignited and burned to total destruction resulting in the Lytton WU fire disaster on June 30, 2021.
- Communicating understanding and awareness specifically related to the Lytton WU fire disaster examination revealing fundamental principles of all WU fires that can be generally applied by residents, municipal and emergency managers such that all communities can choose to become more wildfire resilient and more likely to avoid future disasters.
- Making recommendations for readily attainable ignition resistant materials and designs, and best practices for rebuilding and maintenance of fire-resistant communities at the Village of Lytton and Lytton First Nations, Klahkamich (IR 17) and Klickkumcheen (IR 18).

The Lytton WU fire disaster site examination was conducted August 10 – 14, 2021.

The Lytton Creek Fire started the afternoon of June 30, 2021 just south of the Village of Lytton. Although the wildfire burned until contained in early August at over 83,000 hectares, the Lytton community was involved in the first several hours of the first afternoon leading to the disastrous community destruction. Nearly all the totally destroyed primary structures were in the three Lytton communities of the Village of Lytton (112 homes and businesses), Klickkumcheen (IR 18, 34 homes), and Klahkamich (IR 17, 5 homes) totaling 151 totally destroyed homes and businesses.

The extreme wildfire behavior at the Lytton community was a rapidly spreading surface fire due to high wind speed, high temperature and low relative humidity in fine dead fuels of grass, light shrubs and understory pine needle litter. The wildfire remained a surface fire without producing the large flames of a crown fire. Thus, the Lytton community was not exposed to a broad scale shower of wildfire burning embers. The uncontrollable extreme wildfire behavior was from high rates of fire spread that quickly developed into four separate paths that simultaneously spread along or spread to the boundaries of all three Lytton communities in less than one-hour.

The high wildfire spread rate resulted in the near simultaneous initiation of community ignitions along the boundaries of each Lytton community. Analysis of aerial reconnaissance photos revealed more than 20 primary structures burning at 1800 hours in the Village of Lytton, IR 18 and IR 17 without the presence of wildfire activity adjacent to the Lytton community. The wildfire quickly spread, quickly consumed the fine vegetation and burned out leaving the initial burning structures to continue fire spread within the community for about two hours without further wildfire influence.

Ignition and fire spread, whether wildland or urban, only occurs as a process that meets the requirements for combustion – a sufficiency of fuel, heat and oxygen. Post-fire observations of totally destroyed structures with adjacent green vegetation indicate the requirements for structure ignitions must have been met in close proximity to the structures. Science has shown that the ignition vulnerabilities of a structure in relation to burning objects on and within 30 metres of a structure principally determine its ignitions. This relatively small area of a structure and its immediate surroundings is called the home ignition zone (HIZ) and identifies where the most effective activities must occur to prevent WU fire disasters without necessarily controlling extreme wildfires.

Wildland-urban fire disasters are a structure ignition problem and an ignition resistance approach within the HIZ is how potential structure ignition vulnerabilities (fuel) and potential burning objects (heat) within 30 metres can be eliminated or reduced to create significant ignition resistance during extreme wildfire conditions. In a community of overlapping HIZs such as the Lytton community, the collective ignition resistant HIZs create an ignition resistant community resulting in low risk of destruction during extreme wildfires.

Wildfires are inevitable and during severe conditions, extreme wildfires are inevitable. The Lytton community experienced this inevitability. However, WU fire disasters are not necessarily inevitable. We have the readily available opportunity for taking an effective alternative ignition resistant structure approach for preventing WU fire disasters. Our current emergency response approach to wildfire is failing in two significant ways: 1) it is not restoring fire as an appropriate ecological factor and paradoxically, increasing the extent of detrimental ecological severity, and 2) fire control fails during extreme wildfire behavior and structure fire protection fails when extreme wildfire encroaches ignition vulnerable communities. We have the readily available opportunity to create ignition resistant communities and not only prevent WU fire disasters, but importantly, low community risk from wildfire will facilitate an expanded restoration of more wildland fire as an appropriate ecological factor.

Key Findings

1. Wildfire conditions were extreme, not from a high intensity fire spreading through tree canopies (crown fire), but from a rapidly spreading surface fire burning through grass, forest litter and shrubs, aided by largely short distance ignition spotting from a profusion of burning embers.

2. Given the Lytton wildfire conditions of rapid fire spread along four different fronts and necessary considerations for life-safety under such conditions, it is unrealistic to expect a successful initial attack wildfire suppression response.

3. Wildfire spread to Lytton community boundaries and initiated community ignitions in less than one-hour. Wildland surface fuel outside the community had burned well before 1800 hrs. and any continued influence from wildfire had ceased. By 1800 hrs., 20 primary structures were heavily fire involved and fire spread primarily from burning structures continued within the Lytton community without wildfire influence for 1.5 to 2 hours.

4. Surface fire and short-range spot fires from burning embers initiated multiple structural ignitions, largely at the edges of the Village of Lytton, IR 18 and IR 17 within 1 hour of the reported wildfire. Within one and one-half hours of the wildfire report (by 1800) more than 20 primary structures were significantly burning, distributed along the 4 wildfire Spread Paths in the Village of Lytton, IR 18 and IR 17. The rapid, simultaneous fire involvement of this many primary structures would have overwhelmed any reasonable municipal structure protection response in that region.

5. Structure ignitions during extreme wildfires are principally determined by the local ignition conditions of the home ignition zone (HIZ); that is, a structure and its flammable attachment's ignition vulnerabilities to burning embers in relation to burning materials within 30 m.
   An extreme wildfire provides ignition hazards from flames and burning embers; HIZ ignition vulnerabilities determine structure ignitions and community fire disasters. Hence, WU fire disasters are a structure ignition problem.

6. Lofted, wind-driven burning embers – principally from burning structures – initiated ignitions across streets to adjacent blocks of ignition vulnerable structures thus continuing fire spread through the Village of Lytton and IR 18.

7. Fire spread continued through the Lytton Community was principally determined by the highly vulnerable ignition conditions within individual HIZs, and by high structure-to-structure flame spread potential due to overlapping HIZs. Density of structures in Lytton-area communities was commonly increased by placement of highly ignitable sheds, workshops and other outbuildings close to primary structures.

8. The non-flammable exterior walls remaining until structure collapse prevented flame radiation and contact sufficient for ignition at the adjacent surviving house. This indicates an opportunity to use common building materials that mitigate structure-to-structure community fire spread where there are densely overlapping HIZs.

9. The Lytton WU fire disaster, as with previous WU fire disasters, occurred during extreme wildfire conditions; however, total building destruction does not indicate a high intensity wildfire flame exposure. Most structures are unprotected due to an overwhelmed structure fire response; thus, any sustained structure ignition from burning embers or contact with low intensity surface fire results in total destruction. For individual structures and collectively communities, ignition resistance is the most effective approach for reducing community wildfire risk and preventing WU fire disasters.

Based on our examination, these findings and accepted science, we close the report with recommendations for recovery, rebuilding and maintenance of wildfire-resilient Lytton communities. These have equal application to all other communities in wildfire-prone regions of Canada, whether they are existing or planned.

Four strategic recommendations point to the need for re-framing the fundamental WU fire problem (to one of structural ignition, rather than wildfire itself); and to shifting the focal point of individual and collective community efforts onto pro-active mitigation activities which will directly reduce the ignition vulnerability and exposure of homes, businesses and critical infrastructure. These are followed by more specific categorical recommendations addressing recognized "FireSmart" disciplines (e.g., vegetation management, building criteria, regulations, infrastructure, fire response capability and planned re-introduction of wildland fire to the surrounding landscape).

Most importantly, we advocate for a collaborative, community-wide approach that actively engages residents and local/provincial emergency management personnel in a long-term partnership to raise awareness of the WU fire problem, develop a functional framework for action, and motivate effective WU fire risk reduction activities by property owners and authorities, working together within the boundaries of the re-building community.

Background

Purpose of Lytton WU fire disaster examination

The British Columbia FireSmart Committee, a broad coalition of national, provincial and municipal emergency agencies, dedicated to mitigating losses from WU[1] fires, initiated this examination of the Lytton WU fire disaster.

The purpose of this examination is to:

a) Understand the relationship between the wildfire conditions and how homes and businesses ignited and burned to total destruction resulting in the Lytton WU fire disaster on June 30, 2021.

b) Communicate understanding and awareness specifically related to the Lytton WU fire disaster examination revealing fundamental principles of all WU fires that can be generally applied by residents, municipal and emergency managers such that all communities can choose to become more wildfire resilient and more likely to avoid future disasters.

c) Make recommendations for readily attainable ignition resistant materials and designs, and best practices for rebuilding and maintenance of fire-resistant communities at the Village of Lytton and Lytton First Nations, Klahkamich (IR 17) and Klickkumcheen (IR 18).

This report is based upon intensive field observations made in Lytton August 10 – 14, 2021 by the authors with assistance from Kelly Johnston[2] and Brendan Mercer[3], and on imagery and first-hand oral reports gathered from a variety of sources.

Introduction

The Lytton wildland fire was reported on June 30, 2021 at 1638 (PDT) located south of the Village of Lytton. The wildfire rapidly spread as a surface fire primarily through fine dead vegetation to initiate structure ignitions at the periphery of the community. The Lytton wildfire burned until early August and grew to over 83,000 hectares (BC Wildfire Service); however, the wildfire affecting the Lytton community rapidly spread as a surface fire and initiated ignitions at the edges of the Lytton community within about an hour of the wildfire's ignition. Then without further wildfire influence, fire continued to spread through the Village of Lytton and Lytton First Nations, burning structures, vegetation and other flammable urban materials. The fire destruction of Lytton area communities occurred during the first afternoon of the Lytton wildfire on June 30. It resulted in 151 totally destroyed primary structures: 112 in the Village of Lytton, 34 in Klickkumcheen (IR 18), and 5 in Klahkamich (IR 17) (Fig. 1). Hereafter, we collectively refer to the Village of Lytton, Klickkumcheen (IR 18) and Klahkamich (IR 17) as the Lytton community; this was the spatial scope of this examination.

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[1] See "Terminology Noted inside front cover of report

[2] Wildland Fire Professionals

[3] First Nations Emergency Services Society, Kamloops

Figure 1: Lytton, British Columbia and the principal areas of examined community destruction.

Lytton location and community

Lytton, British Columbia (community population ~450 persons) is located about 260 km northeast of Vancouver (Fig. 1, inset). The community is situated on the east side of the steep sloped Fraser River Canyon, on a bench elevated above the confluence of the Thompson and Fraser Rivers.

Lytton, for the purposes of this report, is actually comprised of three distinct but adjacent jurisdictions. These are: the Village of Lytton with 120 primary residential and business structures, adjoining Klickkumcheen (IR 18) located immediately to the north with 35 primary structures, and Klahkamich (IR 17) upslope and about 500 m southeast across the Trans-Canada Highway 1 with 16 homes (Fig. 1). In total, about 179[4] primary structures comprised the three Lytton – area communities. The Village of Lytton and contiguous IR 18 area span a distance of approximately 1,300 m along the river. The Lytton community is positioned in one of Western Canada's busiest and most congested transportation corridors which includes the Canadian National (CNR) and Canadian Pacific Railways (CPR), the Trans-Canada Highway 1, and its junction with Highway 12.

The Village of Lytton was a mix of residential, business and public structures. IR 17 and IR 18 were primarily residential. The residential lots of all three Lytton areas typically had wood constructed homes with garages, sheds and workshops creating common separation distances of 2-5 meters between structures of all types, within and between lots. The Lytton business district along Main Street, was comprised of larger buildings, tightly spaced or sharing a common wall. The older buildings of the business district (estimated at 50+ years old) were largely wood construction. The map in Figure 1 provides street locations for later reference (Examination of community destruction section) when community fire location and progression are described.

[4] Data gathered by the First Nations Emergency Services Society

The Lytton Creek wildfire

The Lytton Creek wildfire[5] ignited on June 30 at the peak of an unprecedented provincial heat wave. Province-wide, new wildfires were occurring at a rate of 40 per day, including two other nearby "wildfires of note" (George Road, June 09; Mc Kay Creek, June 30). The Lytton wildfire spread along the boundaries of each of the three Lytton area communities and initiated structure ignitions primarily at the community edges. These resulted in continued fire spread within the community without further influence from the wildfire (Fig. 2). Here, we describe the wildfire that initiated Lytton community ignitions in terms of the topography, significant fire weather before and during the wildfire, and the vegetative fuels primarily responsible for the type and spread of wildfire. Distinctly different from wildland fuels, community fuels include all combustible materials associated with structures and human residency and are responsible for determining ignition potential and fire spread within the built environment. Community fuels are described in detail later in the report.

Topography

The Village of Lytton, IR 17 and IR 18 are located near the bottom of a steep sided canyon at the confluence of the Fraser and Thompson Rivers. The Village of Lytton and contiguous IR 18 (Fig. 1) sit on a largely level bench that gently rises from south to the north, about 60 meters above river level. At the southern extent of the Village of Lytton, a steep (60%) south-facing slope drops 35 – 40 meters in elevation to a nearly level ½-hectare drainage basin. The basin is bounded by River Drive and near the CNR tracks. The Lytton Public Works yard is also south of Lytton Village and mid-slope between the basin and homes at the southernmost edge of the community. The west side of the Village of Lytton/IR 18 bench is bounded by a steep slope extending abruptly down past the CNR tracks to the Fraser and Thompson Rivers. The east side of the Village of Lytton Village and IR 18 ascends steeply with a series of steps occupied by the CPR tracks, several homes adjacent to the Old Trans-Canada Highway and then to the Trans-Canada Highway 1. IR 17 is located on moderate slopes, east of the Village of Lytton and above Highway 1.

Weather

Lytton and its regional area experienced high pressure that persisted from April through June. This resulted in significantly above average temperatures and below average precipitation. The total precipitation for the period April through June was about 5 percent of average with June receiving a negligible 0.8 mm.

Lytton[6] daily high temperatures for the 5 days, June 25 – 29, before the fire disaster were above 40° C with the all-time Canadian record high of 49.5° C occurring on June 29. The afternoon temperature on June 30 approached that record high. The inland regional area around Lytton also experienced similar temperatures. Combined with highly dissected terrain and specifically the deep, steep slopes of the Fraser River canyon, the sunlit slopes and high temperatures produced strong slope-canyon winds channeled up the river canyon. The canyon winds develop as slopes are heated and temperatures increase becoming strongest in the later afternoon between 1600 and 2000 with relative humidity decreasing to below 15 percent. On June 30, afternoon wind speeds in Lytton were reported at about 35 km/hr with gusts of 50 km/hr and greater. These are the conditions that prevailed as the Lytton Creek wildfire ignited, grew rapidly, and led to the initiation of multiple ignitions in community fuels.

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[5] Designated K71086 by the BC Wildfire Service, final size 83,671 hectares

[6] Data from Environment Canada weather station, in Lytton

Wildfire spread and intensity

Importantly, a relatively moderate intensity but rapidly spreading surface wildfire, principally burning along the ground in dead grass, dry low shrubs and deep accumulations of leaf and needle litter, was the predominant and most notable wildfire characteristic. A surface burning wildfire caused Lytton community ignitions; not a crown fire producing an extreme intensity "wall" of flame spreading through conifer tree canopies and long range (> ½ km) ignitions from lofted burning embers.

The oblique aerial photo (Fig. 2) taken shortly after the fire shows extensive amounts of unburned (green) tree and shrub canopies in the surrounding forest areas and within the community. The unconsumed canopy foliage substantiates that a high intensity crown fire did not occur; thus, could not be responsible for the resulting total fire destruction. Conversely, our on-site examination revealed nearly 100% of the surface fuel had been consumed with pervasive evidence of an intense burning ember exposure; for comparison, visualize a winter blizzard of snow pellets but the snow pellets are burning embers instead.

Figure 2: Green tree and shrub canopy foliage within the blackened areas of surface fire and adjacent to destroyed structures within the community. The photo does not include the IR 17 residential area that is off the scene to the center-right.

We graphically estimated the four separate principal paths of wildfire spread out of a small basin near the CNR tracks south-southwest of Lytton Village (Fig. 3). Spread along the four paths was simultaneous, but the spread rates were not necessarily equal. Figure 3 notations locate the basin (B) and Spread Paths numbered 1 to 4. Numbering of the Spread Path arrows does not imply chronological order, or an intensity ranking.

Figure 3: Arrows trace the estimated eventual Spread Paths of wildfire that exposed Lytton Village, IR 18 and IR 17 to flames and burning embers that initiated community ignitions.

Spread Path descriptions:

(1) Fire spreads along the steep slope above the CNR tracks on the west side of Lytton;

(2) Fire spreads directly into the Lytton Village area south of 1 St;

(3) Fire spreads along the east side of Lytton Village on both sides of the CPR tracks and along the west side of Trans-Canada Highway 1; and

(4) Fire spreads up the steep forested slope across Main St and the CPR tracks to Highway 1 and across Highway 1 to the western edge of IR 17.

Wildfire and structure fire observation timeline

1610 – Personal observation of no observed smoke while walking south on Main St.

1638 – First recorded report of wildfire south of and toward the CNR tracks below and south of the Village of Lytton.

1649 – Personal observation at 5 St and Main apartment of smoke with ash and ember debris carried by a strong wind (Fig. 4b).

1654 – Personal observation of surface fire burning rapidly upslope towards CPR tracks, homes, Old TCH and Highway 1 at rear of Main Street buildings, opposite First Street. (Fig. 7a)

1709 – Personal observation while traveling north on Highway 1 past IR 17 that the wildfire had reached the west side of Highway 1.

1715 – Personal observation of heavy smoke originating from steep slopes between CNR tracks to rear of Fraser St. homes, and gusting to the north.

1716 – Personal observation from 5 St and Main apartment of structure fire in the vicinity of south Fraser St.

1718 – Personal observation while traveling south on Highway 1 past IR 17 that fire had crossed the highway and burning on the western side of IR 17 (Fig. 8a).

1720 – Personal observation of fire in IR 18

1830 – Personal observation across from the Post Office while leaving the Village of Lytton that spot ignitions of structures had occurred north of 6 St between Main and Fraser (Fig. 14).

Wildfire spread narrative

The following wildfire spread narrative is based on the observed wildfire timeline, the authors' on-site examination of the burn pattern and ember debris, evidence of weather/fuel conditions and aerial photos of the wildfire areas burned (Figs. 2 and 3). Computed wildfire rates of spread were used for comparison with observed wildfire locations.

The wildfire was likely burning in the basin, above the CN tracks when first reported. It spread across the discontinuous patchwork of bare soil and dead surface fuels in the basin (**B** in Fig. 3; Fig. 2, 4a), burning all of the available surface vegetation. Fuel discontinuities likely hindered wildfire spread within the basin (Fig. 4b); however, high temperature, low relative humidity, and southerly winds increased the likelihood of short-range spot ignitions by burning wind-driven embers propelled across gaps. Steep bluffs bordering the basin to the south (upwind) would have generated gusty, swirling wind characteristics enabling spot ignitions across fuel discontinuities within the basin. Given the observation of fire spreading along Spread Path 3 east of Main and 2 St at 1654 hrs (Fig. 7a), we estimate the wildfire spread within the basin (**B** in Fig. 3) took 10 to 12 minutes before reaching the top of the basin and spreading along the four Spread Paths.

Spreading out of the basin (**B** in Fig. 3), the wildfire had more continuous dead grass and heavier accumulations of litter surface fuels on the northwest, north and northeast steep slopes (40 to 60 percent) of the basin. Beyond the basin, wildfire spread would have been more rapid, enabled by more continuous surface fuels resulting in Spread Paths 1, 2 and 3 (Fig. 3) dominated by dead grass and increased exposure to strong south winds (Figs. 5, 6 and 7a and b).

Surface wildfire spreading east along Spread Path 4 primarily spread through a continuous surface layer of loose Ponderosa pine needle and twig litter until reaching Highway 1. Fire spread would have been largely dominated by steep slopes (30 to 60 percent) as the forest canopy and terrain shielded the understory from strong winds. Path 4 fire spread was exposed to strong winds upon reaching Highway 1 and likely spotted across into grass on the west side of IR 17. All of the wildfire Spread Paths would have been characterized by a ground blizzard of flaming and glowing embers that generated numerous spot ignitions in advance of the fire front, and able to stream across fuel gaps such as roads and a railroad bed.

Figure 4: a) Discontinuous burned patches in the basin (B in Fig. 3) with the steep bluff in upper center of photo (left); b) Smoke rising from vicinity of the basin (B) at 1649 hours, as viewed from Main and 5 St. (Zoey Shamley)

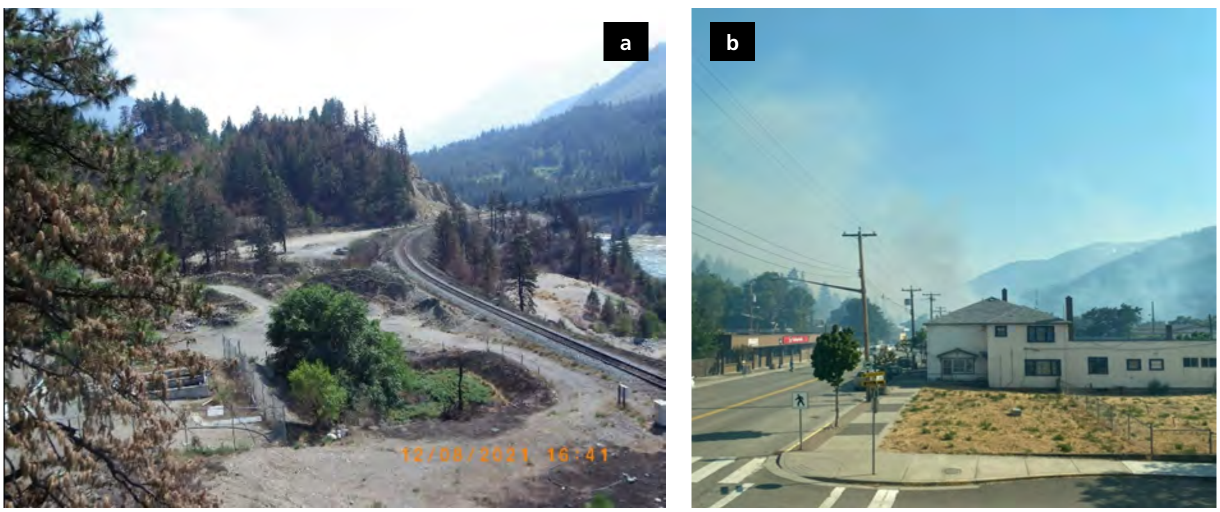
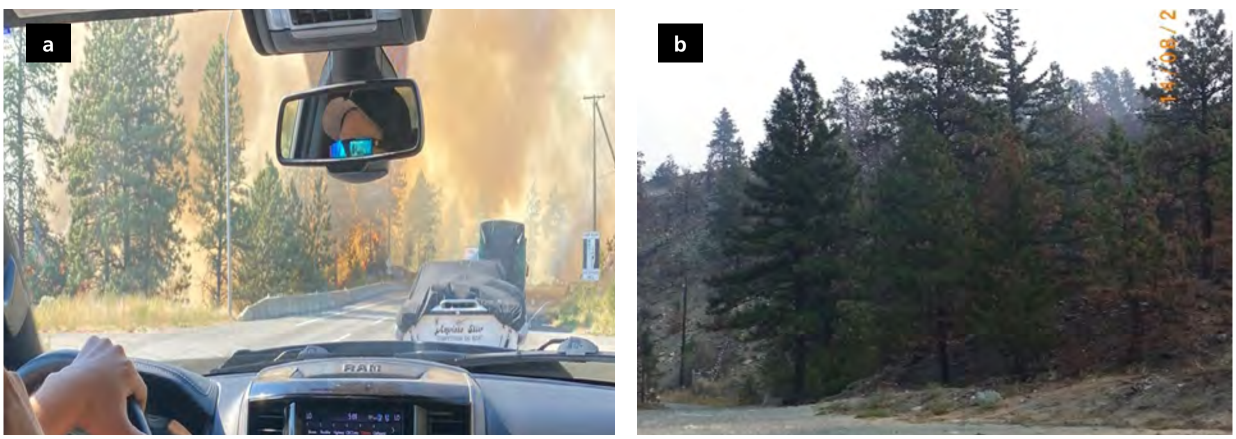


Figure 5: Spread Path 1 on the west side of the Village of Lytton and extending to IR 18.

Figure 6: Spread Path 2 at the top of the basin leading into the Village of Lytton.

Figure 7: a) Along Spread Path 3, east of Main & Second St., the Village of Lytton, burning at 1654 hrs. (Zoey Shamley); b) Post-burn view of Spread Path 3 on the east side of the Village of Lytton extending up to IR 17.

Figure 8: a) Wildfire along Spread Path 4 reaching Highway 1 below IR 17 at 1709 hrs. (Zoey Shamley); b) Post-burn view of Spread Path 4 leaving the basin to the east toward IR 17.



Computed wildfire spread rates were applied to the Spread Paths (1, 2, 3 and 4) after the wildfire burned out of the basin. The computed fire spread rates confirmed the likelihood of wildfire rapidly spreading to encroach the boundaries of the Village of Lytton, IR 18 and the west side of IR 17. The "Wildfire observation timeline" above indicates wildfire had spread to and along the Lytton community boundaries within about 40 minutes from the reported time of fire (1638). Using the Canadian and U.S. fire behavior systems and guidance from the fire behavior that occurred, wildfire rates of spread were computed for continuous short grass (Spread Paths 1, 2 and 3), and typical understory surface litter of a long-needle pine forest (Spread Paths 4).

Canadian and U.S. equivalent fine fuel moisture inputs (FFMC – 96.4 and about two-percent moisture content) were used for all fine fuels. A constant 40 km/hr wind speed and zero slope was used for short grass fuels (Paths 1, 2 and 3). Calm wind (pine canopy sheltered, 0 km/hr wind speed) and 50 percent slope were used for understory pine litter (Path 4). The computed spread rate for Spread Paths 1, 2 and 3 ranged from 150 m/minute to 230 m/minute; the computed spread rate for Spread Paths 4 ranged from 20 m/minute to 40 m/minute. Using the lowest computed spread rate, fire spread spanning Spread Path 1 (1,300 m) and similarly for Spread Path 3 would have taken less than 9 minutes. Fire spread along Spread Path 2 (150 m) to the Village of Lytton, south would have occurred within one minute and along Spread Path 4 to IR 17 would have taken less than 30 minutes.

Key Finding (1): Wildfire conditions were extreme, not from a high intensity fire spreading through tree canopies (crown fire), but from a rapidly spreading surface fire burning through grass, forest litter and shrubs, aided by largely short distance ignition spotting from a profusion of burning embers.

Key Finding (2): Given the Lytton wildfire conditions of rapid fire spread along four different fronts and necessary considerations for life-safety under such conditions, it is unrealistic to expect a successful initial attack wildfire suppression response.

Examination of community destruction

The examination of the home destruction started on August 11, five weeks after the Lytton community destruction occurred. Typical of post-fire examinations, the total destruction of structures had eliminated most evidence of ignition vulnerabilities and where and how many ignitions led to the fire destruction. Although there was minimal disturbance to most totally destroyed building sites (i.e., within 0 – 30 m. from structures), details of conditions contributing to structure ignition potential were also severely diminished. For example, vegetation and structure conditions at the time of the fire were not evident at the time of examination thus limiting our ability to reliably evaluate fire exposures and ignition vulnerabilities. As is common in post WU fire examinations, no attempt was made to assign specific causes of structure ignition; however, we categorically determined whether structures could have ignited from high intensity wildfire or must have ignited from burning objects near the structure and/or directly from burning embers. The significant benefits of images in Figures 2, 4a, 6, 7b, and 8a, b is to highlight post-fire unconsumed, and still green vegetation leading to and adjacent to totally destroyed structures.

Aerial photo time sequence, general analysis of fire spread in the community

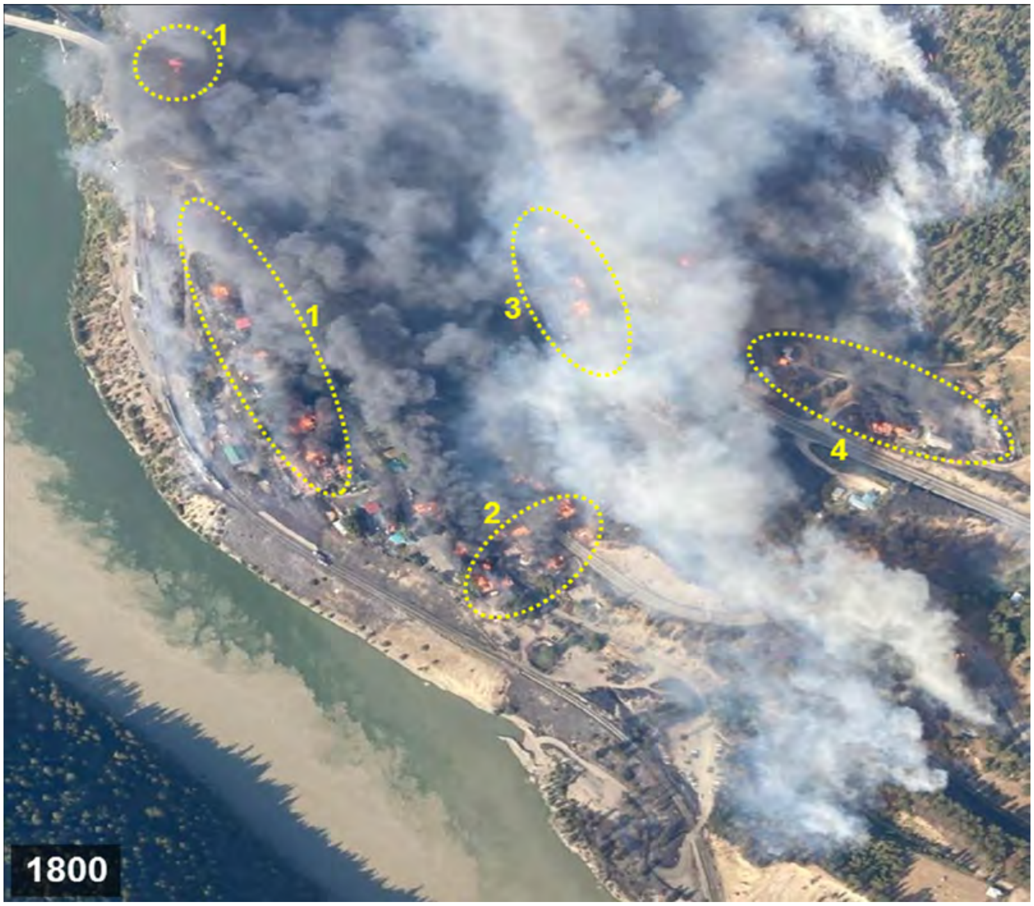
The following 3 aerial photos[7] reveal disconnected areas of structures burning in the Village of Lytton, IR 18 and IR 17. The photos span 29 minutes beginning at 1800 (82 minutes after the fire was reported) and thus continue the timeline of wildfire observations presented above.

The following aerial photos and analysis provide details that reveal:

- There is no wildfire burning adjacent to or toward the Lytton community at 1800 hrs; community fire spread and burning to total destruction is continuing without a wildfire influence;
- The burning structures are adjacent to or downwind from the wildfire Spread Paths identified in Figure 3;
- The ignition and burning of community structures has not occurred in a contiguous, "line" fire spread pattern through the community;
- Over 20 heavily fire involved structures are burning in the initial 1800 hrs photo;
- Structure-to-structure ignitions are occurring from the initially ignited sheds, homes and businesses;
- The elapsed time between home burning, to fully involved, to collapse into smoldering debris is an hour or less.
- Highly tilted smoke columns from burning structures indicate strong south winds influencing potential structure-to-structure flame exposure and short-range, downwind deposition of burning embers from burning structures.

[7] Taken by responding BC Wildfire Service air attack officers

Figure 9: Aerial photo at time 1800 hrs. (BC Wildfire Service photo)



1800 photo

Less than 1.5 hours after the Lytton Fire was reported (1638 hrs), the community in this scene is burning without any active wildfire adjacent to the community. Blackened areas on the perimeter show where the wildfire has burned adjacent to the community; it has since burned out and is no longer smoking after consuming the fine fuels. As well, there is no evidence of high intensity crown fire in the green-canopied forest surrounding the community.

Burning structures (Fig. 9, numbered yellow dash ovals) are associated with the previously discussed wildfire Spread Paths 1 – 4 (Fig. 3). The spacing and similar degree of structure fire involvement spanning Path 1 (1 oval) supports an assumption of near simultaneous structure ignitions due to the rapid fire spread.

Burning structures along the Lytton community perimeter indicates the surface wildfire-initiated ignitions of flammable materials on private property that spread to then ignite structures. Ignitions have been initiated in IR 18 and a fully involved structure is burning (Fig.9, upper left 1 oval). Smoke is likely obscuring other structures that may be burning in IR 18. Ignitions of structures and nearby urban fuels initiated by Spread Path 2 have resulted in community fire spread with structures burning in the southern part of the Village of Lytton (2 oval). Similarly, Spread Path 3 initiated home ignitions along the old Trans-Canada Highway and has resulted in several homes burning (3 oval). Homes and sheds are burning in IR 17 initiated from Spread Path 4 (4 oval). Over 20 primary structures are burning.

Figure 10: Aerial photo at time 1813 hrs. (BC Wildfire Service photo)

1813 Photo

Thirteen minutes later most of the structures south of 1 St are completing consumption (**A** oval). Just to the west, structures between Fraser St and River Dr continue to burn vigorously. Although smoke obscured, the Village of Lytton north of 2 St between Fraser and Main St (**B** oval) does not show significant fire involvement. However, the contiguous fire involvement west of Fraser St and east of Main St north of 2 is becoming increasingly fire involved indicating structure-to-structure fire spread (**C** ovals). For example, the buildings of and around the Totem Motel on the west side of Fraser St between 2 and 3 St have become more involved, and just north of there, the Catholic Church and the front of the pool building and Chamber of Commerce appear to be burning.
The homes burning along Spread Path 3 (Fig. 3) are now in the final stage of consumption (**D** oval).

Figure 11: Aerial photo at time 1829 hrs. (BC Wildfire Service photo)

1829 photo

In the 16 minutes since the last scene, all the structures on the south side of 2 St from the west side of Fraser St to the east side of Main St are burning (**a** oval). Most of the structures burning south of there have largely been consumed. Structures on the west side of Fraser St continue to burn (**b** oval). Compared to Figure 10, it appears the Totem Motel structures have largely been consumed with the Catholic Church in the last stages of consumption (southern portion of b oval). Fire has advanced north on the east side of Main at 3 St (**c** oval). The Village of Lytton north of 2 St between Fraser St and Main St has yet to start significantly burning (**d** oval). A structure on the east side of Station St and 7 St is fully involved (**e** oval). Although obscured by smoke and not evident in the above Figure 11, the original photo reveals "glows" of flame indicating a number of involved structures in IR 18 (**f** oval).

Figure 12: South Lytton Village at 1800h, 1813h, and 1829h. Photos are referenced to one another by a yellow x on two different buildings with turquoise-colored roofs. Yellow arrow locates the surviving home of interest.

Residences and businesses, the Village of Lytton

Specific time sequence analysis, burning structures in the south Village of Lytton

1800 – The yellow arrow identifies the house that did not burn. The neighboring house to the south is burning; the house on the north side (red roof) is not. Across Fraser St. from the surviving house is a structure becoming fully fire involved.

1813 – The house burning south of the survivor house is not showing significant flame indicating it has largely been consumed. There is no indication of fire protection at either 1800 or at 1813. The house to the north of the survivor has yet to exhibit signs of ignition. The structures directly across Fraser St from the survivor show an increase in intense fire involvement.

1829 – The structures directly across Fraser St from the survivor home have been consumed. Now the adjacent house to the north is significantly involved, despite not showing involvement at 1813.

Specific time sequence analysis, burning homes in IR 17

Closer analysis of burning homes in IR 17 provides more detail of how the homes ignited and burned than is apparent from a post-fire examination. The ignitions in IR 17 resulted from Spread Path 4 (Fig. 3), to the east and above the Trans-Canada Highway. Specifically, a "ground blizzard" of burning embers streaming across Highway 1 ignited surface fires, largely in dead grass, along the western edge of IR 17. Surface fire and ember deposition in cured grass and leaf litter most likely initiated ignitions on residential property that spread in vegetation, sheds and debris to ignite the five destroyed homes.

Figure 13: Time progression of 5 destroyed houses in IR 17. Each photo references the houses with yellow letters a – e.

Residences IR 17

1800 – Each of the five residential lots, **a** – **e**, have structures burning but only 3 homes are involved at 1800. The two homes not yet involved, **b** and **e**, both have sheds burning. The burning house, **d**, is fully involved suggesting it was the first to have significant structure flame spread. The house next door to the south, **c**, is heavily involved on the side adjacent to the burning house suggesting a structure-to-structure thermal influence. House a is smoking but does not show significant exterior flaming.

1813 – The initial burning home, **d**, has collapsed to a burning debris pile and the adjacent house to the south, **c**, is now heavily involved. The house, **a**, that had been smoking at 1800 is now fully involved. The house to the north, **e**, with the shed burning, is now fully involved. The other house, **b**, with a burning shed does not show signs of significant fire involvement.

1829 – The burning homes **a**, **c**, **d** and **e**, are largely consumed. Notably, house **a**, was only smoking at 1800, fully involved at 1813 and at 1829, shows little flame indicating near consumption in roughly 30 minutes. Similarly, the isolated house e, was not showing involvement at 1800, fully involved at 1813 and is in the last stage of consumption at 1829. Structures **d** and **c** appear to have burned the longest. House **b** shows no appearance of ignition; however, it burned to total destruction after 1829.

Structure ignitions in the north Village of Lytton

The following photo (Fig. 14), taken in a northwesterly direction at 1830 hrs, shows the Post Office (left) and two homes (right) that have ignited and are beginning to burn. Contiguous fire spread could not occur due to fuel gaps from streets and discontinuous fuels commonly between structures; thus, burning embers became the primary ignition source. This produced the structure "spot fire" ignition pattern of structures downwind of other burning structures. Except for the Post Office, all the primary structures bounded by Main and Fraser St, and 6 and 7 St were totally destroyed from ember-initiated ignitions.

Figure 14: Structure ignitions from burning embers in the Village of Lytton, at Main St and 6 at 1830 hrs. Smoke obscured this area in the 1829 hrs photo (Fig. 11) preventing a photo determination of the initial burning in the north Village of Lytton that is provided by this photo.

Examination overview

Aerial photo analysis confirmed the wildfire had primarily spread in surface fine fuels along with short-range spotting from burning embers. The wildfire spread along four different Spread Paths initiating community ignitions at the perimeter of the Lytton community. The photo analysis in conjunction with first-hand observations of the fire timeline indicated rapid wildfire spread resulting in near simultaneous ignitions of multiple structures. The 1800 hrs. aerial photo (Fig. 9) reveals more than 20 burning structures in a similar stage of significant fire involvement after a wildfire influence. The absence of destroyed structures at 1800 hrs and the progression of fire involvement and destruction in the two following aerial photos, indicate the burning structures at 1800 were the first to ignite from wildfire.

The burning Lytton community independently continued the spread of fire, leading to its own total destruction in about 2 hours after the wildfire had ceased burning at the community perimeter. Similar to previous examinations of WU fire disasters (Cohen 2000; Cohen 2003; Cohen and Stratton 2003; Cohen and Stratton 2008; Graham et al. 2012; Cohen 2016), the total destruction of a structure occurred within about an hour after the beginning of the structure's significant fire involvement. From the stage of burning at 1800 hrs (fig. 9), we estimate the burning structures at 1800 hrs had been significantly fire involved for 20 to 30 minutes. Thus, most of the significant structure burning would have started at 1730 to 1740 hrs. This is supported by a personal observation at 1716 hrs indicating a burning structure at the southern extent of Fraser St on Spread Path 2. The simultaneous burning of more than 20 dispersed primary structures in the Village of Lytton, IR 18 and IR 17 in little more than one-hour after the reported discovery (1638 hrs) would have overwhelmed any realistically available structure protection (see Fig. 22, WU Fire Disaster Sequence).

The previous wildfire time line discussion determined the wildfire, spreading at Lytton community boundaries, initiated ignitions in urban fuels along the community edge (but not necessarily structures directly) within about 40 minutes (1638 – 1720 hrs). The Figure 11 and 14 photos indicate that by 1930 hrs, most structures in the Village of Lytton, IR 18, and the 5 homes in IR 17 had either been totally destroyed or were significantly burning. The Lytton community supported continued fire spread for about 2 hours without further wildfire influence.

Given total destruction, we could not specifically determine particular vulnerabilities or how structures ignited from our site examination. The following section, "How structures ignite" will show how flammable materials leading to, or on, ignition vulnerable structures would have contributed to their ignition during the Lytton community WU fire.

Key Finding (3): Wildfire burning in light surface fuel and short-range spot fires from wildfire embers initiated multiple structural ignitions, largely at the edges of the Village of Lytton, IR 18 and IR 17 within 1 hour of the reported wildfire. Within one and one-half hours of the wildfire report (by 1800) more than 20 primary structures were significantly burning, distributed along the 4 wildfire Spread Paths in the Village of Lytton, IR 18 and IR 17. The rapid, simultaneous fire involvement of this many primary structures would have overwhelmed any reasonable municipal structure protection response in that region.

Key Finding (4): Wildfire spread to Lytton community boundaries and initiated community ignitions in less than one-hour. Wildland surface fuel outside the community had burned well before 1800 hrs and any continued influence from wildfire had ceased. By 1800 hrs, 20 dispersed primary structures were heavily fire involved and fire continued to spread primarily from one burning structure to another within the Lytton community without wildfire influence for another 1.5 to 2 hours.

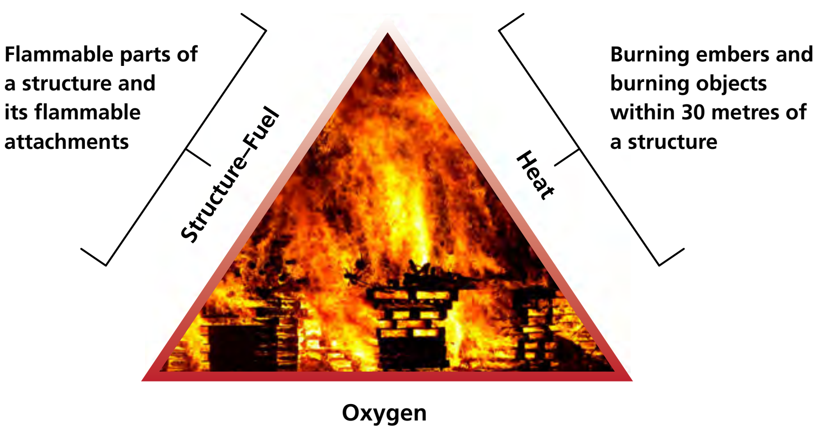
How structures ignite

The science of structure ignition during extreme wildfires

Fire, whether wildland or urban, is determined by meeting the requirements for combustion at the fuel location. Thus, fire is a process, not a thing that moves from location to location. During WU fires, structures ignite and burn when the requirements for combustion – sufficient fuel, heat and oxygen – are sustained at one or more places on a structure. We know this as the "fire triangle." However, in the case of WU fire (Fig. 15), the structure is the "fuel" and burning embers on the structure and all things burning adjacent to the structure (including other structures) are the "heat." Oxygen is always sufficient in this context.

Figure 15: The fire triangle for WU fire designates structures as the "fuel," and burning embers on the structure and burning materials immediately surrounding the structure as "heat."

Requirements for ignition within the Home/structure Ignition Zone



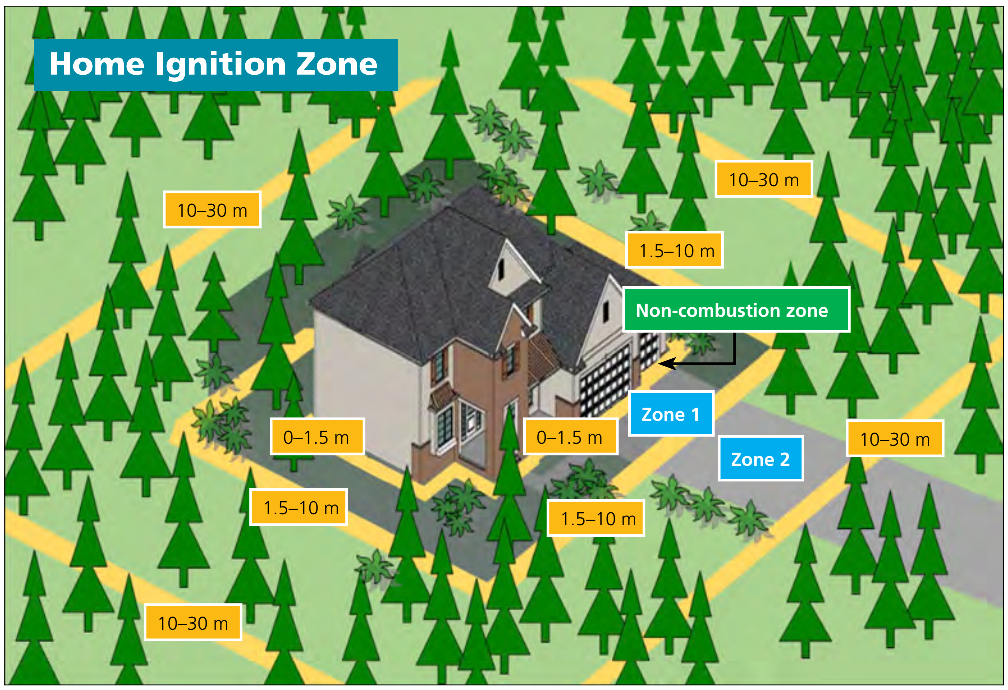
Following from fire as a process and structures being the fuel during WU fire, we define community fire destruction during extreme wildfires in terms of the requirements for combustion:

> ***Wildland-Urban fire occurs when the wildfire spreads from wildland fuels (Wildland) to community fuels (Urban); that is, the homes, businesses, vegetation, vehicles and any other flammable objects within the built environment. For this to occur the wildfire must be close enough for its lofted burning embers and/or flames (sufficient heat) to ignite community fuels leading to burning structures (sufficient fuel).***

Available science (Cohen 2000; Cohen 2003; Cohen and Stratton 2003; Cohen 2004; Cohen and Stratton 2008; Cohen 2010; Graham et al. 2012; Cohen 2016; Westhaver 2017) shows how local conditions at a structure determine its ignition during extreme wildfires. That is, given an exposure to burning embers or flames, a structure's ignition characteristics (vulnerabilities) in relation to burning materials (heat exposure) in its immediate surroundings principally determine structure ignitions during extreme wildfire. Importantly, science has shown the large flames of high intensity crown fire (and thus lesser intensities) are not sufficient to ignite a structure's wood wall beyond 30 metres.

This knowledge resulted in a foundational concept of wildfire loss mitigation, known as the *Home/structure Ignition Zone* (HIZ, Fig. 16). The HIZ encompasses a home/structure in relation to three surrounding zones of influence. Collectively, conditions within the HIZ principally determine the potential for a home, or any structure, to ignite during extreme wildfires. The HIZ incorporates all aspects of structure design and materials, as well as all potential sources of ignition exposure from embers and burning materials (vegetation, other structures and objects, and debris).

Figure 16: The Home Ignition Zone (HIZ)



The example HIZ in Figure 16 does not overlap with other HIZs, but in reality it is very common for neighboring homes and other structures to share common HIZ space. Such overlaps do not change how structures ignite but do change the social dynamics, requiring shared responsibility for creating ignition-resistant homes, businesses, and collectively, communities.

Thus, structure ignitions from flames occur from fires burning within the HIZ; that is, within 30 metres of a structure/home and its flammable attachments. Fires within the HIZ either spread into the HIZ from outside, or burning embers ignite flammable materials within the HIZ. Importantly, structure ignitions from burning embers, whether from wildfire or the burning community, require the burning embers to contact and accumulate on flammable structure surfaces before ignitions can occur. Extreme wildfires may initiate ignitions within HIZs, but the ignition conditions of HIZs, and collectively the community, principally determine the development of a WU fire disaster.

Wildland-Urban fire spread is commonly sustained by the burning community, principally structures as well as vegetation and other materials. Previous WU fire disaster examinations (Cohen 2000; Cohen and Stratton 2003; Cohen and Stratton 2008; Graham et al. 2012; Calkin et al. 2014) determined that fire spread within a community, particularly communities with overlapping HIZs, occurred hours after the wildfire ceased significant burning near the community. Hence, disastrous community fire destruction during extreme wildfires is a structure ignition problem not a wildfire control problem.

Key Finding (5): Structure ignitions during extreme wildfires are principally determined by the local ignition conditions of the home ignition zone (HIZ); that is, a structure and its flammable attachment's ignition vulnerabilities to burning embers in relation to burning materials within 30 m. An extreme wildfire provides ignition hazards from flames and burning embers; HIZ ignition vulnerabilities determine structure ignitions and community fire disasters. Hence, WU fire disasters are a structure ignition problem.

Examples illustrating how HIZs determine ignitions

Figure 17: Post-fire Lytton Village scene between 1 and 3 Streets on July 12. The yellow X identifies the surviving house identified by a yellow arrow in Figure 14 (First Nations Emergency Services Society of BC).

Figures 9 – 11 above generally revealed the Village of Lytton structure fire involvement and progression during the brief period from 1800 to 1829 hrs. Closer examination of events within shared HIZs and between HIZs reveals more about the evolving disaster.

This post-fire view of a southern area of the Village of Lytton shows the overlapping HIZs typical of the community (Fig. 17). With the exception of the small lower left area identified as Spread Path 1, this scene had no wildland fuel. Surface fire in short, dry turf grass within the HIZs was likely initiated by embers and continuous low intensity surface fire from wildfire behind the two houses (dark area burn marks at lower left) south of the surviving house (yellow X). The house south of the surviving house (dashed yellow rectangle, Fig. 17) was burning at 1800 and largely consumed by 1813 (Figs. 9 and 10).

Here, with the context of burning structures on both sides, we specifically examine a house on the west side of Fraser St just north of 1 St (identified with the yellow X) that survived the Lytton Fire without apparent evidence of protection.

The house north of the surviving house (dashed yellow rectangle) was not burning at 1813 and significantly involved at 1829 (Fig. 11). There are no dark burn marks from surface fire within 5 metres of the surviving house unlike the adjacent houses that did burn. Science tells us the requirements for sustained ignition were determined by ignition conditions immediately adjacent to the two burned houses (Cohen 2000; Cohen 2003; Finney and Cohen 2003; Cohen and Stratton 2003; Cohen 2004; Cohen and Stratton 2008; Cohen 2010; Calkin et al. 2014; Cohen 2016). Although likely exposed to embers and radiant heat, the surviving house clearly did not meet the requirements for sustained ignition; further details are discussed with Figures 19a, b below. The thermal exposure to the surviving house from burning structures directly east across Fraser St (yellow coarse dashed rectangle) did not produce a sufficient ignition exposure. Expanding our view to the north reveals totally destroyed structures that ignited and burned well after local wildfire activity ceased. These structures ignited from the embers lofted across streets from already burning structures. Structure-to-structure fire spread from flames, as well as burning embers, spread fire within each block of buildings.

Key Finding (6): Lofted, wind-driven burning embers – principally from burning structures – initiated ignitions across streets to adjacent blocks of ignition vulnerable structures thus continuing fire spread through the Village of Lytton and IR 18.

Outbuildings and other flammables

Outbuildings such as storage sheds, workshops, play structures, garages and lean-to's (Fig. 18) in effect, increase the structure density of HIZs. When they ignite and burn, they can become significant ignition sources within the HIZ (see Fig. 13 and discussion). Outbuildings are potentially vulnerable to direct ember ignitions due to gaps and openings at doors, windows, under eaves, etc. The firewood shed (right photo) is highly vulnerable to ember ignition and if burning will assure the home's destruction. However, outbuildings are commonly ignition vulnerable from fire spreading to them or adjacent debris. For example, the shed in Figure 18 (left photo) has dead grass continuous to the wall, debris at the rear and an adjacent wood fence at the property boundary. Commonly, a wood fence at the property boundary has continuous dead vegetation and debris outside the fence. The destroyed outbuilding in the center photo was next to a wood fence adjacent to continuous wildland vegetation outside. The wildfire burned through continuous vegetation to ignite the fence leading to the shed. Outbuildings are commonly positioned close to homes, potentially becoming critical sources of ignition exposure to adjacent homes.

Figure 18: Outbuildings such as the shed on the left are ignition vulnerable from fire spreading in dead grass, flammable debris or a wood fence to contact and ignite it or directly ignite from burning embers such as the firewood on the right. Once ignited, the burning outbuilding or adjacent firewood ignites the house or business.

Key Finding (7): Fire spread continued through the Lytton Community was principally determined by the highly vulnerable ignition conditions within individual HIZs, and by high structure-to-structure flame spread potential due to overlapping HIZs. Density of structures in Lytton-area communities was commonly increased by placement of highly ignitable sheds, workshops and other flammable materials close to primary structures.

Surviving home in the Village of Lytton, south

Although the houses on both sides of the surviving house burned, the local ignition conditions of the surviving house did not meet the requirements for sustained ignition and thus, it did not burn. Inspection and Figure 17 showed no burning within the HIZ leading to the surviving structure, and, importantly, both adjacent burned houses had non-flammable stucco exterior walls (note the wall remnants) that acted as a radiation shield to their surroundings and confined flames to the burning interior. Thus, no structure-to-structure flame ignition occurred, as was particularly common with the high structure density in the Village of Lytton (Figs. 2, 17).

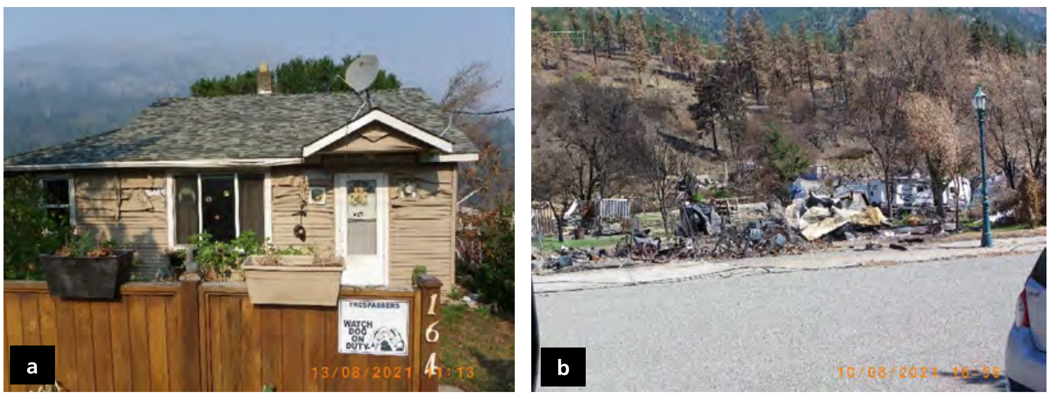
Figure 19: a, b) Adjacent burned houses to the south (left) and north (right) have non-flammable stucco exterior walls.

The south side burning house (Fig. 19a) did not thermally damage the surviving house (about 9 m separation), and there was no char on the wood fence panel (about 2 m separation). The north side burning house (Fig. 19b) was much closer (about 3m) to the surviving house. The top rail of the low wire fence was not charred, and the PVC vinyl siding had little thermal damage within 1 m of the ground. The thermal damage to the surviving house was likely radiation from the burning roof and attachments. As can be seen in Figure 19b, the vinyl siding melted off a portion of the exterior wall wood board sub-sheathing and eave enclosures. None of the exposed wood board sub-sheathing was significantly charred. The plate glass windows fractured but the small glass panes remained held in the vinyl sashes. For perspective, PVC softens to produce damage starting at 95 –100ºC; PVC liquefies starting at 180ºC; and PVC begins to decompose to produce flammable vapors starting at 140ºC. In contrast, wood surface temperature associated with flame ignition is about 325ºC. Thus, melted PVC siding is not indicative of the potential for wood wall ignition.

Key Finding (8): The non-flammable exterior walls remaining until structure collapse prevented flame radiation and contact sufficient for ignition at the adjacent surviving house. This indicates an opportunity to use common building materials that mitigate structure-to-structure community fire spread where there are densely overlapping HIZs.

The vinyl siding on the upper portion of the surviving house was thermally damaged from burning structures directly across Fraser St (Fig. 20). As discussed above, the thermal exposure required to damage and even liquefy vinyl siding is significantly less than the thermal requirements for wood ignition. The wood fence at the sidewalk and closer to the burning structures shows no evidence of thermal decomposition (scorch/char).

Figure 20a: Thermally softened vinyl siding on the upper third of the front facing burning structures across Fraser St. Note the wood fencing closer to the thermal source without char. Figure 20b: Burned structures across Fraser St. produced the thermal radiation that damaged the vinyl. These structures are identified in the coarse dashed yellow rectangle of Figure 17.



Ember ignitions from burning structures

Radiant heating across streets (10 m or more) from burning structures was insufficient to, and did not, initiate ignitions in adjacent blocks. If not flames, then burning embers principally from burning structures must have produced the ignitions from block to block resulting in the Village of Lytton fire spreading across streets. Key Findings (5) and (6) are consistent with observations from other WU fire studies (Cohen and Stratton 2008; Cohen 2010; Calkin et al. 2014) and with the science that developed the HIZ (Cohen 2004). Figure 21 provides an example of this typical mechanism of fire

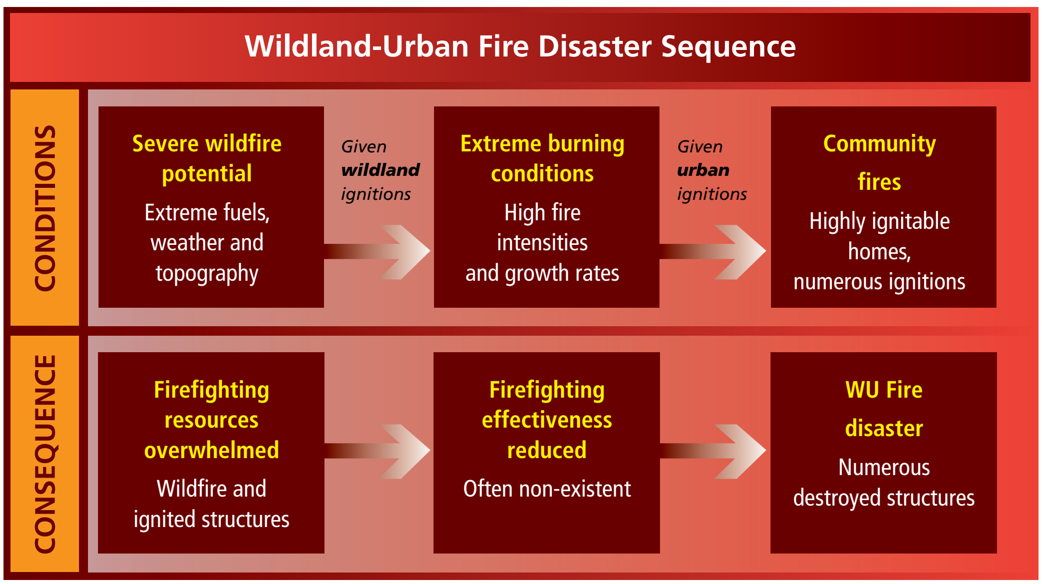
Figure 21: Burning embers ignited the ignition vulnerable wood steps and decking at the front entry way (a) of the house (a, yellow oval). Another ember ignited structure (b) is in the background to the left of the house in front. This house is also shown to the right of the Post Office in Figure 14.

spread, wherein burning embers were likely generated by burning structures in the adjacent upwind block, and windblown to the house in the photo. The paired images of before (left, October 2018) and during (right, 1830 hrs) the Lytton WU fire illustrates the principal vulnerability that likely contributed to the ignition. The highly weathered wood with openings beneath and between members of the wooden stairs and landing would have accumulated leaves and other combustible debris in addition to the inside corners of the stair/landing construction where burning embers commonly accumulate during extreme wildfire conditions.

How disastrous community fire destruction occurs

The Lytton WU Fire displayed the same general pattern of community destruction as previous WU fire disasters (Cohen 2000; Cohen and Stratton 2003; Cohen and Stratton 2008; Graham et al. 2012; Westhaver 2017) and followed the WU fire disaster sequence in Figure 22 (Cohen 2010; Calkin et al. 2014). The wildfire conditions at the Lytton community were extreme, burning during strong winds and dry fuel conditions to produce high spread rates with fire intensities and ember ignited spot-fires that could not be realistically controlled by realistic initial attack wildfire suppression (Key Findings 1 and 2) . In less than 1 hour (~1720 hrs), the extreme wildfire had rapidly spread to expose a broad area of structures along four separately spreading flame fronts at the margins the Village of Lytton, IR 18 and IR 17.

Figure 22: The WU fire disaster sequence.



The three top boxes of Figure 22 identify the principal WU "Conditions" factors leading to numerous synchronized structure ignitions. That is, given severe wildfire potential and a wildfire ignition, extreme wildfire behaviour results that typically overwhelms initial attack suppression. Given a community of highly ignition-vulnerable homes and businesses (HIZs), the extreme wildfire initiates simultaneous structure ignitions in numerous HIZs from showers of burning embers and wildfire flames spreading into HIZs. Note how the Lytton WU fire description above closely follows the top row "Conditions" of the "WU Fire Disaster Sequence" (Fig. 22).

The lower three boxes of Figure 22 identify the overwhelming task of community fire protection under conditions like those that prevailed at the time of the Lytton WU fire disaster. At best, without consideration for public evacuations or life-safety of fire responders, available structure fire protection can neither extinguish the vast majority of numerous initial HIZ ignitions nor suppress burning structures and protect adjacent buildings (Key Findings 3 and 4). Finally, as fire spreads between structures in community fuels, there is exponentially increasing urban fire involvement. This renders community fire protection effectiveness non-existent for most structures. Without the ability to extinguish even small structure ignitions, any sustained ignition results in free burning homes and business leading to their individual destruction, and collectively, to a conflagration.

Although firefighters might be tactically successful at saving some homes and businesses, strategically, fire protection cannot prevent the WU fire disaster.

This raises an important question regarding the potential effectiveness of structure protection during the Lytton WU fire.

Could the Lytton fire disaster have been prevented with a structure protection response?

At 1800 hrs, about 1 hr., 20 min. after the reported wildfire, at least 20 structures, mostly homes, were fully involved in fire. An expected successful structure fire response is three engines per structure assuming an adequate water supply (otherwise, water tenders are required). If no new fires ignited from the burning structures, the Lytton community structure protection task at 1800 hrs would have required 60 urban engines. The best realistic area wide emergency response availability for Lytton would have been overwhelmed. The answer to this question is "No."

The extreme wildfire behavior during the Lytton WU fire disaster is common to all WU fire disasters in the United States and Canada from 1990 to 2020; including those listed in Appendix B. These extreme wildfires are within the 2 to 5 percent of wildfires that could not be controlled with initial attack and this proportion has not changed with increased wildland firefighting technology and resources. Nor is there any likelihood that enhanced rural and municipal departments could manage to control the extraordinarily prolific structural ignitions that occur within the brief timeframe of WU disasters.

Expectations are unreasonable that broad scale fuel treatments will reduce uncontrollable extreme wildfires (Calkin et al. 2014; Finney and Cohen 2003). Thus, preventing WU fire disasters by controlling wildfires is unreasonable (Calkin et al. 2014). We must assume the inevitability of extreme wildfires, but we do not concede the inevitability of WU fire disasters. Ignition resistant communities are the effective alternative for preventing WU fire disasters.

Similar to the general findings from previous WU fire disaster reviews and supporting science (Cohen 2000; Finney and Cohen 2003; Cohen and Stratton 2003; Cohen 2004; Cohen and Stratton 2008; Cohen 2010; Calkin et al. 2014; Cohen 2016; Westhaver 2017), the Lytton examination repeatedly demonstrated that conditions within HIZs principally determined structure ignitions. Local conditions determining structure ignitions during extreme wildfires provide opportunities to reduce structure ignition potential within HIZs, and collectively create ignition resistant communities, thereby preventing WU fire disasters without necessarily controlling extreme wildfires.

Key Finding (9): The Lytton WU fire disaster, as with previous WU fire disasters, occurred during extreme wildfire conditions; however, total building destruction does not indicate a high intensity wildfire flame exposure. Most structures are unprotected due to an overwhelmed structure fire response; thus, any sustained structure ignition from burning embers or contact with low intensity surface fire results in total destruction. For individual structures, and collectively, community ignition resistance is the most effective approach for reducing community wildfire risk and preventing WU fire disasters.

How can future WU fire disasters be prevented?

The opportunity for preventing WU disasters is evident in the WU fire disaster sequence. If the "Highly ignitable structures," the third condition of the Disaster Sequence (Fig. 22), becomes "Ignition Resistant Structures & Community – Few Ignitions.," the "Disaster Sequence" is prevented. The following list provides the general attributes of an ignition resistant HIZ, the fundamental building block of ignition resistant communities that would interrupt the disaster sequence, and prevent large scale community conflagrations.

An ignition resistant HIZ (reference Fig. 16):

1) Does not support high intensity fire; high intensity burning does not develop within the HIZ and ceases within Zone 2 of the HIZ if spreading inward from wildland vegetation.
2) Can have low intensity fire but cannot have any flame contact or long duration radiation sources of radiation (sheds, woodpiles, etc.) exposing the primary structure to burning objects within the HIZ.
3) Does not have any ignitable/burning material within 1.5 m of the primary structure and its flammable attachments.
4) Is only exposed to burning embers from the wildfire and burning community fuels; these become the only ignition source.
5) Does not have flammable debris on the structure and its flammable attachments.
6) Does not have unscreened openings to the structure's interior, or burning embers accumulating against exterior flammable inside corners or in gaps of flammable exterior materials, or flammable wood roofs.

These attributes, applied to the structure and its surrounding zones of the HIZ, develop individual ignition resistant structures.

Groups of ignition resistant HIZ's function synergistically to produce ignition resistant communities. This is essential in most built environments because, more often than not, HIZs overlap. Consequently, ignition resistance for each structure depends on ignition resistance of neighboring structures. This interdependence presents additional social challenges. Achieving wildfire-resilient communities will require programs that motivate, educate and engage residents/owners in action implement ignition resistance for each and every structure.

An ignition resistant community:

1) Understands and supports a structure ignition approach for wildfire risk reduction at all levels; the elected and administrative officials make strategic decisions and investments commensurate with an ignition resistance approach.
2) Has residents and property owners who collaborate and share responsibility for actions toward achieving ignition resistance.
3) Has inter-governmental/agency/departmental capacity and collaborations to facilitate community wildfire risk reduction, operationally and financially.
4) Has achieved individual overlapping, ignition resistant HIZs that collectively create community ignition-resistance.

Ecological benefits of wildfire-resilient communities

Wildfire, and more generally, wildland fire is not solely a social disruption and destructive agent of communities. Inevitable wildland fire is both a natural disturbance providing ecological resource benefits as well as a natural hazard resulting in community fire destruction. This dilemma represents a profound management challenge: restoring fire as an appropriate ecological factor at landscape scales without having WU fire disasters.

Science reveals wildland fire to have been an important ecological factor in developing and sustaining ecosystems for thousands of years post-Pleistocene, across most North American landscapes (Stewart 2002). As an example, the ecosystems surrounding Lytton are dominated by fire-resistant and dependent plant and tree species that developed with frequent fires at 4 to 50-year intervals. Ironically, the dramatic reduction in wildfire occurrence has led to increased fire intensity, fire size, ecological fire severity and WU fire disasters – the "wildfire paradox" (Arno and Brown 1991; Cohen 2010).

Along with lightning, First Nations cultural burning practices contributed to frequent fires[8] that developed landscape patterns with less dense forest patches, less continuity between forest patches, and species sustainable with wildland fire. However, since European settlement, burning under all conditions of fire spread has greatly reduced (Hessburg et al. 2005). Settlement suppressed First Nations burning practices, changed land use practices and attempted to eliminate and suppress wildfires.

Science (Finney and Cohen 2003; Cohen 2004; Cohen 2010; Calkin et al. 2014) and the corresponding findings from our Lytton WU fire examination show us that we can create and maintain local ignition resistant HIZ conditions that collectively create an ignition resistant community during extreme wildfire conditions. That is the opportunity now open to us, by re-building Lytton as a model wildfire-resilient community, the role of fire in ecosystems that are dependent upon it can be carefully restored.

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[8] First Nation fire use historically accounted for most area burned in some locations, not lightning. Unknown for this area.

Key findings and conclusions

Key findings

The following are the key findings of this examination as presented throughout the report:

1. Wildfire conditions were extreme, not from a high intensity fire spreading through tree canopies (crown fire), but from a rapidly spreading surface fire burning through grass, forest litter and shrubs, aided by largely short distance ignition spotting from a profusion of burning embers.
2. Given the Lytton wildfire conditions of rapid fire spread along four different fronts and necessary considerations for life-safety under such conditions, it is unrealistic to expect a successful initial attack wildfire suppression response.
3. Wildfire spread to Lytton community boundaries and initiated community ignitions in less than one-hour. Wildland surface fuel outside the community had burned well before 1800 hrs and any continued influence from wildfire had ceased. By 1800 hrs, 20 primary structures were heavily fire involved and fire spread primarily from burning structures continued within the Lytton community without wildfire influence for 1.5 to 2 hours.
4. Surface fire and short-range spot fires from burning embers initiated multiple structural ignitions, largely at the edges of the Village of Lytton, IR 18 and IR 17 within 1 hour of the reported wildfire. Within one and one-half hours of the wildfire report (by 1800) more than 20 primary structures were significantly burning, distributed along the 4 wildfire Spread Paths in the Village of Lytton, IR 18 and IR 17. The rapid, simultaneous fire involvement of this many primary structures would have overwhelmed any reasonable municipal structure protection response in that region.
5. Structure ignitions during extreme wildfires are principally determined by the local ignition conditions of the home ignition zone (HIZ); that is, a structure and its flammable attachment's ignition vulnerabilities to burning embers in relation to burning materials within 30 m. An extreme wildfire provides ignition hazards from flames and burning embers; HIZ ignition vulnerabilities determine structure ignitions and community fire disasters. Hence, WU fire disasters are a structure ignition problem.
6. Lofted, wind-driven burning embers – principally from burning structures – initiated ignitions across streets to adjacent blocks of ignition vulnerable structures thus continuing fire spread through the Village of Lytton and IR 18.
7. Fire spread continued through the Lytton Community was principally determined by the highly vulnerable ignition conditions within individual HIZs, and by high structure-to-structure flame spread potential due to overlapping HIZs. Density of structures in Lytton-area communities was commonly increased by placement of highly ignitable sheds, workshops and other outbuildings close to primary structures.
8. The non-flammable exterior walls remaining until structure collapse prevented flame radiation and contact sufficient for ignition at the adjacent surviving house. This indicates an opportunity to use common building materials that mitigate structure-to-structure community fire spread where there are densely overlapping HIZs.
9. The Lytton WU fire disaster, as with previous WU fire disasters, occurred during extreme wildfire conditions; however, total building destruction does not indicate a high intensity wildfire flame exposure. Most structures are unprotected due to an overwhelmed structure fire response; thus, any sustained structure ignition from burning embers or contact with low intensity surface fire results in total destruction. For individual structures and collectively communities, ignition resistance is the most effective approach for reducing community wildfire risk and preventing WU fire disasters.

Conclusions

A rapidly spreading wildfire, surface fire burning grass and forest surface litter, initiated ignitions of HIZs at the edges of the community. There was no exposure of the Village of Lytton, IR 18 or IR 17 to high intensity crown fire and there was no significant tree canopy torching. Thus, Lytton homes, businesses and public buildings did not ignite from wildfire flame contact, radiant heating or experience a community wide wildfire generated shower of burning embers. Multiple homes located at widely separated sectors of the community's south, northwest, and northeast perimeters were exposed almost simultaneously to surface fire and short-range burning embers resulting in a large number of concurrent structure ignitions.

Once established in residential fuels at the perimeter of the community, fires spread rapidly to adjacent structures by flame radiation, flame contact, and by heavy showers of burning embers primarily from burning structures. At this point, the fire was free-burning in the community, without any further involvement or influence from the wildfire.

The Village of Lytton, IR 18 and IR 17 largely burned after its wildfire exposure and the initiation of scattered community ignitions. We attributed the continuing ignitions of structure and their total destruction, nearly 90 percent, to overlapping HIZs dominated by high structure density and highly ignitable materials in their immediate surroundings. At close range urban fuels were readily susceptible to direct ignition by flames and burning embers from upwind burning structures.

Past WU fire disasters have only occurred during extreme wildfires, when burning conditions overwhelmed fuel treatments[9] and reasonable fire control response. The Lytton WU fire followed the same pattern, identified as the "*Wildland-Urban Fire Disaster Sequence*." Extreme wildfires produce showers of burning embers and intense, rapidly spreading fire that initiate ignitions within a community. However, WU fire science has discovered that the local ignition conditions within HIZs principally determine whether and how structure ignitions occur leading to continued burning within the community.

Our Lytton WU fire examination revealed important opportunities for preventing future WU fire disasters during extreme wildfire conditions. Working together, agencies and residents have the opportunity to practically and effectively address WU fire disasters as a structure ignition problem and create ignition resistant communities, rather than continue with failed expectations of wide-scale fuel treatments, wildfire control and structure fire protection. A structure ignition problem approach, using effective measures creating structure ignition resistance, changes the 3rd upper row "CONDITION" factor in the WU Fire Disaster Sequence (Fig. 22) from "*highly ignitable structures and numerous ignitions*" to "*community ignition resistance with few ignitions*." Thus, the "CONSEQUENCES" would then change to the favourable outcome of, "*effective community fire protection and a WU fire disaster prevented*."

We ultimately conclude that ignition resistant HIZs and communities of the future can sufficiently reduce structure ignitions to enable successful community fire protection and thereby prevent WU fire disasters. Furthermore, ignition resistant communities can enhance the ability of First Nations practitioners to conduct local cultural burning and wildland fire managers to restore increased landscape-scale fire with ecologically appropriate prescribed burning without the threat of WU fire destruction. Implementing both these activities will enhance human benefits by maintaining fire adapted ecosystems and preventing WU fire disasters.

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9 Either by embers skipping over them, or lowered intensity fire burning through them

Recommendations

These recommendations are based on findings of the Lytton WU fire examination, and on accepted science relevant to all incidents of extensive community wildfire destruction. Although motivated by our objective to assist Lytton area citizens recover, rebuild and establish a more wildfire-resilient community, these recommendations are equally applicable to all existing or planned communities located in wildfire-prone landscapes, as well as to isolated homes and smaller settlements in rural, agricultural or recreational settings.

Therefore, while these recommendations are addressed specifically to Authorities Having Jurisdiction (AHJ) for planning, re-constructing and maintaining the future Lytton community, we are hopeful they will gain the attention of authorities at all levels with responsibilities for public safety, emergency management and fire protection, Canada-wide. Throughout, we recognize the inevitability of extreme wildfires, and their likely increased frequency with climate warming.

The four over-riding strategic recommendations below are followed by others pertaining to the full scope of potential wildfire risk mitigations, and relevant to Lytton and similar WU communities.
We recommend that:

1. Strategic:

1.1 The root cause of community wildfire destruction be recognized and re-defined, by all stakeholders, as being a problem of easily ignitable structures and homes, and no longer as merely a wildfire problem.

1.2 The management perspective and priority for efforts to avoid future destruction of wildland-urban communities (and all structures in landscapes prone to wildland fire) are more appropriately shifted to mitigating the vulnerability and exposure of structures (and immediate surroundings), thus multiplying the probability of success by available fire response capability.

1.3 The Home (structure) Ignition Zone, as illustrated Fig. 16), be adopted as the fundamental area of effective wildfire risk reduction activity, and that residential assessments be adapted to place primary emphasis on identifying and resolving local factors affecting ignition vulnerability and contributing to ignition exposure.

1.4 Given the inadequacies of post-fire research, the BC FireSmart Committee aggressively pursue their initiative of conducting early-arrival WU fire case studies as per (Westhaver and Taylor 2020, and Cohen and Westhaver 2021) in order to further advance our understanding of WU problems and mitigation solutions.

2. Reconstruction and safe return of residents to Lytton-area communities:

2.1 AHJ’s and individuals responsible for reducing the ignition potential of homes, businesses, outbuildings and infrastructure make community wildfire protection their top priority.

2.2 Based on the foundational understanding that the ignition potential of structures is the root problem of community wildfire destruction, and not the wildfire itself, authorities shift to a paradigm of pro-active wildfire risk mitigations to reduce critical exposure and vulnerabilities within Home Ignition Zones. This is the most effective approach for avoiding future WU fire disasters. It is the only way communities and their people may become wildfire-resilient.

2.3 AHJ's and housing authorities adopt National Research Council of Canada guidance (i.e., the "*National Guide for Wildland-Urban Interface Fires*,[10] *2021*") for the construction or reconstruction of new and damaged homes, landscaping and for renovations to existing buildings in Lytton communities.

2.4 An interim program of annual mowing of grass and herbaceous vegetation be implemented (2022) at the end of each growing season. Removal of hazardous accumulations of fine surface fuel minimizes risk to residents and new construction. Mown areas should include portions of HIZ's extending onto public lands, temporarily vacant residential lands and right-of-ways of Federal, Provincial, Municipal and Regional District roads designated as evacuation or emergency access routes.

2.5 AHJ's of Lytton-area communities collaborate with the Union of British Columbia Municipalities, Indigenous and Northern Affairs Canada and other agencies to ensure grant programs include and prioritize allocations for fuel/vegetation modification treatments and hazard reduction activities within, and immediately adjacent to HIZ's.

3. Community engagement, longer-term resilience and living in a wildfire prone environment[11]:

3.1 An awareness program be developed in consultation with community leaders including elders, elected officials, administrators, planners, builders, and residents of re-building Lytton communities to enhance the understanding of how the disaster occurred and the degree of collaboration that will be required to become a model wildfire resilient, ignition resistant community, thus preventing future disasters.

3.2 A local Wildland-Urban Steering Team (W.U.S.T.) be convened with a mandate to share information about community wildfire risk mitigation initiatives among partners and stakeholders, promote programs of community engagement, ensure collaboration and coordination among intra/inter-agency initiatives, and coordinate responsibility for vegetation management within 100 m. of HIZs.

3.3 The Local Fire Department have dedicated staff with the understanding and communication skills required to lead community education and engagement programs for residents and property owners toward establishing and maintaining community wide ignition resistant HIZs.

3.4 The BC FireSmart Committee and Lytton W.U.S.T. facilitate full implementation of the *FireSmart Canada Neighbourhood Recognition Program*[12] (FCNRP) in all Lytton-area neighbourhoods. This functional program, is the only proven means of educating, motivating and facilitating sustained active engagement of Canadian WU residents, businesses and property owners in reducing wildfire community risk.

3.5 A full-time "FireSmart Coordinator" position, attached to the Lytton Fire Department and Lytton First Nations, be established to support Lytton fire authorities and the W.U.S.T. with grant applications, implementing the FCNRP and coordinating multiple other aspects of wildfire risk reduction.

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[10] The "Guide" was developed through a rigorous multi-year process involving significant stakeholder input from the construction industry and wildfire science community.

[11] We recognize the majority of local conditions determining home ignition potential and survival are within the purview of home owners and occupants. Becoming a wildfire resilient community is not possible without actively engaged residents.

[12] Minor adaptations for the local situation may be required for optimal success of the program.

3.6 Lytton residents be encouraged to continue including adequately irrigated lawns, productive gardens, and flower beds as important components of their 1.5 m non-combustion zone and fire-resistant HIZs.

3.7 Information on fire-resistant xeriscaping alternatives be provided to Lytton residents.

4. Local and regional authorities responsible for development and building permits on Municipal and First Nations lands will review and amend current regulations, by-laws and approval processes to incorporate regulatory mechanisms related to WU fire mitigation, such that:

4.1 It is made mandatory for property owners/residents to establish and maintain a contiguous 1.5-metre-wide non-combustion zone surrounding all structures (including outbuildings).

4.2 Minimum clearances of 8 metres for 1-story structures, and 13 metres for 2-story structures between all new homes, businesses and out-buildings.

4.3 Where structures already exist, less clearance is mitigated with non-flammable exterior materials; removal of windows facing other structures within minimum clearances, metal screening/shutters for small windows (< 0.6 m x 0.6 m) or re-fitting with dual pane tempered glass or wire glass.

4.4 Outbuildings and other large flammable objects (e.g., firewood) are adequately separated from all main structures and structures are not connected by flammable objects (e.g., fences, landings).

4.5 Once-annual removal/mowing of tall grass and weed cover (as the grass becomes cured) by owners on all residential, commercial and corporate lands, is mandatory.

4.6 Permission is freely given to residents participating in the FireSmart Canada "Neighbourhood Recognition Program", and to business owners allowing them to maintain/treat vegetation on public land which is beyond their property line but within their HIZs to meet recommended standards for reducing wildfire risk.

4.7 Structural foundation designs with ground-level openings which allow accumulation of fine debris and embers beneath structures, and use of re-cycled ties for foundations are prohibited.

4.8 Authorities of the Village of Lytton, Lytton-area First Nations and the Province of BC explore regulatory means for compelling corporate landowners to manage vegetation on right-of-ways and other lands within the limits of municipalities to standards that limit wildland fire threats to the community.

5. AHJ's with responsibility for management of urban lands:

5.1 Operational and fiscal resources be allocated to enable once-annual mowing of grass and weeds (at the end of the growing season) and, on a four-year rotating basis to remove excessive new re-growth, space immature trees, and lower branches of evergreen trees within 30 metres of the community perimeter, and remove excessive needle accumulations; apply these activities to:

5.1.1 Public lands within 30 metres of any private residence or business (but beyond the owners respective property line);

5.1.2 Within 30 metres of any public building, public health/educational facility, critical infrastructure installation, or public road; and

5.1.3 Any vacant public lands, or parkland within subdivisions.

5.2 Coordinate with other jurisdictions (e.g., BC Highways) and corporate landowners (e.g., CN Rail, CP Rail) to ensure similar mitigations occur on the right-of-ways of public highways, railways, etc.

5.3 Funding be provided to incentivize replacement of fire-resistant deciduous shade and fruit-bearing trees destroyed by the WU fire on private and public lands within Lytton communities.

6. Critical community infrastructure:

6.1 A reliable domestic water supply and water delivery system be provided and maintained for fire response at the Lytton community, and that the supply is sufficient to avoid the necessity for water rationing, and to sustain gardening lifestyles and fire-resistant vegetation in an arid climate.

6.2 A gravity-flow water delivery capability be established to ensure: continued water supply during power outages, and increased capacity for fire protection.

6.3 All surviving critical infrastructure, and plans for replacement infrastructure be scrutinized by a WU fire specialist to ensure existing WU fire risks are sufficiently reduced prior to the 2022 fire season.

7. Enhanced emergency response:

7.1 Local fire response capability be enhanced, with priority on added expertise and equipment to facilitate rapid response to small spot fires in wildland and residential fuels using a highly mobile, multiple ignition approach with initial attach capable side-by-side ORVs and Type 5 engines.

8. Ecosystem management

8.1 A sustained prescribed fire program be established as a means of restoring natural disturbance and regular vegetation/fuel maintenance.

8.2 Provincial programs for forest fuel modification are coordinated with programs designed to encourage an increase in annual area burned near WU communities, both by agency-sponsored planned prescribed burns and by the cultural burning activities of First Nations. This will encourage the restoration of ecologically appropriate wildland fire.

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Appendix A: Glossary of Terms

Burning Ember: A burning ember lofted or falling out of burning vegetation or structures that may be flaming, or glowing that singly or in accumulations potentially ignites adjacent flammable materials.

Community Exposure of the HIZ: The burning residential fuels, vegetation and structure, within the community potentially produces a significant burning ember and flame exposure of the HIZ. This is particularly significant when a community of high-density housing has multiple overlapping HIZs.

Ember – see Burning Ember.

Extreme Fire Behaviour: A level of fire behaviour 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 (CIFFC 2017).

Combustible: Any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn. (NFPA, Firewise. Hazard Assessment Methodology. WUI Fire Working Team).

Community Ignition Resistance: The ignition resistance of many homes and other structures that collectively creates ignition resistance of whole or part of a community.

Exposure: The potential heat transferred from burning embers and flames based on the conditions of burning sources irrespective of the ignition vulnerability of an object of interest (from L.M. Johnston et al., 2019). Example, flame exposure of a home depends on the magnitude and duration of the radiant heat flux and flame contact with flammable exterior structure materials.

Exposure Level: The degree to which structures are exposed to embers, radiation, or flame contact (NRC).

Firebrand: see Burning Ember.

Fire Behaviour: 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 (CIFFC 2017).

Fire Hazard: Any situation, process or material or condition that can cause a fire or explosion or that can provide a ready fuel supply to augment the spread or intensify a fire or explosion, all of which poses a threat to life or property. (NFPA 921, 2017). Alternatively, "a fuel complex, defined by kind, arrangement, volume, condition, and location that determines the ease of ignition and/or resistance to fire control" (NFPA 1144, 2018).

Fire Protection Availability: The presence of effective fire protection to prevent significant home destruction from sustained home ignitions or prevent the spread of fire to other neighboring homes. Given that "fire proofing" homes in a community is unrealistic, the community wildland-urban fire destruction risk is determined by the conditional probability involving home ignition exposure, home ignition vulnerability, and fire protection.

Fire Resistant: Ignition-resistant construction methods using building materials and design features that reduce the vulnerabilities of buildings to ignite from burning embers (firebrands) and flame exposures (NFPA 1144, 2018).

Fire Resistive: see Fire Resistant.

Flame Hazards: Any flame producing burning source within the HIZ. Research has designated the extent of the HIZ such that flames beyond the HIZ do not transfer sufficient heat to directly ignite a home.

Forest Overstory: Layer of tallest or dominant trees in the forest, generally mature trees. Syn. canopy.

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.

Fuelbreak: An existing barrier or change in fuel type (to one that is less flammable than that surround it), or a wide strip of land on which the native vegetation has been modified or cleared, that act as a buffer to fire spread so that fires burning into them can be more readily controlled. Often selected or constructed to protect a high value area from fire. In the event of a fire, may serve as a control line from which to carry out suppression operations (CIFFC 2017).

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

Hazard Assessment: Assess hazards to determine risks. Assess the impact of each hazard in terms of potential loss, cost or strategic degradation based on probability and severity. (NFPA, Firewise. Hazard Assessment Methodology. WUI Fire Working Team).

Hazard Factor: In the terminology of the Canadian FireSmart® program: a "hazard factor" is one of many structural (components or design), vegetative, or other combustible elements within a Home Ignition Zone that contributes to a structure's susceptibility to ignition during a WUI fire event. Typically, each hazard factor is evaluated and rated individually during a comprehensive structural hazard assessment.

Hazard Reduction: Any treatment of living and dead fuels to diminish the likelihood of a fire starting, to lessen potential rate of spread and resistance to control (CIFFC 2017).

Home Ignition Potential: The conditional probability of ignition exposures and the home ignition vulnerabilities resulting in ignition probability.

Home Ignition Response: The probability/likelihood of a home to sustain ignitions from an exposure of burning embers and flames.

Home Ignition Zone (HIZ): A home and its flammable attachments in relation to immediately surrounding burning objects that principally determine home ignitions during WU fires. The HIZ includes the home and flammable attachments, and the immediate surroundings within 30 meters.

Home Ignition Zone 1: the area of the HIZ located 1.5m to 10m of the home and its flammable attachments.

Home Ignition Zone 2: the area of the HIZ located 10 – 30m from the home and its flammable attachments.

Ignition: the process of initiating self-sustaining combustion (NFPA 921, 2017).

Ignition Assessment: A term used in this User Guide more pertinent to and focused on the problem of home ignitions leading to destruction. Ignition Assessment replaces the term "Hazard Assessment" in recognition that "hazard" involves ignition exposure, but home ignition requires ignition vulnerability to a given "hazard" exposure for determining potential home ignitions, the WU fire problem.

Ignition Hazard: Sources of flames and embers, one of three important elements of WU fire destruction risk (along with ignition vulnerability and fire protection availability).

Ignition Hazard Exposure: see Ignition Hazard.

Ignition-Resistant Building Material: A type of building material that does not sustain ignition and flaming combustion (NFPA 1144, 2018) (See Fire Resistance).

Ignition Vulnerability (also Response): One of three principal elements of WU fire destruction risk (along with ignition hazard and fire protection availability).

Mitigation: Related to preventing WU fire destruction – an action that reduces home ignition potential by reducing home ignition vulnerabilities in relation to ignition exposures from wildfires and community burning, and those that can be reduced within the HIZ.

Non-Combustion Zone: Area of the HIZ located 0 – 1.5m from the outermost perimeter of the home and its flammable attachments (i.e., walls, foundation or any home attachment such as deck, porch, stairs).

Real-time Observations: research techniques applied or operational during the structural ignition phase – time period when structures are exposed to heat transfer from a wildland fire.

Residential Fuels: Structures, vegetation and any other combustible materials or objects found within the community that become a source of ignition exposures.

Resilience: the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions (NFPA, 2014).

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. FireSmart guidelines are founded in standards developed by the National Fire Protection Association, supplemented by research by the Canadian Forest Service pertaining to crown fire reduction.

Spotting: A fire producing burning embers (firebrands), lofted in the fire's convection column and carried by the wind, or lofted in a fire whirl that fall beyond the main fire perimeter and result in separate ignitions/spot fires (CIFFC 2017).

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

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

Wildfire Exposure of the HIZ: This is primarily a burning ember exposure of the HIZ. The HIZ is defined (see Home Ignition Zone) as an area extending a distance that the flames of intensely burning crown fires cannot sufficiently heat a home's flammable materials to ignition and can be conditioned to halt crown fire spread.

Wildfire Risk: The potential value change of something of interest resulting from a wildfire occurrence. It is the product of an occurrence probability and a change probability resulting in value changes from the wildfire. Typically, "wildfire risk" is viewed as a negative value change when the wildfire is a natural hazard. However, when considering wildfire also as a natural disturbance, the "net value change" of an occurrence can be positive.

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

Wildland-Urban (WU) Fire: The recommended term (2021) to replace "Wildland/Urban Interface (WUI)" because home destruction during wildfires is not determined by a geographical definition relating largely residential development in proximity to undeveloped land without consideration of wildfire potential. Rather, home destruction is determined by meeting the requirements for combustion that occur immediately adjacent to the surface of a flammable material.

Wildland-Urban Disaster Risk: The probability of an exposure to extreme wildfire conditions and an ignition resulting in extreme wildfire conditions times the probability of exposing largely residential development of a given vulnerability to ignitions as depicted in the Wildland/Urban Interface Disaster Sequence.

WU: Abbreviation for wildland-urban, an increasingly acceptable term for WUI.

WUI: Abbreviation for wildland-urban interface.

Appendix B: Significant United States & *Canadian*[13] Wildland-Urban Fire Disasters(1990 – 2021)

Year	Incident	Location (USA)	Homes destroyed (appr.)
1990	Painted cave	Santa Barbara, CA	479
1991	WA state 'Firestorm' Tunnel	Spokane, WA Oakland, CA	108 2900
1993	Laguna Hills, Old Topanga	Laguna & Malibu, CA	634
1996	Millers Reach	Big Lake, AK	344
1998	Florida wildfires	Flagler & Volusia County, FL	300
2000	Cerro Grande	Los Alamos, NM	239
2002	Hayman Rodeo-Chediski	NW of Colorado Sprgs, CO Heber-Overgaard, AZ	139 426
2003	Aspen Old, Cedar, etc.	Summerhaven, AZ Southern CA	340 3640
2003	*Okanagan Mountain Park*	*Kelowna, B.C. Canada*	*238*
2006	TX, OK Wildfires	TX & OK	723
2007	Angora Witch, Slide, etc.	Lake Tahoe, CA Southern CA	245 2180
2010	Fourmile Canyon	Boulder County, CO	168
2011	Bastrop Complex, etc.	Central TX	2725
2011	*Flat Top Complex*	*Slave Lake, AB Canada*	*428*
2012	High Park, Waldo Canyon	Colorado Front Range	605
2013	Black Forest	El Paso County, CO	511
2014	Carlton Complex, etc.	Okanogan County, WA	342
2015	Butte, Valley	Amador & Lake County, CA	1797
2016	Chimney Tops 2	Gatlinburg, TN	2000
2016	*Horse River*	*Fort McMurray, AB Canada*	*2400*
2017	Tubbs, Nuns, Thomas, etc.	No. & So. California	9000
2018	Carr, Camp, Woolsey, etc.	No. & So. California	16,000
2019	Kincade	Sonoma County	374
2020	Almeda Dr., Beachie Creek Glass Fire, North Complex	Jackson County, OR Northern CA	2000
2021	*Lytton Creek*	*Lytton, B.C. Canada*	*151*

[13] Canadian W-U fires are noted in italics

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