CITY COUNCIL
STUDY SESSION AGENDA

MEDFORD
OREGON

October 10, 2019
6:00 P.M.
Medford Room, City Hall
411 West 8th Street, Medford, Oregon

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1. Wood and Shake Shingles

2. Defensible Landscaping Space

3. Grant Priorities

MEDFORD
OREGON

MEMORANDUM

To: Mayor and Council

From: Greg Kleinberg/Deputy Chief-Fire Marshal

Study Session Date: October 10, 2019

Subject: Wood Shake and Wood Shingle Roofs

COUNCIL DIRECTION

Staff is providing information to the Mayor and Council about wood shake/shingle roofs and seeking direction as to what action shall be taken regarding use of such materials.

PRESENTATION OUTLINE

- Presenter: Greg Kleinberg - Deputy Chief/Fire Marshal
- Sam Barnum - Building Official

PREVIOUS STUDY SESSIONS AND G-3 MEETINGS ON THE TOPIC

- None

BACKGROUND

- Deputy Chief Greg Kleinberg addressed concerns about the combustibility of wood shake and wood shingle roofs in a staff report (dated April 19, 2019) to the Planning Department regarding MMC Chapter 10 proposed code changes to the Historic Building provisions (DCA-19-022). Further discussion occurred at the Planning Commission Meeting on July 25, 2019. This topic was brought up at the August 1, 2019 Council meeting, specifically the concern of allowing combustible roofing on any building in the city limits. DC Kleinberg answered questions and spoke to the issue. At the conclusion of the agenda item, a motion was passed by Council to direct staff to research wood shake and wood shingle roofing materials and bring information back to the Council via a study session.

EXHIBITS

- Exhibit #1: Outline of Presentation
- Exhibit #2: Wood Roof Guidelines – Los Angeles Fire Department
- Exhibit #3: Pathways for Building Fire Spread at the Wildland Urban Interface, March 2015, The Fire Protection Research Foundation

Thank you,
Greg Kleinberg
Deputy Chief-Fire Marshal

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Wood Shake and Wood Shingle Roofs

Council Study Session Outline 10-10-2019

1. Introduction
2. Shingles vs. shakes
   - The difference
   - Quality differences
3. Weathering of wood
   - How exposure degrades wood
4. Ignition threat to combustible roofing
   - How fires start
   - The threat of ember (firebrand) ignition to roofs
5. Class A fire-rated roofing
   - Characteristics and common materials
6. Class B, C fire-rated and unrated roofing
   - Characteristics and common materials
7. Fire-resistant rating basis
   - Tests used to evaluate fire-resistance
8. Fire-retardant wood shakes and wood shingles
   - Current code requirements and fire-rated wood shakes/shingles
9. Los Angeles Fire Department findings
   - Summary of why Los Angeles upholds ban on all wood shake/shingle roofs
10. 2015 Fire Protection Research Foundation Report
    - Conclusions of research report
11. Medford wildfire hazard
    - The threat to Medford
12. Council options to consider
    - No change to roofing requirements
    - Direct staff to prepare an ordinance that requires minimum Class A or Class B rated roofs
    - Direct staff to prepare an ordinance that bans all wood shake and wood shingle roofs

Medford Fire-Rescue | 200 S. Ivy St. #180, Medford, OR 97501 | 541-774-2300 | medfordfirerescue.org

Wood Shake/Wood Shingle Roofs

The Los Angeles Municipal Code (91.1504.1) excludes wood shakes and shingles from the list of approved roofing materials that can be used in the City of Los Angeles. L.A. City Roofing Ordinance #165047 effective August 25, 1989, restricted wood shake and shingle roofs for new construction and replacement over 10% of the roof surface. The ordinance restricted all wood roofs and did not differentiate between untreated or fire retardant pressure treated wood shakes and shingles since they both support combustion.

The City recognized that wood roofs were one of the major factors responsible for spreading fires not only to adjacent properties but structures considerable distances away.
In the Chemco FTX Five Year Natural Weathering Test, the shingles ignited three minutes into the test and burned for an additional 23 minutes and 30 seconds after the burner flame was turned off. The results of that test and the Los Angeles Fire
Department's Standard No. 43 Test for Determining the Flammability of Solid Materials demonstrated that the fire retardant pressure treated wood shakes and shingles support combustion.

The five-year test proved that treated wood shakes and shingles ignite and continue to burn long after flame exposure. It is our experience that a material that exhibits that type of burning characteristics combined with our local climactic conditions (high wind velocities, low humidity, and high temperatures) has the potential for spreading fire downwind in the form of flying burning brands.

The UBC 32-7 Roof is nationally recognized, however, the testing criteria are not representative of the actual conditions in the City of Los Angeles. The wind velocity used in the testing during flame exposure is 12 miles per hour. The moisture content of the roof test deck must be within the range of 8% to 12% just prior to the test while in actual conditions the fine fuel moisture content may be at least 4%. The temperature of the testing facility must be maintained between 50-90 degrees F. while in actual conditions the temperature may far exceed 100 degrees F. The natural weathering test does not exceed 10 year while in reality the life of a wood roof in the City often exceeds 20 years. The impact of the destructive effect of UV light, rain and moisture, and temperature changes on the fire retardancy beyond 10 years is not evaluated. There are no assurances that the treated roof will perform as tested since the actual conditions are much more severe than the test criteria.

The City has for many years been proactive in reducing the risk of another conflagration. Extending the brush clearance zone around structures to 200 feet and prohibiting the installation of wood roofs are two of the major preventative measures taken.

https://www.lafd.org/fire-prevention/fire-development-services/wood-roof-guidelines

Pathways for Building Fire Spread at the Wildland Urban Interface

Final Report

Prepared by:

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FOREWORD

Fires in the WUI communities are a rapidly growing problem in the US. The last 15 years contains six of this century's top ten most damaging U.S. single fire events; all of these events occurred in WUI communities. Over 46 million homes in 70,000 communities are at risk of WUI fires (Bailey, 2013). Since 2000, over 38,000 homes have been lost to WUI fires in the U.S.

There are many potential pathways for wildland fires to ignite buildings within the WUI. These pathways (including both fire and ember exposure) depend on the characteristics of the wildland (e.g., fuels, terrain, weather, etc.), the characteristics of the community (e.g., construction materials, building designs, housing density, landscaping, etc.), and the characteristics of the interface (e.g., separation distance, physical barriers, extent of perimeter, etc.).

NFPA Standard 1144, *Standard for Reducing Structure Ignition Hazards from Wildland Fire*, and NFPA 1141, *Standard for Fire Protection Infrastructure for Land Development in Wildland, Rural, and Suburban Areas*, address hazards to structures at the wildland interface and appropriate mitigation measures (NFPA, 2013; 2012). Understanding the pathways above and their contribution to fire risk will help inform future editions of these NFPA standards.

The goal of this project is to identify pathways for fire spread at the wildland urban interface and identify gaps in information to inform prevention and protection strategies.

The Research Foundation expresses gratitude to the report author Michael Gollner and his research team at the University of Maryland. Likewise, appreciation is expressed to the Project Technical Panelists and all others who contributed to this research effort for their on-going guidance. Special thanks are expressed to the National Fire Protection Association (NFPA) for providing the funding for this project.

The content, opinions and conclusions contained in this report are solely those of the authors.

ACKNOWLEDGEMENTS

The Fire Protection Research Foundation expresses gratitude to those that assisted with the development and review of the information contained in this report. The Research Foundation appreciates the guidance provide by the Project Technical Panel, and from the NFPA who provided funding.

About the Fire Protection Research Foundation

The Fire Protection Research Foundation plans, manages, and communicates research on a broad range of fire safety issues in collaboration with scientists and laboratories around the world. The Foundation is an affiliate of NFPA.

About the National Fire Protection Association (NFPA)

NFPA is a worldwide leader in fire, electrical, building, and life safety. The mission of the international nonprofit organization founded in 1896 is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education. NFPA develops more than 300 codes and standards to minimize the possibility and effects of fire and other hazards. All NFPA codes and standards can be viewed at no cost at www.nfpa.org/freeaccess.

Keywords: embers, fire, firebrands, firefighting, fire risk, fire spread, ignition pathways, wildland fire, wildfire, wildland urban interface, WUI

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National Fire Protection Association

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EXECUTIVE SUMMARY

While the Wildland-Urban Interface (WUI) is not a new concept, fires in WUI communities have rapidly expanded in frequency and severity over the past few decades. The number of structures lost per year has increased significantly, from around 900 per year in the 1990's to almost 3000 per year in the 2000's (Bailey, 2013; NIFC, 2014). This trend is the result of many factors, including increased development in rural areas, fuel management policies, and climate change, all of which are projected to increase in the future (Krawchuk et al., 2009).

Responsibility for the protection of these buildings falls between both wildland and urban fire authorities, with mixed guidance available for homeowners, code officials, etc. (IBHS, 2014; ICC, 2012; CBC, 2009; Fire Adapted Communities, 2015). The NFPA has begun to address this problem by instituting several standards, including NFPA 1141, 1142, 1143 and 1144, which aim to reduce structural ignitions and provide adequate firefighting infrastructure in WUI communities. A necessity for improvement of these standards and others is technical knowledge which can be used to understand pathways for fire spread and their statistical and/or quantitative contribution to fire risk. While the general pathways for fire spread in the WUI (flame, radiative and ember exposure) are known, the exposure conditions generated by surrounding wildland fuels, nearby structures or other system-wide factors and the subsequent response of WUI structures and communities are not well known or well understood. Several key pathways into structures, such as eaves, vents, windows, roofs and decking have received attention and limited study, but no effort has been made to compile all available data quantitatively for use in an applied, risk-informed framework.

A thorough literature review of multiple pathways to ignition and their requisite exposure conditions in WUI communities has been performed, along with a gap analysis to identify data needed to inform prevention and protection strategies. Information has been compiled from a wide array of resources, including archival publications, conference papers, research reports from academia and federal agencies, case studies and investigative reports from WUI fire incidents, existing codes and standards, and interviews with leading incident commanders and fire researchers. These studies have been compiled from local (US) resources, as well as international sources in North America, Europe, Asia and Australia who have amassed a wide variety of experience on these topics.

After reviewing the available literature, many areas related to pathways for fire spread in the WUI were found to still be in need of additional research. As part of a gap analysis, these areas were broken down into those related to quantification of risk and hazard and more practical and specific issues. Areas necessary to inform quantification of risk and hazard included pre- and post-fire data collection, improved testing of firebrands, understanding of ember and wildland fire fundamentals, and improved understanding of structural ignition mechanisms. There are also many other practical issues, which relate to specific areas of code and standard development and WUI community protection or firefighting that are in need of rapid research and development. These included understanding fuel management, defensible space, community planning, development of test standards, design of ignition-resistant materials, assessing the effectiveness of mitigation strategies, understanding the impact of wildland fires on health and the environment, improving firefighting techniques and identification of educational needs.

These categories represent a wide spectrum of subjects within possible WUI research. One of the most important gaps identified through this review is that most work to date has not *quantified* effects in a repeatable manner. While it is useful to identify vulnerabilities and best practices, protection of WUI communities cannot evolve without more quantitative analyses to optimize protection schemes, standards and risk and hazard analyses. Improved dissemination of literature, especially through more peer-reviewed studies will also enhance the technical credibility and wide dissemination of work on the field.

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PART I: LITERATURE REVIEW

Introduction

Three fundamental pathways have been identified for the spread of fire into and within WUI communities. First, radiant exposure may occur where large flames are close to exposed structural elements. The effect of radiation can often be minimized or eliminated through proper vegetation selection, location and management and defensible space around structures (the home-ignition zone, HIZ); however, the influence of other nearby structures and their impact on radiant exposure must be taken into account (e.g. conflagrations where fires spread from home to home within a community) (Calkin et al., 2014). Second, direct flame contact exposure, which occurs between flames from smaller fires and adjacent structural elements, such as litter or wood piles, can be mitigated by creating a similar defensible space around structures, entirely clear of combustible material. Third, fires may spread into and within a WUI community via the transport of firebrands (also called burning embers or brands[1]) generated either by the main fire front, nearby flammable material (e.g. vegetation) or nearby burning structures (e.g. conflagrations) (Pellegrino et al., 2013). Protection of structures must therefore incorporate all of these potential sources of ignition, as well as incorporate the cumulative effects of fires on nearby surrounding structures within the community contributing to overall fire spread. This framework has been utilized in this literature review. Part I of this report breaks down these potential pathways into research and knowledge on potential exposures to structures and the response of structures to these exposures. They deserve equal importance, particularly because recent data indicates that at least 50% of ignitions, if not more, occur due to indirect exposure, i.e. firebrands (Mell et al., 2010).

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[1]The terms brand, firebrand, flaming brand, flying brand, burning brand, ember, flying ember, or burning ember are used synonymously in the literature to denote small pieces of burning vegetation or structures (whether smoldering or flaming) lofted into the fire plume and transported ahead of the fire front. The terms firebrand or burning ember are therefore used synonymously throughout this report. Similarly, an ember "storm" or firebrand "shower" denotes a large flux of small burning particles lofted through the air, whether produced by a fire front or artificially in a laboratory.

While the underlying ethos of fire spread is known, quantitative knowledge of the effectiveness of specific approaches for risk mitigation and prevention within WUI communities, especially coupled to relevant exposure conditions and homeowner maintenance, is not well known. Spearheaded by the California fire season of 1985, a joint initiative by the NFPA and the USDA Forest Service (USFS) highlighted the WUI problem and generated initial research into the problem (NFPA, 2014; Firewise, 2015). As a result, several research projects on the radiative exposure of building assemblies to large wildland fires were begun, with large-scale testing performed during the International Crown Fire Modelling Experiments from 1997-2001 (Cohen, 2004a). From these experiments, it was determined that when a clear, defensible space of 120 feet (36 m) was maintained around a structural facade, radiative exposure was insufficient to ignite wooden exterior walls from experimental crown fires, meaning that only firebrands or local combustible material (e.g. mulch) could ignite a structure. Recent analysis of the Angora fire (2007) has shown that fuel treatments that reduced the fire intensity beyond the HIZ were not effective in reducing WUI losses (Murphy et al., 2007; Safford et al., 2009). Therefore particular attention must be paid to more local, low intensity fires and the source of local ignitions (from firebrands) (Calkin et al., 2014). While different frameworks for wildfire risk assessments are available (Cohen, 2004a; Maranghides and Mell, 2013), the existing framework only allows qualitative predictions of radiative exposure. Significant assumptions are made when using many of these tools, such as ignoring firebrands and assuming that fires will occur under ordinary fuel and weather conditions, when realistically it is only the most extreme fires (high winds and low humidity) that challenge current methods of fire control (Calkin et al., 2014).

More recent efforts by the National Institute of Standards and Technology (NIST), USFS and the Insurance Institute for Business & Home Safety (IBHS) have identified clear vulnerabilities of WUI structures to low intensity fires and firebrands, including roofing components, eaves, vents, wood piles, mulch, fences, decks, etc. (Calkin et al., 2014; Mell and Maranghides, 2009; Pellegrino et al., 2013a; Quarles et al., 2012). While a significant body of work exists on the transport of embers or firebrands (Tarifa et al., 1965; Woycheese et al., 1999), limited knowledge exists on quantitative ember exposure, ignition properties or vulnerabilities of structures to embers (Hadden et al., 2010; Manzello et al. 2006a,b). The development of a testing platform, the NIST Dragon (Manzello et al., 2012a), and several detailed investigations (Cohen, 2000a; Cohen and Stratton, 2008; Maranghides et al., 2013; Mell and Maranghides, 2009; Quarles et al., 2012) have been particularly significant in developing an understanding of large-scale ember ignition. The arrangement of homes and layout of communities (land-use planning) also greatly affects the probability of ignition in WUI communities (Syphard et al., 2012). Some gaps in knowledge are being studied, so recent progress is reviewed here; these gaps include the rate of generation of embers from natural fuels and structures, the effectiveness of local fuel treatments on reducing fire intensity and, in particular, homeowner maintenance of their home and property, including the impact of community education. Many more gaps will be identified, as the effectiveness of strategies to minimize the impact of WUI fires, such as new regulations in California, have yet to be documented.

While this report will focus on fire spread in the WUI, there is no way to constrain such a review to physical factors alone. For example, appropriate planning and continued maintenance of fuel treatments on both public and private land is essential for some of these mitigation strategies to remain viable. Available knowledge on the maintenance of these efforts, specifically of defensible space by homeowners will be addressed, as will the impacts of community efforts, such as Firewise, Fire Adapted Communities, Ready Set Go!, etc.

WILDLAND-URBAN INTERFACE PROBLEM

Even though the term "wildland-urban interface" generates the perception of a problem that is determined primarily by geographic location, the WUI problem can be more simply envisioned as a *structure ignition problem* (Cohen, 2004b). If structures are safeguarded against ignition sources, property loss and costs incurred (not to mention potential loss of life) can be avoided. Changes in the location of a structure (specifically surrounding fuel and topography) can certainly affect the exposure conditions which impact any structure; however, if the pathways to ignition are fundamentally prevented via hardening structures, communities and surrounding wildland, then the WUI problem can be greatly reduced. This report will detail many of the pathways that fires can spread into and within a WUI community with the aim of preventing future WUI tragedies via informed decisions in codes, standards, future structure and component design, remodel/renovation of existing buildings and community planning.

The definition of what community areas are WUI and not often encompasses a comparison of the housing density and location of surrounding wildland (Cohen, 2008). The WUI can be defined as encompassing both interface and intermix communities, where vegetation is continuous in the intermix, except where structures are located, and less contiguous within the interface. Many studies have worked to define this interface boundary and map it (e.g. Figure 1); however, this will not be a focus of this report and can be found elsewhere (Lampin-Maillet et al., 2010; Radeloff et al., 2005; Stewart and Radeloff, 2007).

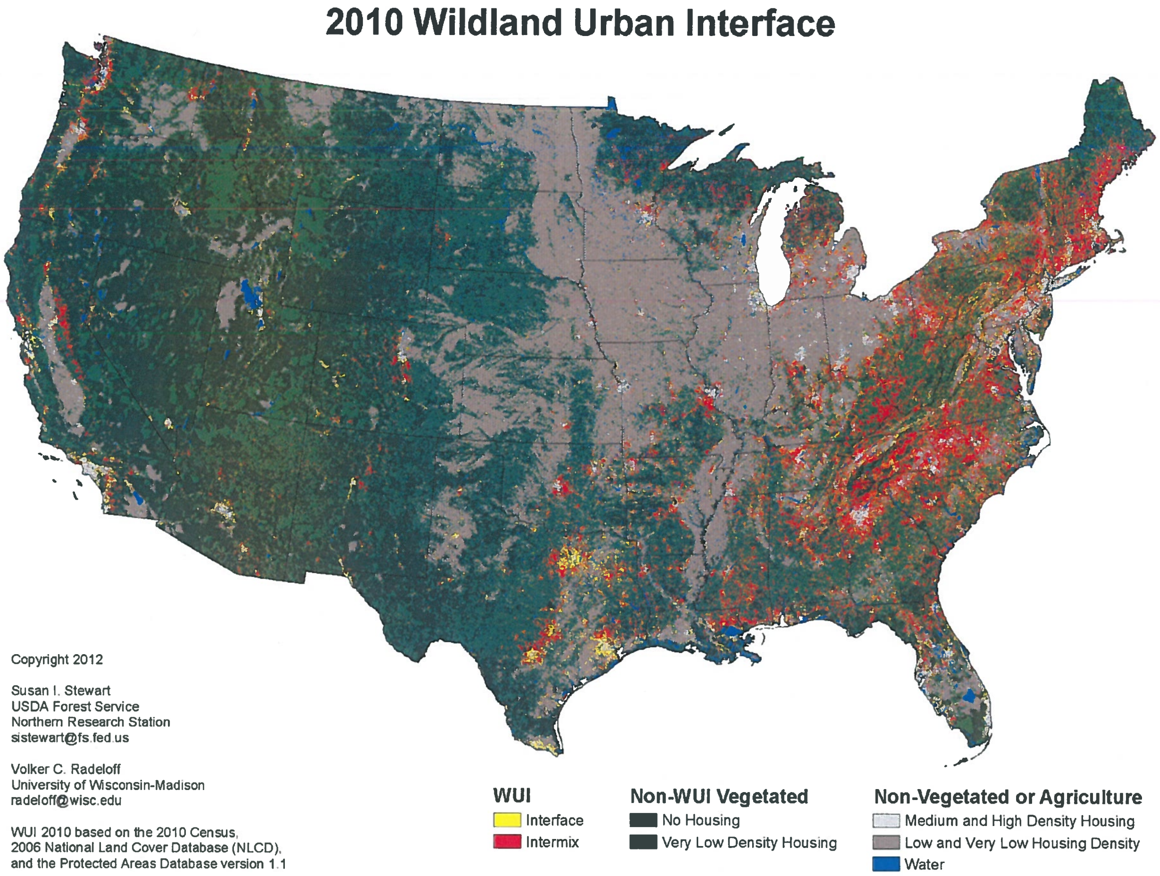

Figure 1: Map of the wildland-urban interface in 2010 (Radeloff et al., 2005 and Radeloff, 2014).

Fires in the WUI are not a new problem, but perhaps just a problem that has been more recently forgotten. During the same week as the Great Chicago Fire in 1871, the Peshtigo Fire killed between 1500 to 2500 people and burned somewhere around 1.5 million acres, completely destroying twelve communities (Brown, 2004). Comparing that to the Great Chicago Fire, which killed about 300 people and burned down only 3.3 square miles, shows the extent by which these events differed. Despite the tragic toll of the Peshtigo fire, it is rarely mentioned, while the anniversary of the Great Chicago Fire is still used as a catalyst for NFPA's Fire Prevention Week every year (NFPA, 2014a). The Peshtigo Fire and subsequent fires between 1896-1910 served as catalysts for the "fire exclusion" movement – a push for fire control and suppression of wildfires largely led by the USFS (Pyne, 2008).

Despite this long history of fire suppression in the United States, the frequency and severity of wildland fires has continued to increase, especially recently. Large WUI conflagrations such as the 1991 Oakland Hills Fire, the 2012 Waldo Canyon Fire and the 2003, 2007 and 2014 San Diego Firestorms have served as constant reminders of the threat large wildland fires pose in the WUI. Recent data show that 3% of the wildland fires in the United States are now responsible for 97% of the area burned (Short, 2014). Following decades of intense wildfire suppression policies, large areas of unburned fuels have built up in the wildland and contribute to the growing size and intensity of wildland fires. Known as the fire paradox, wildfire suppression meant to eliminate large and damaging wildfires has in turn ensured the inevitable occurrence of these fires (Arno and Allison-Bunnell, 2002). According to some studies, over 73 million acres of national forest land meet high priority for treatment of fuel buildup in WUI areas (Service & Bosworth, 2004). On top of this, a mass movement from urban residences to rural communities has increased the size of the WUI, where natural or modified wildland fuels meet traditional structures including residences, businesses and other community structures. This transition has increased the number of at-risk risk homes significantly. In 2000, WUI development was estimated to cover 465,614 km^2, an expansion of 50% from 1970 (Theobald and Romme, 2007). In the western United States, 50% of future housing development is estimated to occur in the WUI (Gude et al., 2008), highlighting a massive increase in future WUI lands. With only 14% of the interface developed, firefighting costs are now between $630 million and $1.2 billion/year. It is projected that if 50% of the interface is developed, the cost would range from $2.3 billion to $4.3 billion/year. These costs could make up nearly the entire annual budget ($4.5 billion in 2008) of the USFS, so improved land-use planning is critical (Gude et al., 2008). An illustration of this problem is presented in Figure 2, which shows a map of structures lost to wildfire in the United States from 1999-2011.

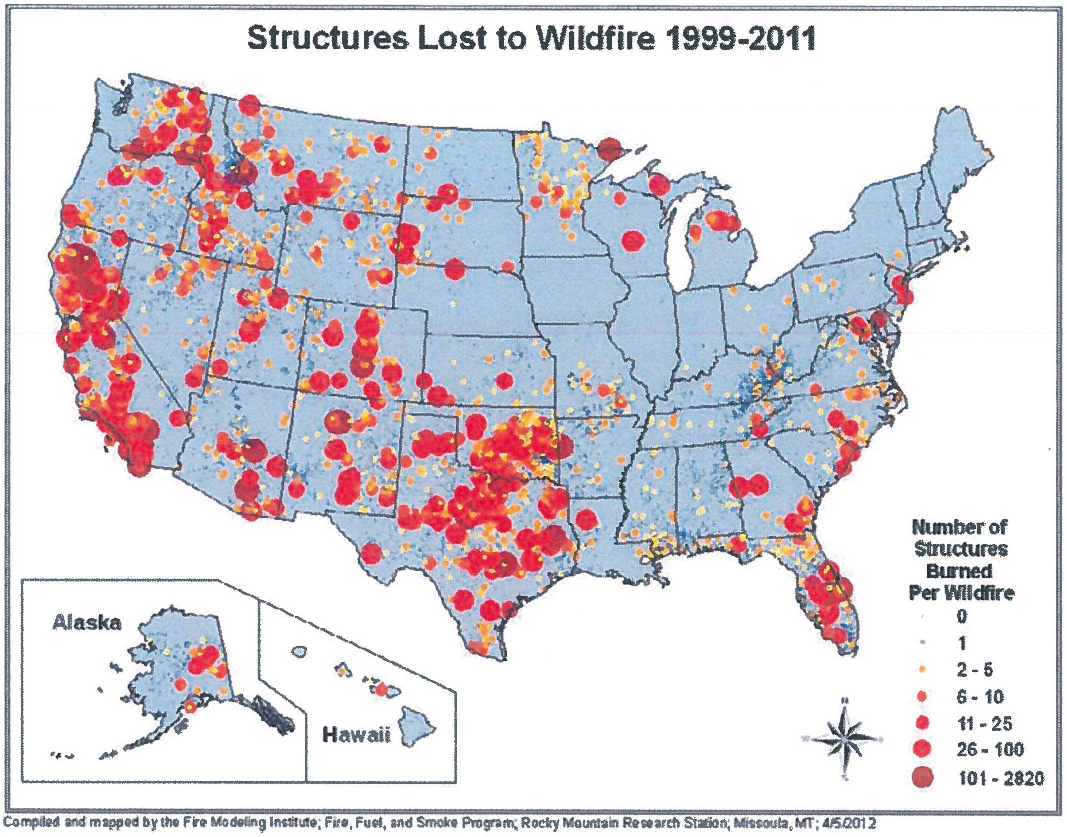

Figure 2: Map of structures lost to wildfire in the United States between 1999–2011. Data are limited to burned structures reported through the National Interagency Coordination Center database. Data source(s): Situation Report (SIT/209). Compiled and mapped by the Fire Modeling Institute, Fire, Fuel, and Smoke Program, U.S. Forest Service, Rocky Mountain Research Station, Missoula, MT, April 2012 (NIFC, 2015).

With the advent of more extreme fires becoming the norm (Figure 3), a different thought process must be taken in comparison to traditional structural firefighting techniques and risk assessments (Figure 4). In structural firefighting, the assumption for most occupancies is that the structural design of the building, passive fire protection systems and automatic fire protection systems will provide sufficient protection for the occupants to escape and for the fire department to enter the building to provide full extinguishment. In large WUI fires, many buildings burn down tens of hours after the main fire line passes through a community due to firebrand ignition. Firebrands and other smoldering debris slowly transition to flaming from innocuous sources that are difficult to identify, while the main fire front threatens new homes and communities miles away. These firebrands can also be transported several kilometers ahead of the front depending on atmospheric conditions; therefore, a large area is affected over which no firefighting crew has sufficient resources to cover (Koo et al., 2010). A different theory or approach to firefighting and structure protection must be envisioned to prevent future large scale losses. Current strategies for exterior fire protection in the WUI (e.g. homeowner checklists, mesh coverings for vents, etc.) pale in comparison to those developed for use within buildings (e.g. fire sprinklers, smoke detectors, fire retardant materials, etc.). One concept is to limit the pathways by which firebrands or other fire sources can penetrate a property or community and destroy a structure, a problem this report will shed further light on.

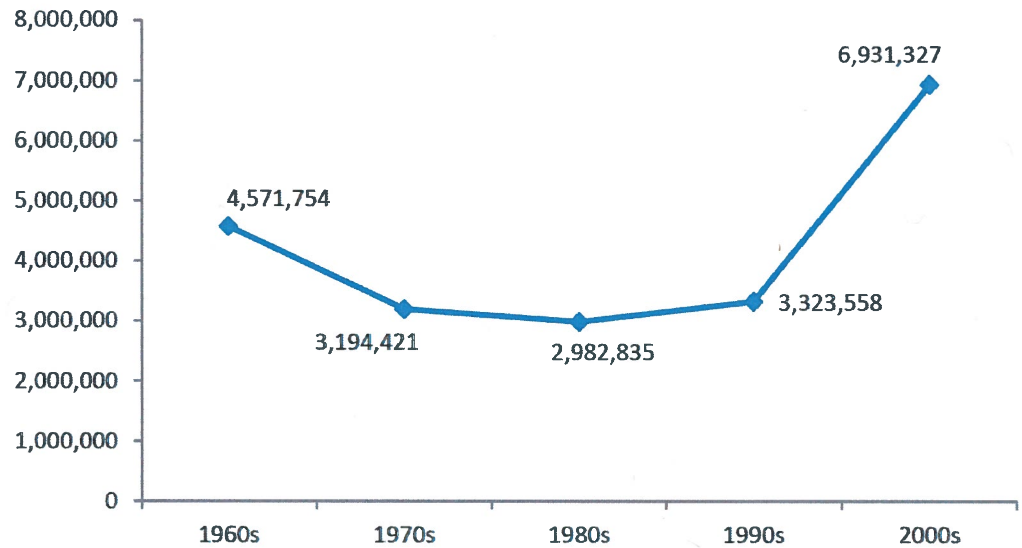

Figure 3: Average annual acres burned, by decade. Rising firefighter effectiveness and other factors steadily lowered the number of acres burned until the 1990s, when a slight rise was followed by a sharp increase in the 2000s due to fuel buildups and worsening fire weather conditions (USFS, 2013).

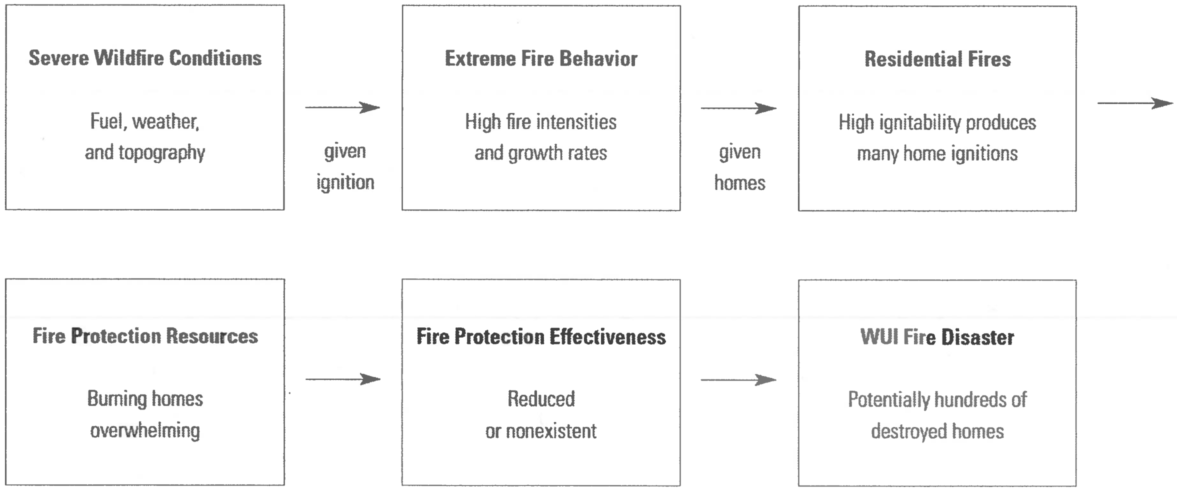

Figure 4: The WUI fire disaster context depends on exposure of vulnerable homes to uncontrollable, extreme fire behavior. If the number of burning and vulnerable homes overwhelms the fire protection capability, fire protection effectiveness is reduced, and many homes are left without protection. If homes are ignition-resistant then many homes do not ignite and fire protection is not overwhelmed by the ignitions that do occur. Thus, an extreme wildfire can occur without a WUI fire disaster (Cohen, 2008).

A higher occurrence rate of extreme fires also means that it will become important to assess incident fire severity based upon the most extreme weather conditions where high wind speed, low moisture content, etc. create challenging fire scenarios. This means that relying on historical fire and weather data will only be useful if some sense of the ecological fire regimes and drought patterns are taken into account.

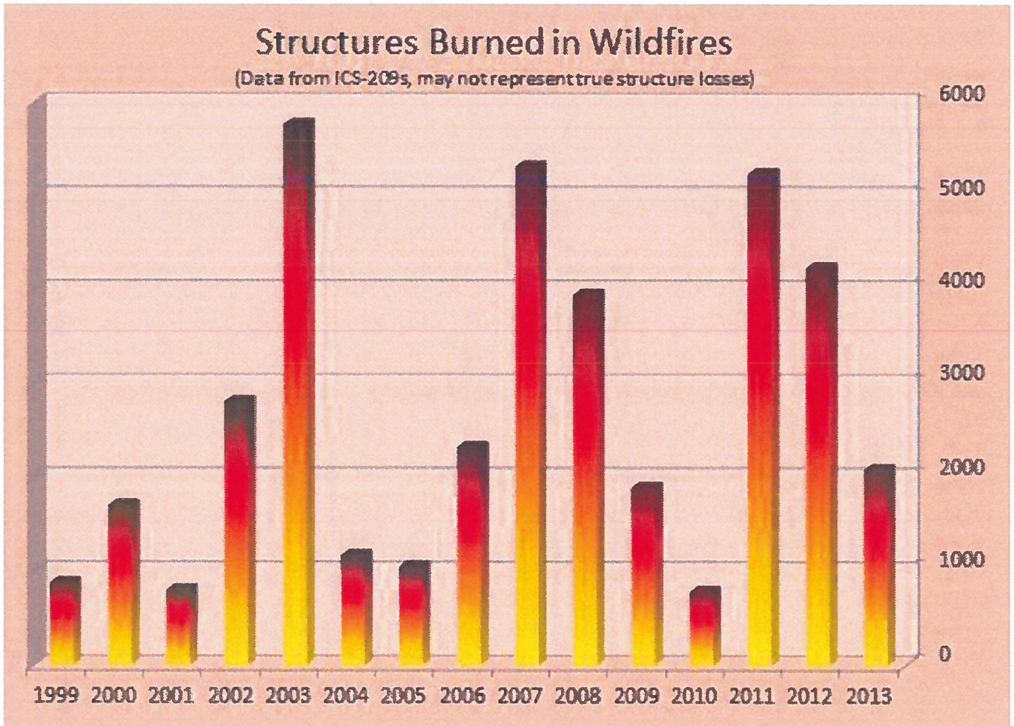

Figure 5: Historical data on structures burned in wildfires (from https://fam.nwcg.gov).

There are many means for improvement beyond direct structure protection. State laws addressing defensible space, ingress, egress, and water supply can create a safer environment for firefighters, resulting in more structures being saved (Gude et al., 2008). Many of these issues are already covered in NFPA 1141 and 1144; however, they could be improved with further knowledge including case studies and research. Data needed for quantitative risk analysis, such as wildfire exposure conditions or the reaction of components to these conditions, is severely lacking (Maranghides and Mell, 2013). Policies that address existing and future development in the WUI should be coupled with national, state, and local policies that address wildland fuel management (Gude et al., 2008).

As protection of property in the WUI has now become an increasing firefighting priority, firefighters are constantly endangered while striving to protect structures. In 2013, 97 firefighters died while on-duty. Of these, 28 of the deaths occurred at 10 separate wildland fires. An average of four wildland firefighters have died annually at wildland fires or prescribed burns in the years 2002-2012. In the most recent incident, the Yarnell Hill Fire killed nineteen members of a Hotshot wildland firefighting crew and huge media attention was focused toward the problem of safe WUI firefighting (Leblanc et al., 2014). This event was the largest single loss of life for firefighters since the September 11, 2001 terrorist attacks on the World Trade Center in New York (Manzello, 2014). Thought and planning for firefighter safety, including access to safety zones, adequate egress, etc. needs to be built into community planning (Butler, 2014).

While there still exists a large void in knowledge as to how future climate change might alter global wildland fire activity, most estimates suggest that severely altered fire regimes may increase fire activity in some regions, but reduce it in others (Krawchuk et al., 2009). Fire management policies may have to shift in the future as climate, rather than human intervention, plays a stronger role in driving fire trends than it has over the past two centuries (Pechony and Shindell, 2010). In the western U.S. in particular, a significant increasing trend in the number and size of wildland fires has been found between 1984-2011, with fires increasing by a rate of seven fires per year and 355 km^2 burned per year. These changes were most significant for southern or mountain ecoregions, with drought is a significant source of increased fire severity. (Dennison et al., 2014). While climate change may be a significant driver in making the wildland fire problem worse in some regions, proper forest management practices, such as prescribed burning, may actually help to combat the problem by both reducing the intensity of eventual fires and limiting net carbon emissions. Wiedinmyer and Hurteau (2010) estimated carbon sequestration by forest ecosystems from wildfires vs. prescribed burning, finding that 18-25% reductions in CO_2 emissions are possible in the western U.S. – with as much as 60% in specific ecosystems – by proper prescribed fire use and management practices.

EXPOSURE CONDITIONS

Fundamentally, ignition is the process by which a sustained combustion reaction is initiated. In WUI fires, a solid element is typically heated until the solid fuel releases enough flammable vapors to ignite with or without a spark (piloted or auto-ignition), releasing sufficient heat to sustain the flow of flammable pyrolysis vapors from the solid. Many times there are enough flaming sources in the vicinity of a large wildland fire to assume that piloted ignition will occur for worst-case hazard analyses. Exposure conditions are often studied to assess what thermal insult they can impart to building materials to cause them to ignite. Typically this thermal exposure is described in terms of a heat flux (rate of heat transfer, kW/m^2) and time to ignition, assuming sustained exposure to a certain heat flux.

Three primary categories can be used to describe the types of fire exposure typically imparted on structures in the WUI. The first is radiant exposure. Unlike convection heat transfer, which requires a moving fluid medium, radiation can travel relatively undeterred until impeded by a solid object, typically thought of here as the exterior of a home which may potentially ignite. As the separation distance from the home to the fire increases, the radiant exposure significantly decreases (proportional to one over the distance squared), eventually making it impossible at some distance to ignite. This analysis is often used for assessment of safe separation distances between structures and potential fuels.

Convective or conductive heating can become significant in WUI applications when heating from direct flame contact occurs. While flames of smaller sizes typically do not emit enough radiation for sufficient duration to ignite surrounding structural elements, they can cause ignition if they are close enough to impact a component for a significant duration. Due to the fact that most homes have some separation between the primary structure and a traveling fire front, direct flame contact typically occurs via secondary ignitions of smaller flammable vegetation, mulch, wood piles, forest litter, decks, plastic furniture or other flammable materials nearby or on the structure itself.

Finally, burning embers produced from vegetation or burned structures can contribute to home ignition through a variety of pathways. They can directly travel into buildings via openings such as vents, or they can ignite nearby flammable materials which proceed to ignite a home via direct flame contact or radiant exposure.

Radiant Exposure

Exposure of structural elements to radiant heating is probably the most-studied exposure condition from wildland fires. A significant body of literature is available on means of calculating radiant exposure from a fire (de Ris, 1979, 2000), and radiant ignition of a solid fuel has been understood theoretically (Liñan and Williams, 1972) and practically (Drysdale, 2011; Quintiere, 2006) for some time. Most early research on WUI therefore focused on radiant exposure to structures.

Before several initial studies in the 1980's, there was little data to support quantitative findings on the amount of radiant exposure possible from an approaching wildland fire. Initial studies utilized simplified models to determine the radiant exposure possible between an approaching wildland fire and a simulated wooden siding of a home (Cohen and Saveland, 1997; Cohen, 2004b, 1995; Cohen and Butler, 1998; Cohen, 2000b; Tran et al., 1992). Initial computational models were created to assess a worst-case separation distance, over-estimating the radiant heat flux that would come from an approaching crown fire (assumed to be a worst-case scenario) to incident wood panels (Tran et al., 1992); however, laboratory experiments showed that the model did not underestimate this distance (Cohen, 1995). These calculations estimated that approaching fires with very long flame lengths (e.g. crown fires) could ignite homes at most up to 40 m (130 ft) away. Beyond this distance, radiant ignition was deemed not possible, even from the most intense crown fire. More recent models of ignition of thermally-thick materials have also been performed, incorporating the movement of the flame front toward an exposed area over time (Reszka et al., 2012).

Later testing as part of the International Crown Fire Modeling Experiments between 1997-2000 (Stocks et al., 2004) exposed wooden wall segments to full-scale, active spreading crown fires with deep flame zones. The wall segments experienced both radiative and convective heating, as well as short-range ignitions from firebrands (Cohen, 2004b). The derived flux-time correlation identified two primary ignition criteria for wood: a minimum critical heat flux of 13 kW/m^2 and a critical heating dosage level which accumulates over time (Cohen, 2004b). Interestingly, actual crown fires did not transfer heat sufficiently to ignite these wood panels at distances beyond 10 m. This finding was significant, as no panels at 20 m (65 ft) or beyond ever ignited, and only half of the panels at 10 m (32 ft) from the edge of the fire ignited. High radiant heat fluxes were observed at panels 10 m from the fire (as high as 150 kW/m^2 for mere seconds); however, for panels 20 m or farther away from the fire, these fluxes never reached above 20 kW/m^2, often a limiting heat flux for ignition of wood (though still enough to cause severe burns to human skin (Stoll and Chianta, 1971; Cohen, 2004b). Some of the factors contributing to this low heat flux were that the tree canopy attenuated some flame radiation and that flames were not continuous at their peak, but rather intermittent and exhibited multiple gaps in the flaming front which reduced the ultimate radiant exposure (Cohen and Butler, 1998). Although the experimental conditions were not those that are presented in extreme wildfires due to differences in weather, fuels, and topography, these experimental fires were fully-involved crown fires with significant flame lengths and radiation. In essence, this experiment signaled that unless flames or firebrands ignite close to a structure, the structure is not likely to ignite (Cohen, 2000b).

As the fires tested by Cohen et al. were under a limited set of relatively mild conditions, continuing work is being done to instrument more wildland fires in order to measure heat fluxes and imposed conditions during a fire. NIST has developed deployable instrument packages and tested them with a small shed-like structure placed within a wooded area (NJ Pine Barrens) for a prescribed fire, measuring heat fluxes of up to 100 kW/m^2 (Manzello et al., 2010b). Many other studies, primarily conducted by the USFS in large wildland fires, both prescribed and uncontrolled, have used instrument packages to measure radiant heat fluxes, among other quantities (Frankman, 2013).

For fires of many sizes, flame lengths and fire intensity can be determined using standard fire behavior modeling tools from the wildland fire community (e.g. Rothermel and Forest, 1972). These tools can be used in similar ways to studies by Cohen to determine radiant heat fluxes for different exposure conditions of fuel, topography, weather, humidity, etc. and different separation distances (Tran et al., 1992). These calculations often offer the farthest distance flammable vegetation should be located near the home. More information on material available to estimate these will be covered under direct flame contact, fire behavior.

Direct Flame Contact

Very little work is available in the literature about direct flame contact specifically applied to the WUI; however, there is a broad base of traditional wildland fire literature which describes flame lengths of vegetative fuels under various ambient conditions[2]. Direct flame contact would not typically be considered a direct source of ignition of a structure when brush and other wildland fuels are cleared away; however, it can be a secondary source from nearby burning material, including vegetation and non-vegetative combustible materials (mulch, wood pile, etc.). Heat fluxes by direct flame contact can be as high as 50-70 kW/m^2 for laminar flames (Ito and Kashiwagi, 1988) or 20-40 kW/m^2 (Quintiere et al., 1986) for turbulent flames, sufficient to ignite some components of a structure (Quintiere, 2006). While these heat fluxes are very high and can produce short ignition times, flames must directly contact building or structural materials long enough to cause ignition. Typically direct flame contact does not occur from the main fire front unless extreme conditions are present; rather ignition of combustible materials on or near a structure cause the structure to ignite and burn.

Fire Behavior

The steady rate of spread (ROS) is an especially relevant parameter for WUI purposes, both because it signals the rate at which a fire will spread toward a community through wildland fuels, and also because the ROS can be related to the fireline intensity and flame length of the fire at the moment of arrival. The fireline intensity (kW/m), comparable to the heat-release rate per unit length used in fire protection engineering, can be determined from the steady ROS via Byram's correlation. This quantity is simply derived by multiplying the ROS by the heat content of the fuel and the fuel load consumed in the flaming front (Byram, 1959). This quantity can then be related to the flame length via correlations by Byram for surface fuels (Byram, 1959) and Thomas for crown fuels (Thomas, 1963). Flame lengths can be useful in estimation of radiant heat fluxes from approaching fires to ignite structural components (Cohen, 1995). It should be noted that it is difficult to interpret flame length values for deep fuel beds.

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[2] Some codes and standards, such as the California State Fire Marshal standards associated with the California Building code Chapter 7A, have a flame contact exposure component (CBC, 2009).

Several numerical modeling tools are also available to calculate these parameters. Based upon these same quantities, BEHAVE Plus can calculate one dimensional fire properties such as ROS, fireline intensity and flame length (Andrews et al., 2003). FLAMMAP is available to spatially calculate these values over a geolocated map (Finney, 2006b). FarSITE can then calculate these parameters temporally to provide predictions of fire spread (Finney, 2004). All of these tools are available through the USFS at http://www.firelab.org/.

Other tools are available in other countries. In Canada, most models utilize the Canadian Forest Fire Danger Rating System (CFFDRS) (Stocks et al., 1989), which is based on significant fundamental work by Van Wagner (Van Wagner, 1977). In Australia, models are based on McArthur (1966a,b) for grasslands and McArthur (1967) for eucalypt forests in their fire rating danger system. These models mainly consist of purely empirical correlations of observed fire behavior at field scale, with data augmented by well documented wildfires. Cheney and Sullivan more recently replaced MacArthur grassland FDRS as the preferred tool for grassland fires (Cheney and Sullivan, 2008). Reviews of available models worldwide, including physical and quasi-physical models (Sullivan, 2009a), empirical and quasi-empirical models (Sullivan, 2009b) and simulation tools (Sullivan, 2009c) have been prepared.

When performing predictions of future fire behavior, it is important to follow proper protocols when estimating the extreme wind and weather conditions that could be expected, as well as the fuel loads around structures and communities. Fuel loading and terrain features are especially important for predicting fire behavior and explaining post-fire effects for any fuels treatment meant to decrease fire severity (Hood and Wu, 2006). A how-to guide for using models in the United States is available (Scott, 2012).

While the rate at which a fire spreads is generally determined from correlations, a special effect in steep terrain with canyon walls, sometimes called eruptive fire behavior, has also been documented in the literature (Viegas and Simeoni, 2010). This effect, similar to the trench effect found in urban fires (particularly the 1987 King's Cross fire in London), can extend flame lengths significantly, cause flames to attach to the surface and drastically increase rates of flame spread. While several models are available to describe this effect (Viegas, 2004), these models are designed for firefighter safety, rather than WUI design. Nonetheless community designers should keep this effect in mind when designing placement of structures or escapes, as large inclined canyons with significant fuel loads could cause enhanced flame lengths and rates of spread that are not properly accounted for in other models. This situation could not only endanger structures and occupants, but also be a safety hazard for responding firefighters.

Despite a wide availability of literature on the fire behavior of traditional vegetation under a range of conditions, these models are almost all semi- or fully-empirical approximations of observed phenomena fitted to specific fire conditions. Without a firm physical basis of fundamental heat transfer and combustion processes that drive spread, these models may break down under untested conditions, in particular under extreme fire conditions (Finney et al., 2013). For safety reasons, these extreme conditions cannot be tested during large experiments, such as prescribed burns, despite the fact that extreme fires (high winds, high fuel loads and low moisture contents) are responsible for the majority of devastating wildland and WUI fires. Models also seem to be unable to predict thresholds of fire spread, such as the initiation, acceleration or cessation of fire spread (Finney et al., 2010), which becomes significant when modeling potential effects of firebreaks. Spyphard et al. has indicated it would be useful to have a fire model which accurately determines effectiveness or size of needed fuel break, but such models are unavailable (Syphard et al., 2011a). Finney and co-workers have highlighted these and many other problems with current models (Finney et al., 2013) and recently implemented some work toward resolving these discrepancies (Finney et al., 2010; Finney et al., 2013; Gorham et al., 2014); however, until the results of this and other work are finished, current models should be used with the understanding that their results are not 100% accurate, but provide the best estimates of fire behavior available today. It is important to also remember that these models have been developed for steadily-spreading wildland fires, not for fires spreading through WUI communities. In WUI communities, there are various structures that contribute to the fuel load and may affect spread parameters, although investigation by NIST has indicated that rates of spread in the WUI are lower than in surrounding vegetative fuels (Maranghides et al., 2013).

Firebrands

Firebrands, also called burning embers, are now thought to be one of the primary sources of ignition in the wildland-urban interface. They present hazards because they can either directly ignite components of vulnerable structures or can ignite nearby vegetation and other combustibles which can subsequently ignite the structure via radiant heating or direct flame contact (Quarles, 2012). There does not appear to be a consensus on the percentage of ignitions caused by embers, primarily because it is difficult to determine after-the-fact what caused each individual home or structure to burn down during a fire. There are "hints" though in structures that burned down. IBHS suggests that the majority of buildings in WUI fires are ignited through embers (IBHS, 2014). In many fires, such as the Witch Creek and Guejito fires, firebrands are a major threat to homes; ignition from these firebrands may depend upon the conditions of the fire. Examples of clear ember ignition of homes during the Angora fire are shown in Figure 6 and Figure 7, where spot fires independent of the main fire front were observed to ignite a home and small vegetation fire, respectively. Later sections of the report will review specific vulnerabilities of structures to firebrand ignition, but existing knowledge on the generation, transport and physical mechanisms of transition to flaming will be reviewed here.

There are questions as to how much detailed knowledge of firebrand production, transport and ignition will assist future prevention efforts. Model building, perhaps statistically, is a prominent idea. In the end, worst-case scenarios must become the focus of all risk modeling efforts as the most extreme fires are the ones causing WUI problems. Characterizing this worst case firebrand flux—how far embers can travel and their likelihood of igniting different materials — is needed to inform these risk modeling efforts.

Firebrands by firebrands is most often a chance event, making it difficult to represent using traditional fire models. Still, a probabilistic approach to the problem is possible. Reviews by Babrauskas (Babrauskas, 2003), Koo (Koo et al., 2010) and Manzello (Manzello, 2014) should be referenced for further information beyond relevant details provided here.

Figure 6: A destroyed home following fire spread from the Angora fire. Note the intact, unburned vegetation surrounding the structure. Murphy et al. notes that this house was ignited by wind-blown firebrands, not by surface fire spread or radiant heating (Murphy et al., 2007).

Figure 7: A small spot fire produced by firebrands next to a burning house during the Angora Fire from (Murphy et al., 2007).

Firebrand Production

It is important to understand the size, distribution and flux of firebrands to burning buildings, in order to potentially help in the prediction of spotting or home ignition distances. In models of firebrand transport, there is often an assumption of the size and shape of burning brands, which might not be representative to the type of firebrands actually experienced/received.

Waterman was among the first to study firebrand generation, focusing on generation by burning roof constructions on complete homes (Waterman, 1969). Brands were collected via a screen trap and quenching pools under conditions which varied the wind and heights of buildings. The firebrands collected tended to primarily be disc-shaped, a shape later used in several studies of firebrand transport (Pagni, 1999).

Figure 8: Digital photographs showing samples of the firebrands collected as a function of tree size and moisture content. (left) Douglas-fir with tree height 5.2 m, moisture content 20%. From (Manzello et al., 2007). *(right) 4 m Korean Pine with moisture content 13%* (Manzello et al., 2009).

For vegetative fuels, laboratory tests have been performed to collect firebrands off 2.6 to 5.2 m tall Douglas-fir trees at NIST. The average firebrand size for the 2.6 m Douglas-fir trees was 3 mm in diameter and 40 mm in length. The average size for the 5.2 m tree was 4 mm in diameter with a length of 53 mm. Firebrands with masses up to 3.5 to 3.7 g were observed for the 5.2 m tall tree. The trees did not produce firebrands without wind if the moisture content was greater than 30%. All firebrands were cylindrical in shape and the surface area was directly related to the mass of the brands, as shown in Figure 8 (Manzello et al., 2007).

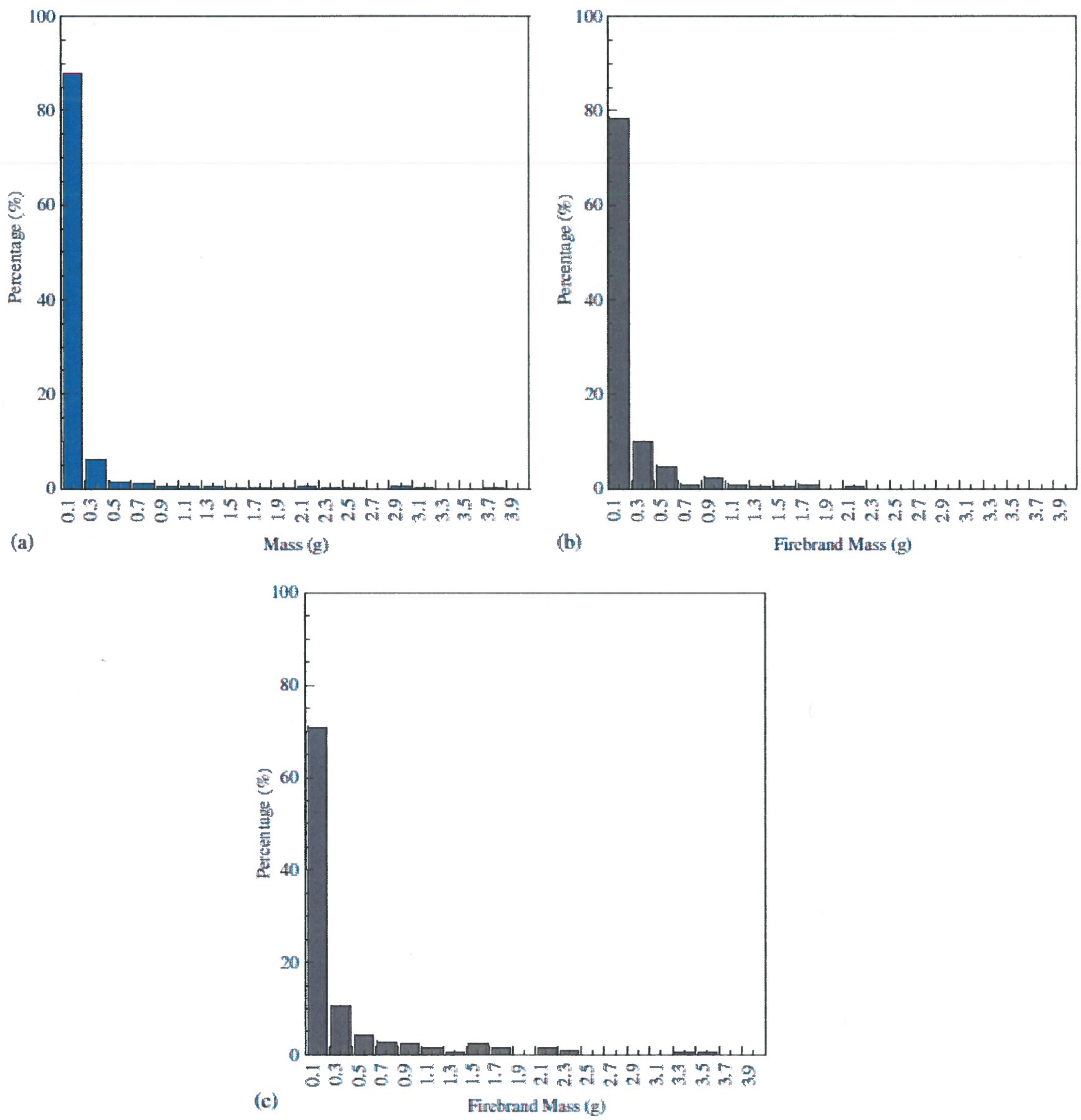

Figure 9: The mass distribution of collected firebrands from (a) 4 m tall Korean pine trees (Manzello et al., 2009) *and (b) 2.6 m tall Douglas-fir and (c) 5.2 m Douglas-fir trees from* (Manzello et al., 2007).

Later experiments performed by Manzello et al. (2009) at the Building Research Institute (BRI) in Japan investigated Korean Pine under varying wind and moisture conditionsTrees were all 4 m tall and moisture content was varied between 10 to 100% on a dry-mass basis. Collected firebrands were cylindrical in shape, similar to experiments on Douglas-fir (Manzello et al., 2007). The average firebrand size was 5 mm in diameter and 40 mm in length. A summary of the mass data collected is provided in Manzello et al. (2007) and Figure 9.

Experiments have been performed to measure the mass and size distribution of firebrands produced downwind from a burning structure as well. It is thought that structures may contribute firebrands of different mass and size distributions than burning vegetation. The earliest documented studies are by Vodvarka, who measured firebrand size and transport distances following five full-scale experimental building fires (Vodvarka, 1970, 1969). Similar to more recent studies, small firebrands dominated the distribution with 89% of the firebrands smaller than 0.23 cm^2. In two of the building fires, a majority of the firebrands deposited were located at a single location downstream, with one sheet used to measure the firebrand distribution receiving over 97% of all deposited brands.

Yoshioka et al. performed experiments in a large wind tunnel where a crib fire ignited a burning house and firebrands from the two fires were collected at the outlet of the wind tunnel in trays with and without water (Yoshioka et al., 2004). A later test was performed by Suzuki et al. (2012) on a controlled burn of a structure in California. They found that the majority of firebrands were produced from the structure during burning, not during application of water to the structure. In this test, 95% of the firebrands were collected about 18 m from the structure and 96% of those collected from about 4 m from the structure had less than a 10 cm^2 projected area[3]. The results from Suzuki et al. (2012) are compared to previous studies by Vodvarka (1970, 1969) and Yoshioka et al. (2004) in Figure 10.

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[3] The results of Suzkuki et al. (2012) does not provide explicit description of the "hose stream" applied to the house during burning, however it appears from photographs in the article that straight stream was applied over the house so as to wet it but not directly impact the structure.

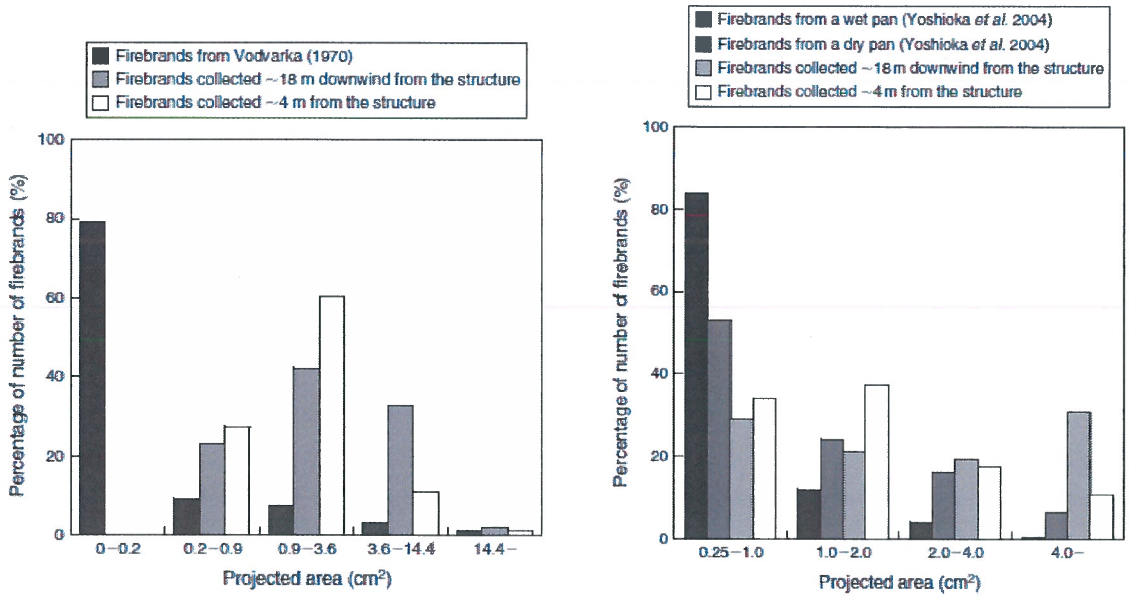

Figure 10: A comparison of the mass distributions of firebrands from (left) Vodvarka (Vodvarka, 1970) versus two collection distances from Suzuki et al. (Suzuki et al., 2012) and (right) mass distributions from Yoshioka et al. (Yoshioka et al., 2004) vs. two collection distances from Suzuki et al (Suzuki et al., 2012).

In a more recent study, Suzuki et al. burned full-scale structures at the Building Research Institute's (BRI) Fire Research Wind Tunnel Facility (FRWTF) in Japan with a 6 m/s wind (Suzuki et al., 2014). More than 90% of the generated firebrands weighed less than 1 g and 56% weighed less than 0.1 g. The mass distribution was similar to previous studies; however, different firebrand collection strategies were shown to induce some small differences between this study and previous studies, as shown in Figure 12. The relationship between a firebrand's projected area and mass was also very well supported in this laboratory study (Figure 11), confirming previous observations form burning vegetation and structures. Another study by Suzuki et al. also tested the ability of isolated building sidings both perpendicular to imposed wind and in a re-entrant corner configuration to produce firebrands, developing mass distribution results very similar to full-scale structure experiments (Suzuki et al., 2013).

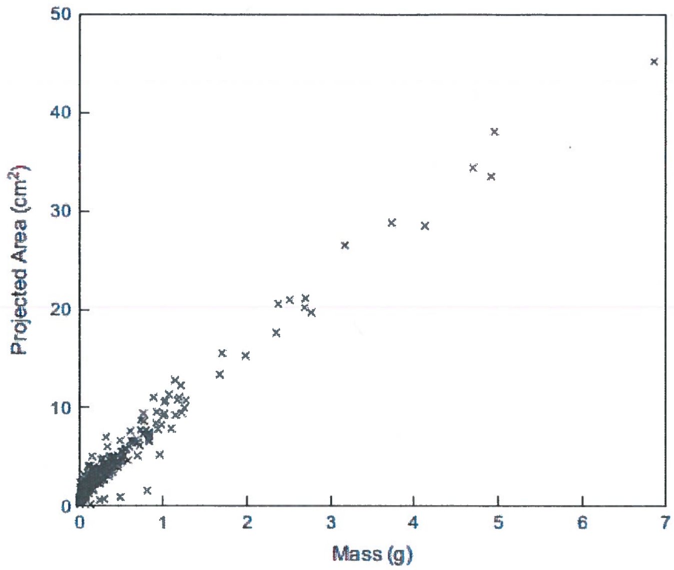

Figure 11: Correlation between the projected area of collected firebrands versus the mass of the brands under controlled laboratory conditions from a burning structure from (Suzuki et al., 2014).

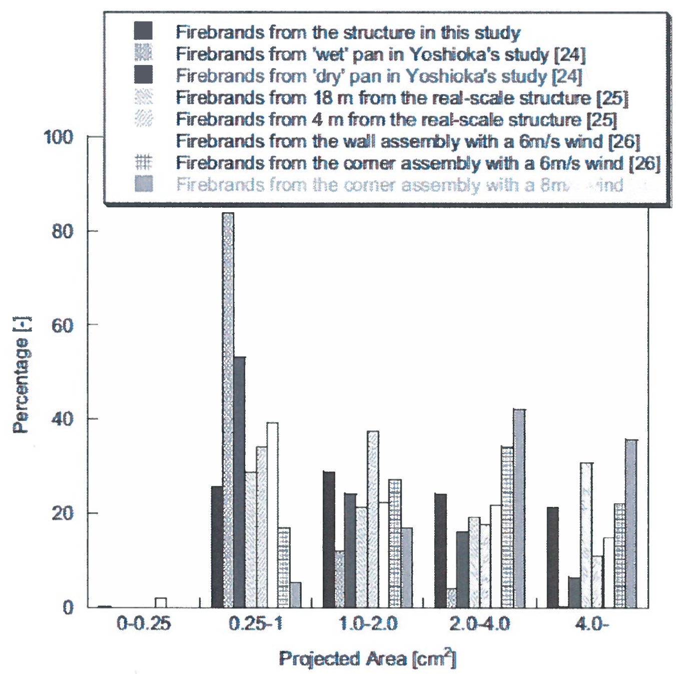

Figure 12: Firebrand size distributions from a structure in a well-controlled wind tunnel from (Suzuki et al., 2014) compared to previous studies by others (Suzuki et al., 2013, 2012; Yoshioka et al., 2004).

Foote et al. (2011) examined the size distribution of firebrands during the Angora Fire, a severe WUI fire in California in 2007 (Foote et al., 2011). Nearby fuel mostly consisted of White Fir and Jeffrey Pine with a heavy understory surface fuel loading[4]. Some shaded fuel breaks were present nearby collection locations. In the study, a trampoline, which was exposed to wind-driven firebrands during the fire, experienced melted "burn holes" from firebrands and served as a representative source for observation of firebrand size and density over an area throughout passage of the fire. The trampoline had an area of 1.5 m^2 with over 1800 burn holes analyzed by digital photographs. The largest hole in the trampoline had a 10.3 cm^2 burned area, while more than 85% of the burned areas were from firebrands less than 0.5 cm^2 and more than 95% were from firebrands with an area of less than 1.0 cm^2. In addition to the trampoline data, burn patterns were observed on building materials and plastic outdoor furniture at 212 individual locations on or near numerous Angora Fire buildings. A large majority of these firebrand indicators were less than 0.40 cm^2, with the largest being 2.02 cm^2.

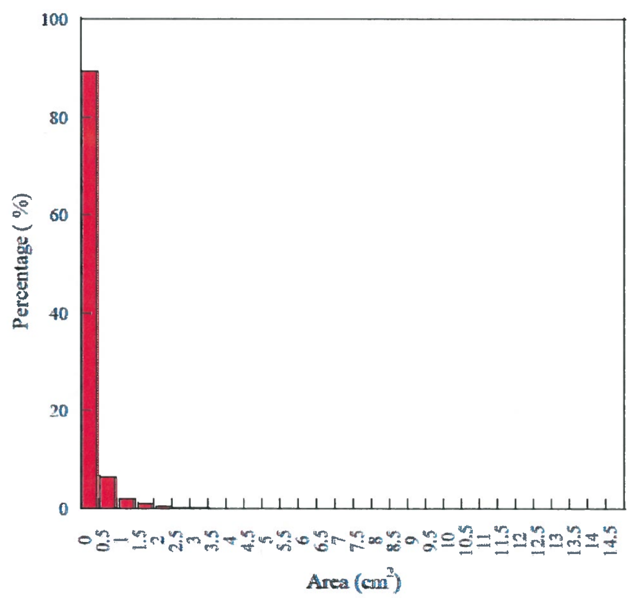

Figure 13: Distributions of the area burned measured from holes in a trampoline following the Angora fire from (Foote et al., 2011).

Limited data is available on the production of firebrands from structures within real wildland fires. Firebrands were observed coming off of a test structure during experiments by NIST and the USFS at a prescribed burn in the New Jersey Pine Barrens, but no quantitative measurements were made (they were observed to be produced via video) (Manzello et al., 2010b). Future tests

[4] See Murphy et al. (2007) for more information on fuel loading.

in the Pine Barrens by groups at the USFS and the University of Edinburgh are ongoing and should be released in the future, but have not been made publicly available yet (Simeoni et al., 2014).

The NIST Firebrand Generator (NIST Dragon) has been instrumental in the testing of many building components, as it is able to continuously produce constant size distributions of wind-driven firebrand showers consistent with previous studies reviewed above (Manzello and Foote, 2014; Manzello et al., 2009; Manzello et al., 2007). The majority of firebrands produced in the apparatus are less than 0.5 cm^2, in close correlation to results from vegetative and building firebrand studies (Manzello and Foote, 2014; Manzello et al., 2009; Manzello et al., 2007). The NIST firebrand generator has been used in Japan at the BRI FRWTF, where experiments can be performed with wind speeds up to 10 m/s in a wind tunnel with a cross section of 4 m by 5 m and a test section length of 15 m (Manzello, 2014). Versions of this apparatus have been produced at IBHS, Underwriters Laboratories (UL) in the United States and at Association for the Development of Industrial Aerodynamic (ADAI) in Portugal.

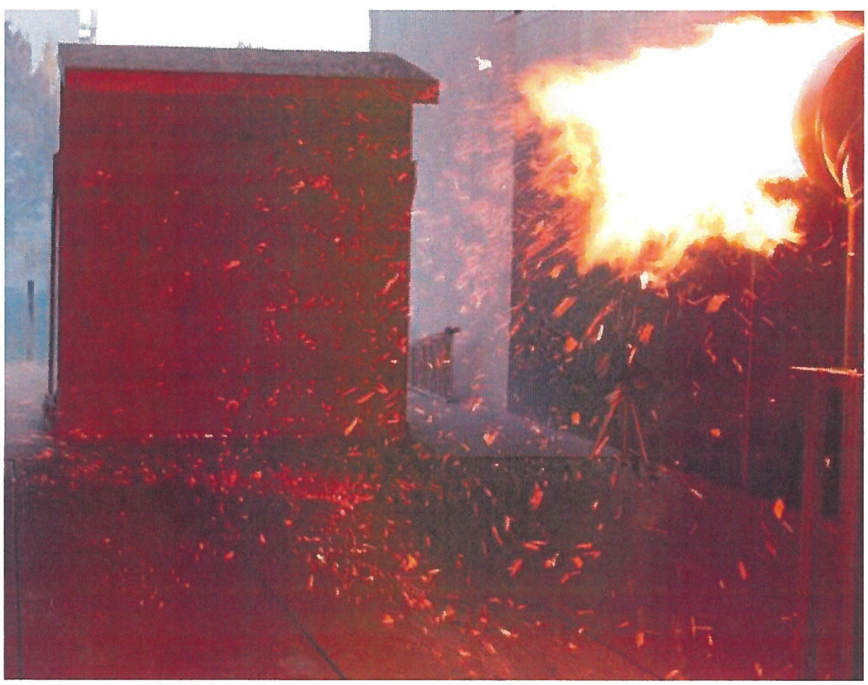

Figure 14: A typical experiment with the NIST Dragon in BRI's FRWTF (Manzello, 2014).

In Richburg, SC, the IBHS research center uses a larger-scale, modified version of the apparatus. Mulch burning equipment creates firebrands similar to the NIST Dragon but significantly scaled up in size. The combination of the large scale, higher winds and the ability to rotate a building during testing make the facility unique in its ability to represent the characteristics of natural winds and firebrands occurring during wildfire conditions. The firebrand generating equipment developed for the IBHS Research Center has been used in several tests which will be presented within this report (IBHS, 2014).

Figure 15: Ember storm produced in the IBHS research facility (IBHS, 2014).

Firebrand Transport

A large body of work is available in the literature on firebrand transport. While it is well known that brands can be transported some distance and ignite new spot fires or structures in WUI communities, it can be surprising just how far these brands can transport. In a NIST report on a community outside San Diego affected by the 2007 Witch Creek and Guejito, firebrands were found to arrive one hour before the flame front, traveling up to 9 km (Maranghides et al., 2013). These firebrands subsequently ignited properties over the following 9 hours.

Tarifa et al. were among the first to study burning brands of woody fuels, examining their burning properties, flight paths, and lifetimes through an innovative wind-tunnel apparatus

(Tarifa et al., 1965b). They studied cylindrical and spherical samples of pine, oak, aspen, spruce, and balsa wood with initial spherical diameters ranging from 10 to 50 mm, and initial cylindrical dimensions ranging from 6 to 15 mm and 18 to 36 mm in diameter and length, respectively. Wind was used as a variable from 0 to 40 m/s, and it was found that brands did not drastically change their shape during burning, nor did moisture content of the brand exert much influence on the brand flight path (Tarifa et al., 1965b).

A variety of models for firebrand transport were later developed based on Albini's 1979 model for the distance a spot fire could ignite from a single burning tree (Albini, 1979). Albini's predictive model calculated the maximum spot fire distance when firebrands are lofted by the burning of tree crowns. Variables included were the quantity and surface/volume ratio of foliage in the burning tree(s), height of the tree(s), the wind field that transports the firebrands, and the firebrand burning rate. No validation data is available; however, later work (Albini, 1983, 1981, 1983; Chase, 1981; Morris, 1987) has incorporated Albini's model into multiple numerical simulations, including FarSITE (Finney, 2004) and HIGRAD/FIRETEC (Koo et al., 2012).

Pagni and Woycheese (2000) significantly expanded on Tarifa's work to develop several models of brand propagation, lofting and burning. Information was found through a series of tests and by utilizing brand momentum conservation with spherical wooden, artificial brands lofted above a symmetric pool fire in a constant horizontal wind. Variations to these conditions were not considered. The dimensionless regression rate of brands depends inversely on both the dimensionless burning parameter and the dimensionless diameter. It was found that the diameter decreases faster in larger brands than the smaller diameter brands. It was also found that for sufficiently large brands, the acceleration during lofting was dominated by the drag and gravity (Woycheese, 1999).

Pagni and Woycheese also expanded their work to study combustion of brands of spherical, cylindrical and disk shapes (Pagni and Woycheese, 2000). Their experiments identified two stages to combustion of brands: flaming combustion and surface (glowing) combustion. It was found that denser wood samples (oak and Douglas-fir) produced flaming combustion for a longer duration than other fuels, but were less likely to transition to glowing surface combustion. Complete combustion of any brand rarely occurred without significant, persistent surface combustion on the upwind face of the brand. Wood with a lower density, such as cedar and balsa wood, more readily transitioned from flaming to surface glowing combustion, with flaming combustion ending relatively early in the brand's lifetime. Also noted throughout the examination of the results is the effect of the wood grain orientation; they found that an end grain faced the end velocity vector (Pagni and Woycheese, 2000).

Pagni later reviewed eight combustion models for burning brands, including an averaged stagnation-point burning model via the use of wood's chemical properties (Pagni, 1999). A Baum and McCaffrey model (Baum and McCaffrey, 1989) was used for the plume and a constant horizontal velocity, driving downwind propagation was approximated. Pagni and Woycheese then applied their own combustion model to determine the maximum propagation distance for disk-shaped brands, which they found to be most common in their studies. Analytic equations for brand thickness and propagation height lofted from large, single fire plumes were determined as a function of time for different heat release rates, wind speeds, and brand properties (Woycheese et al., 1999; Woycheese, 1999). Using their model, they found that brands released from greater heights will typically be smaller in size and thus completely combust in air, whereas brands released from lower elevations will typically be larger, but will result in shorter propagation distances (Pagni, 1999).

Other models, such as those by Wang, have integrated previous models and observations for brand production, lofting and ignition into a statistical form which can be used when modeling (Wang, 2009). Baum and Atreya also recently developed a new model for firebrand combustion, used to determine the duration of burning and thus the ultimate transport distance during lofting. They considered several different shapes and determined an analytical solution for quasi-steady burning (Baum and Atreya, 2014).

Numerical studies of the distribution of firebrands from burning line fires (Sardoy et al., 2008) and burning trees (Sardoy et al., 2007) have also been performed. In the numerical study of line fires, several correlations for the distribution of firebrands were found based upon firebrand initial conditions and the wind. There was also a dual distribution of embers found, with most embers falling close to the fire still in a state of flaming combustion and those further away in a glowing state of combustion. Nondimensional correlations for these distances are presented in both works.

Firebrand Ignition of Fuel

Many variables contribute to the process of target fuel ignition, including the physical dimensions of the firebrand, properties of the material and ambient weather conditions, making firebrand ignition one of the most difficult aspects of the recipient fuel ignition process to describe (Babrauskas, 2003; Pagni, 1999b). Depending on these variables, an ignited recipient fuel may start glowing combustion and then die out, just smolder or transition from smoldering to flaming and grow into a larger fire. Understanding the effects of each of the above variables on the ignition process is important in order to develop a physical model for firebrand ignition.

Because most firebrands cease flaming combustion before landing on recipient fuels (Manzello et al., 2006a; Tarifa et al., 1965), they often land in a state of smoldering combustion (sustained glowing combustion). Modeling, therefore, must incorporate a hot object landing with some initial thermal inertia onto a bed of flammable material. As firebrands are often still smoldering upon landing, they continue to generate heat through chemical reactions while resting on the recipient fuel surface. It has been suggested that the summation of energy stored in a brand (including stored heat or both stored heat and chemical energy for a smoldering brand) is a possible means of correlating and/or modeling the phenomena of ignition (Stokes, 1990). Recent work with heated particles (Hadden et al., 2010) though has found a poor correlation between particle thermal energy (joules) and time to ignition. A possible approach to modeling the problem is that of a "hot spot" ignition theory such as that proposed by Gol'dshleger et al. (Gol'dshleger et al., 1973; Thomas, 1964). This theory neglects the energy of the fuel particle but takes into account a 1-step Arrhenius reaction of the recipient fuel. This approach may be useful because it can take into account the different sizes of heated particles. Qualitative agreement between this approach and ignition of a cellulose-powder fuel bed by hot particles has been achieved (Hadden et al., 2010), illustrating the connection between spherical particle diameters and ignition, not thermal energy. The theory has some limitations, as it does not take into account ongoing reactions in firebrands, the moisture content of fuels, radiative feedback, external radiation, etc., and the theory is still quantitatively different from experimental observations. Continued improvement of theories is ongoing, and includes ideas such as taking into account different thermal properties of materials into Gol'dshleger's original theory (Jones, 1995).

Viegas et al. (2012) has also studied firebrand ignition of fuel beds of varying vegetative materials under different moisture contents with no wind. The results of this study showed that fuel bed properties were more influential in the ignition process than brand characteristics. Spot fires are typically divided into three phases: formations, propagation and ignition; however, Viegas et al. divided them into five different phases : firebrand release, transport of firebrand by fire plume and ambient winds, firebrand combustion, firebrands landing in a fuel bed, and consequent ignition of a new fuel bed. Ignition was much more likely in a fuel bed that received a glowing firebrand with airflow, confirming results from previous studies. Manzello et al. (2006b) has also performed significant work producing realistic firebrands and firebrand showers and using them to ignite fuel beds and building components. One significant insight from this work is that multiple firebrands must contact a fuel source (mulch or building component) for ignition to occur, as no single glowing fire brands could ignite most tested fuel beds.

Weir looked at data from several prescribed fires performed in Oklahoma to observe the probability of spotting downwind of the main fire front as a function of moisture content (Weir, 2004) and found a strong correlation (Figure 16). Whether this threshold has anything to do with ignition on materials in a home is unknown, but maintaining a high moisture content on any vegetation nearby a home will ensure it is less likely to ignite.

Manzello et al. (2009) also performed experiments on common building materials to determine the range of conditions under which glowing firebrands might ignite these materials. Materials tested included oriented strand board (OSB) and plywood, which were oriented in a v-shaped pattern at varying angles to determine how angle, wind speed and number of firebrands would influence the material's contact with glowing firebrands and its subsequent ignition. It was found that single firebrands were unable to ignite the materials used, even after applying various airflows; however, multiple firebrands were able to ignite some materials. It was concluded that the critical angle of interest for ignition was between 60° and 135° for any tested airflow. No ignitions were found below 1.3 m/s for any conditions, signaling that the combined effect of a mass of glowing firebrands and sufficient incident wind are necessary for ignition.

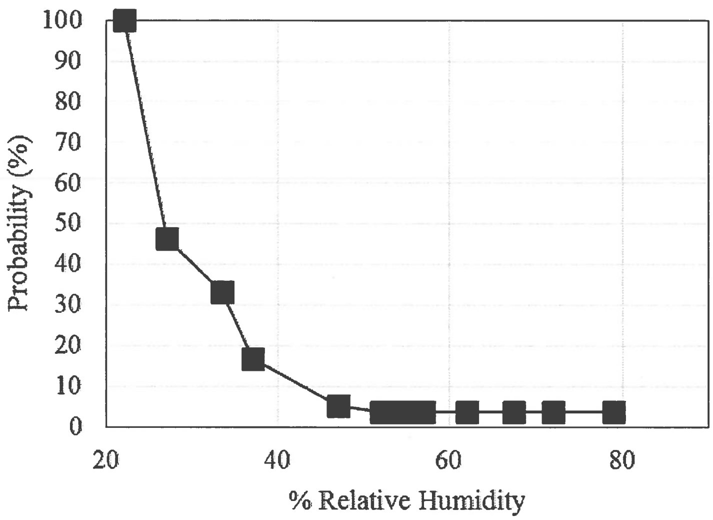

Figure 16: The probability of spot fires as a function of relative humidity, based on 99 prescribed fires conducted across Oklahoma from 1996 to 2002 (Weir, 2004).

Large-scale testing of ignition of building features by firebrand showers has been conducted at the IBHS Research Center (Quarles, 2012; IBHS, 2014). Tests have looked at ignition characteristics of roof gutters, debris on the roof, bark mulch, vegetation on the ground., siding, etc.

RESPONSE OF COMPONENTS AND SYSTEMS

As a structure in the WUI is exposed to radiation, flame contact and firebrands, specific components on the structure will first smolder, then ignite. This section reviews many different components found to be vulnerable to these exposure conditions. This breakdown follows the framework suggested by NIST (Maranghides and Mell, 2013), where information available in each area is reviewed below and reference to quantifiable information for risk-informed planning cited.

Roofing

Flammable roofing on WUI-exposed structures, especially wooden shingles, has been found in several studies to be the most susceptible building component to firebrand attack and ultimately the single most effective predictor of a home burning down. In a study of the 1990 Santa Barbara Paint Fire, 70% of houses with nonflammable roofs survived, while only 19% of houses with flammable roofs survived (Foote, 1994). Later, in an investigation of the 2007 Witch Creek and Guejito fires, it was found that all houses with wood shake roofs were destroyed while only 33% of structures with an approved roof type (Class A) were destroyed or damaged (Maranghides et al., 2013). Of roofs with exposed Spanish tile, 24% were destroyed (Figure 17). In an investigation of the 2012 Waldo Canyon fire it was also found that wood shake roofs and other roof designs that were vulnerable to firebrand accumulation greatly enhanced the chance of home destruction (Quarles et al., 2012).

Fire ratings of roofs are typically governed by the American Society for Testing and Materials (ASTM) Standard E-108 (ASTM, 2011), Underwriters Laboratory (UL) Standard 790 (UL, 2014) and the National Fire Protection Association (NFPA) Standard 276 (NFPA, 2011). These tests are essentially the same test and are designed to evaluate three fire-related characteristics of a roof assembly: its ability to resist the spread of fire into the attic, resist flame spread onto the roof covering, and finally to resist generating burning firebrands. Roofs are ranked into three classes, Class A, B and C, where Class A is considered effective against severe fire testing exposures. Tests include an air flow over an inclined roof which is subjected both to flames and burning "brands", a wood crib made of Douglas-fir sticks[5]. If flames resulting from the burning "brands" penetrate the roofing assembly, the sample has "failed" the test and will not gain a Class A rating. Codes such as Chapter 7A of the California Building Code require a Class A rated roof in very high fire severity zones[6] (CBC, 2009).

	Sample Population	**Destroyed Structures Wood Shake Roofs**	**Destroyed Structures Spanish Tile Roofs**	**Typical Comparisons**	
Typical (only destroyed homes)	74	12	37	16% of destroyed homes had wood shake roofs	50% of destroyed homes has Spanish tile roofs
Complete (all structures within fire line)	242	12	154		
Technically Valid Comparisons		100% of exposed wood shake roofs destroyed	24% of exposed Spanish tile roofs destroyed		

Figure 17: Comparison of influence of roofing material on destruction of structure following the Wttch and Gueijto fires (Maranghides et al., 2013).

Although the current standards include a test of roofing decks exposed to firebrands, it is argued that placing a wood crib on top of the assembly with an applied airflow does not correctly simulate the dynamic process of numerous firebrands landing under roofing tiles or gaps (Manzello, 2014). Embers generated by the "brand" are blown off the roof and therefore do not serve as a realistic simulation of firebrand attack because they cannot accumulate. Recent full-scale research performed at the IBHS Research Center showed ignition to occur both in the field of the roof (i.e., away from the roof edge or roof to wall intersection) for untreated wood shake roofs and at the roof-to-siding intersection via wind-blown firebrand ignition of accumulated

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[5] Note that Class C brands are made from non-resinous white pine.

[6] Note that the California Building Code, Chapter 7A defers to Chapter 15 of the International Building Code for fire rating requirements.

vegetative debris, even when roofs were properly rated[7] (Quarles, 2012).Tile roofing assemblies have also been found to be vulnerable to firebrand attack (Manzello et al., 2010a). Experiments by Manzello et al. were performed using the NIST Firebrand Generator (6 minute duration) in a wind tunnel with a constant velocity of 9 m/s. Tiles were installed with and without tar paper (to simulate "weathering" or other worst-case damage that may occur over time, e.g degradation of the tar paper layer), with and without bird stops, and finally perfectly aligned and slightly off-aligned to simulate gaps that may form with aged roofs. When bird stops were not installed at the base of tiles without tar paper, firebrands collected within the exposed space, first smoldering and finally transitioning to flaming ignition through the oriented strand board (OSB), which could eventually involve a structure (Manzello et al., 2010a). Some smoldering ignitions as a result of firebrand penetration between the tile and bird stops were also found when bird stops were properly installed, but none transitioned to flaming. The presence of needles and dead leaves placed in gaps when bird stops were not installed enhanced the ignitability of roof assemblies with tiles so that all configurations tested transitioned to flaming under firebrand exposure.

Manzello (2013) later extended these roofing studies by investigating the response of concrete and terracotta tiled roof assemblies to wind-driven firebrand showers with an average mass flux of 10 g/m^2s under a 9 m/s constant wind. It was found that concrete tile roofing assemblies (both flat and profiled), as well as terracotta tile (flat and profiled), could allow firebrand penetration through the tile assembly and melting of the underlayment or sarking (sheathing material in the form of a layer of aluminum foil laminate bonded with a fire retardant adhesive to a polymer fabric). The flat tile terracotta roofing assembly performed best, most likely due to its interlocking design. Firebrands were observed to become trapped within the interlocking sections of the tiles and, as a result, the firebrands did not penetrate past the tiles towards the sarking material. Manzello (2013) indicated a potential cost-effective mitigation strategy would be to use a continuous underlayment of firebrand-resistant sarking. The effect of roof slope angle on ignition under wind-driven firebrand attack was also studied by Manzello et al. (2012a). They

[7] Specifically, a Class A fire rated asphalt fiberglass composition shingle roof covering (Quarles, 2012). Note that a smoldering front penetrated through the untreated wood shingle assembly to potentially ignite the attic, but not fully through the Class A rated asphalt composition (fiberglass roof covering).

studied angled crevices made of asphalt shingle roofing assemblies (oriented strand board (OSB), tar paper and asphalt shingles) and OSB alone, which might be exposed if other layers are removed through weathering or damage[8]. Firebrands were able to ignite the inclined samples with only OSB exposed with flaming ignition at a 60° crevice inclination and with smoldering ignition at 90°. As the angle was increased to 135°, ignition no longer occurred. For asphalt shingle roofing assemblies firebrands were seen to accumulate at the seams of shingles, at 60° and 90°; however, they only melted some of the roofing shingles and did not ignite the roof (Manzello et al., 2012a).

Some building codes require wooden roof shingles to be pressure-impregnated with fire retardants to pass test standards, however wood exposed to the elements will weather extensively and may affect fire performance. Several studies on the effectiveness of fire retardants after significant weathering have been conducted by the Forest Products Laboratory (FPL) in Madison, Wisconsin. The first set of studies by Holmes (1971) evaluated various fire retardant treatment systems for western red cedar wood shingles and shakes for their fire performance and durability. An 8-foot tunnel test (ASTM E286-69), a modified Schlyter Test simulating vertical flame spread (Holmes 1973) and a modified class C burning-brand test ASTM E-108-58) were used. Accelerated weathering was simulated with a 28-day exposure with daily water spray and natural rainfall totaling 30 inches, followed by sunlamp radiation at 150°F (65°C). They were then re-tested with the Schlyter and burning brand methods. Four vacuum-pressure impregnations were seen to be viable as Class-C rated woods (ASTM E-108-58). A fire retardant paint was also somewhat successful, but failed the Schlyter test indicating it was lacking in resistance to flaming ignition[9].

Studies were then continued and updated at 2 and 5-years of outdoor exposure Holmes and Knispel (1981) and finally after 10 years of exposure (LeVan and Holmes, 1986). After ten years of exposure, the authors found that, of all treatments evaluated, the commercial treatment NCX (a commercial formulation by Koppers) performed best in fire tests. UDPF (urea-dicyandiamide-formaldehyde-phosphoric acid) and DP (dicyandiamide-phosphoric acid) performed well in the

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[8] However removal of these layers would result in significant leakage that may be observable.

[9] Note CBC Chapter 7A specifically includes coatings, such as this.

burning brand test after exposure, but unacceptably in the modified Schlyter flame spread test. They also correlated the accelerated weathering test of 1,000 hours of light coupled with daily water spray to approximately 2 years of outdoor exposure. Even though the equivalent of 34 years of average rainfall were applied, there was probably not enough UV light exposure. Photodegredation by UV light, resulting in erosion of wood fibers and associated fire retardant chemical and biological degradation was thought to be just as important in maintaining retardancy in treated shingles. Copious amounts of water-repellant re-sealers provided some promise in extended leach resistance, however they would have to be applied periodically and no general results were presented.

Based on past research, untreated wood shakes and shingles are known to be readily ignited by firebrands and pose a significant threat, however some pressure impregnated wood shakes and shingles have a higher fire resistance (LeVan and Holmes, 1986). Still, their rating of Class B or C fire resistance (ASTM E108) rather than Class A remains a worrying factor in their use. Some tests described above have demonstrated the potential for Class-A rated roofs populated with typical debris (pine needles, etc.) to achieve smoldering ignition[10] under wind-driven firebrand attack, therefore without further research indicating pressure-treated wood's ability to resist ignition by firebrands our opinion is that they should not be used on vulnerable buildings. Whether this applies to wood products other than shingles, such as those used on fences or decks is not known either.

More recent research on wood fire retardants by Marney et al. (2008) have incorporated wood fire retardants with wood preservatives that, when tested under a radiant cone heater (cone calorimeter) reduced the rate of fire growth (heat-release rate) by 40%. Its effectiveness after weathering or firebrand exposure was not tested. Marney and Russell (2008) also reviewed the literature on impregnation of wood with chemical systems for resistance to both fire and degradation for outdoor uses. They found that typically boron-based compounds are still used. The review highlighted a lack of consistency in terms of fire performance and wood preservation

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[10] Although during limited testing, smoldering ignition was observed only on flammable members of the assembly, not penetrating into the attic area.

testing. The recommend a more uniform approach using the same fire and preservative testing regime between different studies.

Gutters

Gutters can be significant sources of ignition of a home, primarily because debris collected in the gutter can be ignited by firebrands. Pine litter collected in gutters was found to be a significant cause of ignitions in the Grass Valley Fire near Lake Arrowhead, California (Cohen and Stratton, 2008).

Flat roofing assemblies were tested with a polyvinyl chloride (PVC) gutter attached to the front (Manzello et al., 2008). When flammable materials, such as pine needles, were placed in the gutter, the firebrands deposited in the gutter produced smoldering ignition which transitioned into flaming. The asphalt shingles then melted but did not fully ignite under the conditions tested.

Figure 18: Ignition of pine needles in a gutter after transitioning to flame spread from (Manzello et al., 2008). *This fire did not actually ignite the roof assembly, but there is potential for ignition of the roof assembly depending on the gutter, roof and flammable material inside the gutter.*

IBHS also performed tests on full single-story homes with gutters and observed ignition of gutters with flammable materials such as pine needles and other litter inside. When the debris in a vinyl gutter caught on fire, the gutters disconnected from the house and fell to the ground (IBHS, 2013). In similar tests with a gutter made of metal, the debris can catch the house on fire[11]. Despite potential concerns with metal gutters, vinyl gutters are not necessarily recommended because the roof could still ignite or the falling gutter could ignite debris on the ground which could later ignite the siding of the home. In general, there is a significant body of literature recommending removal of fuels from gutters but very little detailing quantifiable risks.

Mulch and Debris

Mulch, such as bark and rubber, woody vegetation, wood piles and other flammable debris are not recommended to be stored or allowed to accumulate near a structure as a measure to minimize the chance of ignition from subsequent radiant heat and flame exposure (Quarles et al., 2012). Several experimental tests have been performed on mulch and other dead vegetative debris that may be located near homes. Tests performed at the IBHS Research Center (IBHS, 2014), demonstrated that flammable debris on the ground ignited and caused rapid upward flame spread on the side of the house (Quarles, 2012). More fundamental work that quantifies ignition of debris and fuel beds in terms of moisture content and other variables in a statistical form (reviewed under the Firebrands Section) may be useful in risk assessment methodologies (Zak et al., 2014).

Manzello et al. (2006b) performed experiments on several mulches including shredded hardwood and pine straw, both commonly used in the USA, as well as dried cut grass. During experiments, smoldering or flaming ignition were not observed in any of the fuel beds with only one single *glowing* firebrand. With flaming firebrands, all fuel beds were observed to achieve either glowing or flaming ignition with the exception of shredded hardwood mulch fuel beds held at 11% moisture content. Multiple glowing firebrands were also unable to ignite cut grass fuel beds and shredded hardwood mulch fuel beds held at 11% moisture content. Under the mass flux of embers used, the ability for fuel beds to ignite was increased when multiple glowing or flaming

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[11] In these tests, the metal gutter remains in place, so that direct flame contact to the fascia and roof sheathing occurs (IBHS, 2013).

firebrands were introduced, thereby stressing the importance of understanding the flux of firebrands.

Steward (2003) performed experiments on 13 different mulches to measure their relative ease of ignition. Plots were left to sit for 2 weeks before a lit cigarette, match or propane torch was placed on the bed, and monitored for 20 minutes to see if it ignited. Ignition was found in the tests to be a variable process, with ground, recycled pallets and composted yard waste igniting every time when ignited by cigarettes, shredded pine park 3 out of 4 times, oat straw and shredded cypress bark 2 out of 4 times, pine bark nuggets once during tests and decorative ground rubber, pine straw needles, shredded hardwood bark, cocoa shells, bluegrass sod and brick chips never igniting. When igniting with a torch, all mulches eventually ignited, but with ground rubber and pine needles igniting significantly faster than other mulches. The results, unfortunately did not include further quantitative measures on the flammability of these mulches or their behavior under different environmental conditions.

Quarles and Smith (2004) measured some relative flammability properties for 8 mulches in 8 foot (2.5 m) diameter plots. Mulches were exposed to over two and a half months of hot, dry weather exposure in Nevada, presenting normal conditions for Nevada. They were burned under fan-produced winds of 10-15 miles per hour (4.5 - 6.7 m/s) and the resulting flame height, rate of spread across the bed and temperatures above the bed were measured. With the exception of the composted wood chips, all of the mulch demonstrated active flaming combustion. The composted wood chips[12] produced only incidental flaming with smoldering as the primary form of combustion. It is not known if the performance of the composted wood chips was specific to the brand and type purchased for their project, or if composted wood chips from other sources would perform in a similar manner.

Based on the three combustion characteristics measured, shredded rubber, pine needles and shredded western red cedar demonstrated the most hazardous fire behavior. The least hazardous fire behavior was observed for composted wood chips and a single layer of Tahoe chips. The shredded rubber mulch produced the highest temperatures above the bed and greatest flame

[12]Which had a relatively high ask content compared to other materials.

heights for a prolonged period, with pine needles representing the second most-hazardous mulch material based on combustion characteristics. A summary of results for the 8 mulches tested is shown in Figure 19, where relative values of combustion characteristics were determined by normalizing the shown quantities by the highest value in each category. It's important to note these experiments were repeated three times for each bed, producing useful relative information but not quantitative results capable of being applied to WUI risk modeling.

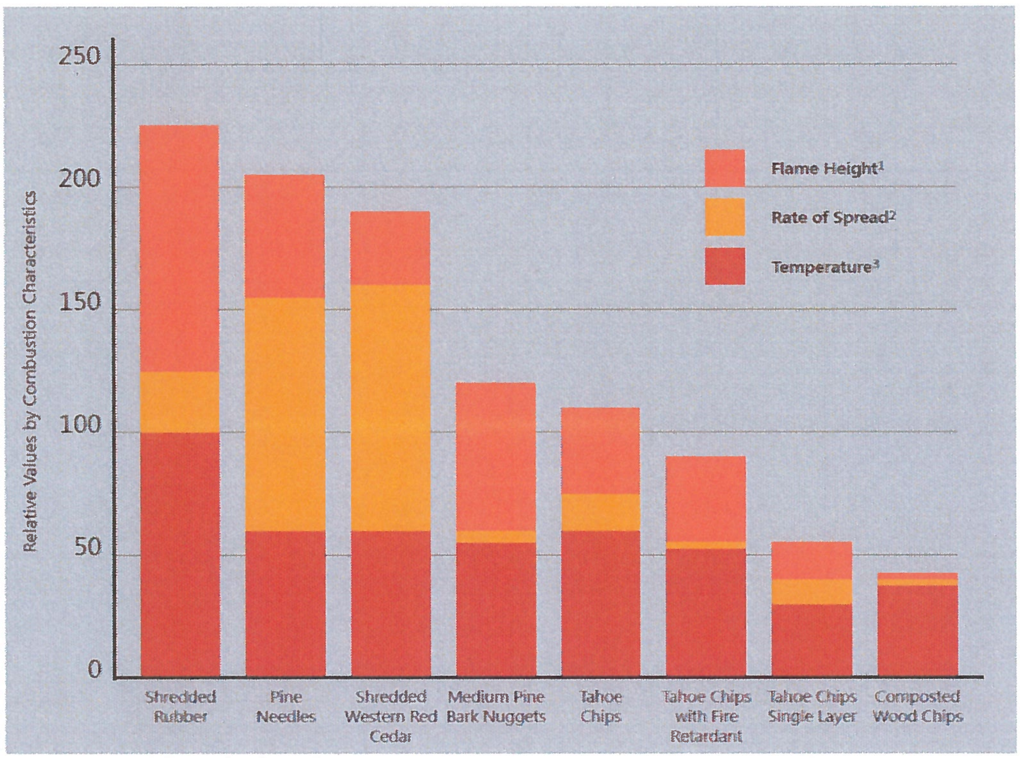

Figure 19: The relative flammability of dried mulches tested in Quarles and Smith (2004). Flame height, rate of spread and temperature shown for each mulch sample are normalized based upon the maximum value measured.

Manzello et al. (2014) performed later experiments exposing shredded hardwood mulch beds with a moisture content of 0 – 25% to continuous firebrand showers using the NIST Dragon apparatus. The mulch was placed at the base of a re-entrant corner, thought to be a worst-case scenario due to a stagnation region, which contributed to a significant accumulation of firebrands, and the fact that a corner fire represents the most rapid rate of fire growth upon ignition (Drysdale, 2011). The mulch was shown to quickly achieve smoldering ignition and later transition to flaming under both 6 and 8 m/s conditions. Full results of the experiments are not available yet; however, design guidelines espousing all flammable materials staying at least 5 feet away from structures appears to be a clear safety decision (IBHS, 2013). Several other experiments are detailed in the Sidings, Windows and Glazing section below, all of which demonstrate easy ignition of building siding from very little impetus on the side of structures. Therefore it is vital to keep the fuel load directly next to structures (typically espoused to be ~5 ft) free of all flammable materials.

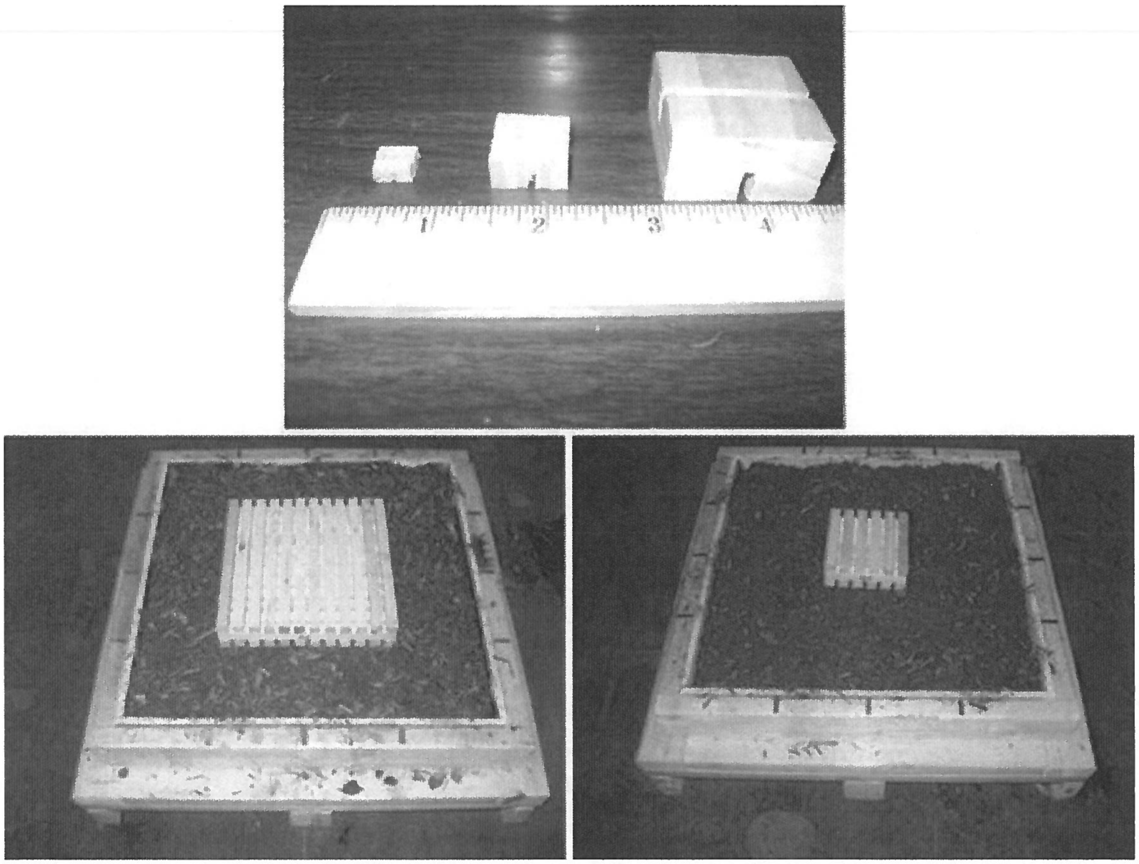

Figure 20: Mulch bed tests from Beyler et al. (2012) showing ¼, ½ and full-size Class C brand ignition sources from the ASTM E-108 test.

Recently a test protocol has been proposed to more quantitatively evaluate ignition and flame spread of different mulch beds (Beyler et al., 2014). This test method was based on the ASTM E-108 test "brand" (essentially a wood crib) which was used to test its ability to ignite a 0.6 m square mulch bed (ASTM, 2011). Characteristics such as mulch depth, moisture conditioning, bed dimensions, ignition properties, slope and wind speed were varied during development to provide a test protocol that is capable of ranking different mulches flammability properties.

While the test is able to evaluate one mulch vs. another quantitatively, it does not intend to provide worst-case conditions.

Eaves and Vents

Eaves and vents have been recognized to be significant sources of ignition for homes in the WUI. Vents provide an opening through which burning brands may penetrate the interior of a structure, often the attics. Most homes have these vents both for thermal efficiency and to minimize the chance of moisture buildup, shown schematically in Figure 21. Meshes used on these vents were traditionally designed to stop entry of rodents, etc. into attic and crawl spaces; therefore considerations of vent size for wildland fire is a recent addition.

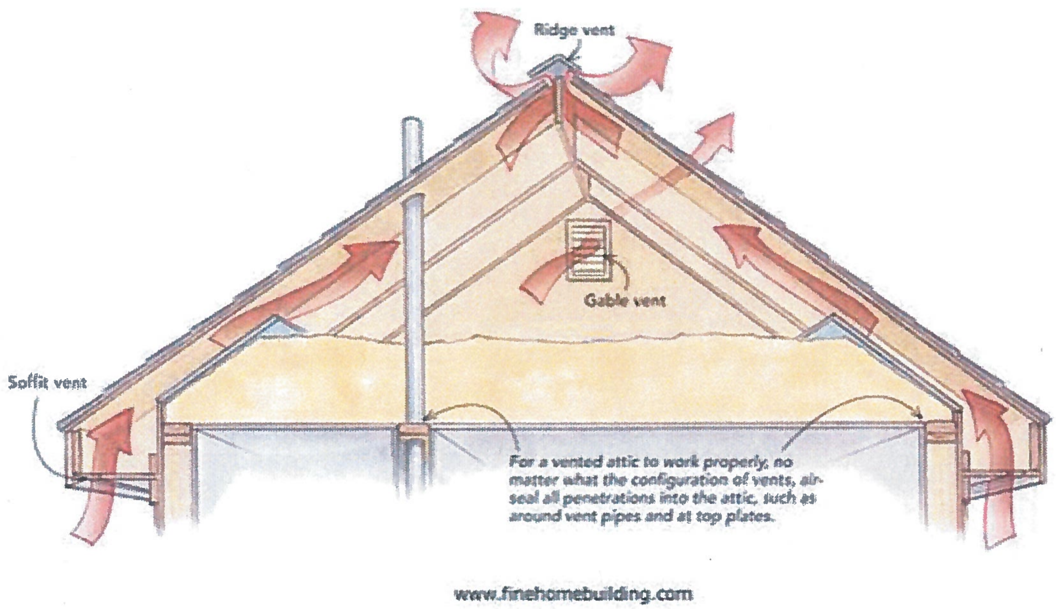

Figure 21: A schematic of vents used to ventilate an attic space from www.finehombuilding.com. It is common to have at least one outlet vent type, for example gable, ridge or soffit.

As shown in Figure 21, three types of vents are typically used for household attic spaces: a soffit vent placed under an eave, gable vents on the exterior wall of a house or ridge vents placed at the top of a roof. The 2007 California Building Code of Regulations, Title 24, Part 2, Chapter 7A first required building vents have a metal mesh of 6 mm placed on all vents to mitigate firebrand penetration (CBC, 2009). Because these regulations were not based on any testing, Manzello et al. (2012a) used the firebrand generator to test the effectiveness of different gable vent opening mesh sizes.

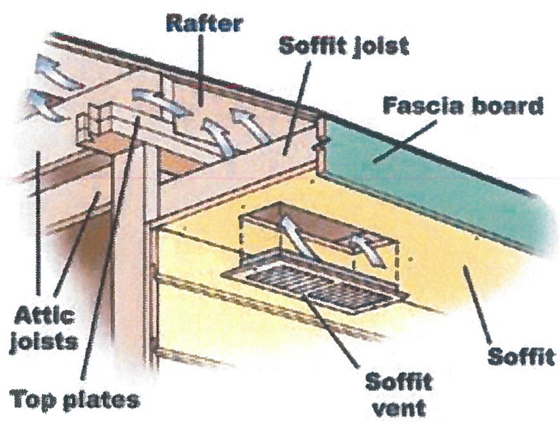

Figure 22: Illustration of a soffit vent and airflow pattern to ventilate an attic space (http://www.cornerhardware.com/howto/ht076.html).

Initial testing was performed on gable vents with mesh sizes of 6, 3 and 1.5 mm. The results of the tests showed that firebrands were not quenched by the presence of the mesh, but rather would continue to burn until small enough to pass through the mesh. All mesh sizes tested resulted in ignition of shredded paper behind the vent; however, larger mesh sizes (6 mm) ignited the paper more quickly.

Later investigations on six mesh sizes (5.72 mm to 1.04 mm), as well as using three different types of ignitable materials (shredded paper, cotton and wood crevices) inside the structure, were used to generate a database of firebrand behavior through a simulated gable vent (Manzello et al., 2012a).

These tests confirmed the fact that firebrands were not quenched by the presence of the mesh and would continue to burn until they were small enough to pass through the mesh, even with an opening as small as 1.04 mm. Reduced mesh sizes were observed to reduce the ignition potential in some configurations, such as small wood crevices, perhaps because the thermal inertia of the smaller brands was reduced, making it harder to ignite denser material, as illustrated in Figure 23. It presented the penetration ratio, defined as the number of firebrands, leaving the mesh over the number of firebrands arriving at the mesh during the sample period (Manzello et al., 2011).

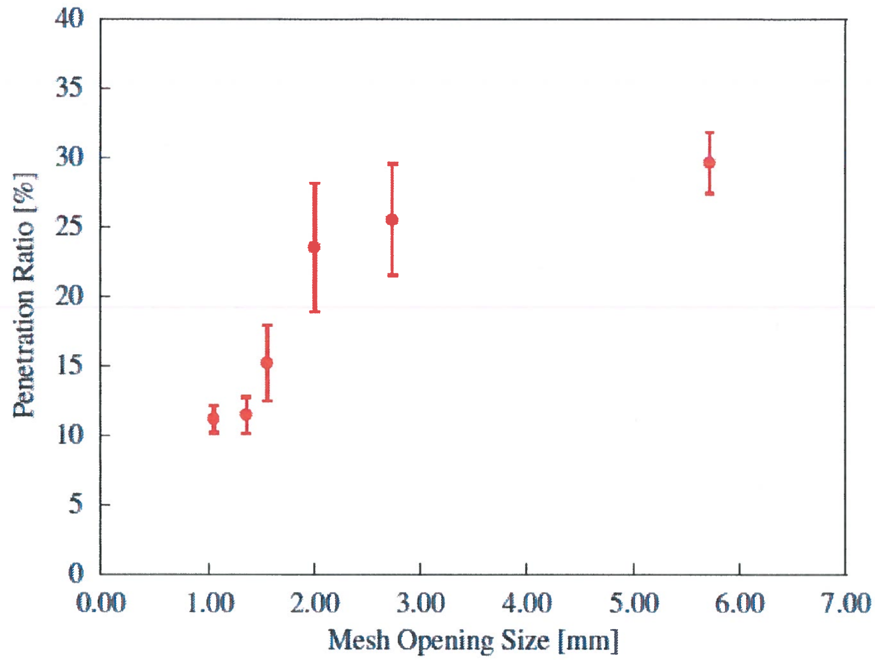

Figure 23: Firebrand penetration ratio as a function of mesh opening size from (Manzello et al., 2011).

A new standard has been developed by the ASTM E05.14 External Fire Exposure subcommittee: ASTM E2886. ASTM E2886, the Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement, is designed to evaluate the ability of exterior vents to resist the entry of burning embers and flame penetration (ASTM, 2014a). The test includes both an ember exclusion/intrusion test and a flame intrusion test. The ember intrusion test is different than previous tests performed with the NIST Dragon, as it produces embers which fall through a vertical shaft and through a vent onto a cotton target, while the NIST Dragon tests were performed horizontally in a large-scale fire wind tunnel. Even though the horizontal wind-driven test is more realistic, the vertical apparatus was considered to be a worst-case scenario and is therefore used in the test standard (Manzello et al., 2010c).

Manzello et al. also used the NIST Dragon at BRI's FRWTF to study open eave construction (where the roof rafter tails extend beyond the exterior wall and are readily visible), as it is often cited as the most severe eave configuration (Manzello et al., 2012b). They used a 61 cm eave overhang with exposed OSB sheathing which was not dried, as the wall was meant to show whether firebrands would accumulate. During tests at 7 and 9 m/s, no accumulation was found at the open eave without vents; however, 11 and 28 firebrands were observed at the 7 and 9 m/s tests with open vents, respectively. These openings had 50 mm holes drilled into blocking material with an 8 x 8 mesh (2.75 mm opening) installed as per the 2009 California WUI code (CBC, 2009).

During the above eave and vent tests, a severe accumulation of firebrands was found at the base of the wall. The 9 m/s firebrand shower exposure was sufficiently severe to cause the wall to ignite from this accumulation. No other combustibles were present at the base of the wall (Manzello et al., 2012b). The wall assembly tested was also modeled using the Fire Dynamics Simulator (FDS) which showed the presence of a large stagnation zone that formed in front of the wall assembly perpendicular to the flow direction and generally increased with increasing airflows. Under the eave there was little to no flow velocity, which would be responsible for driving firebrands into the joints between the eave and wall assembly, supporting conclusions observed in the experiments. Manzello's experiments show that eave vents have less accumulation than gable or foundation vents at this scale, because the horizontal vent structure created recirculating flow that does not carry firebrands as well.

Fences

In an investigation of the 2007 Witch Creek and Guejito fires, it was found that 45% of homes with attached wood fences were destroyed (Maranghides et al., 2013). In most cases, there was evidence that flames came dangerously close to homes by igniting entire wooden fences or sections of them, the ignition of which led flames to surrounding houses. Wooden trellises and other yard structures were also burned (IBHS, 2008).

Post-fire studies conducted by NIST on the Waldo Canyon Fire in Colorado that occurred in 2012 determined that wood fences were vulnerable to ignition from firebrand showers in WUI fires but there has never been any experimental verification of this ignition mechanism (Manzello, 2014). As a result of these observations, a series of experiments were conducted to expose cedar and redwood fencing assemblies to wind-driven firebrand showers by NIST; however, full results have not been released yet (Manzello, 2014).

Decks, Porches and Patios

During the 2007 Witch Creek and Guejito fires, decks were observed to be one of the most significant sources of ignition. Of 16 damaged homes, the ignition location was most often a detached structure or decking (Mell and Maranghides, 2009). Similar observations were made during the Waldo Canyon fire, where wooded slopes with overhanging decks created a large hazard (Quarles et al., 2012). Most of these ignitions were thought to originate from firebrands or local flame contact. One issue is that deck material is tested for flame spread properties and some ignition potential from direct flame contact, but not firebrands or the potential radiant energy production from the deck to ignite the adjacent structure (Wheeler, 2004; CBC 2012). Many houses in the Angora fire had attached decks with combustible material stored under the deck. In some cases, direct flame impingement from a low intensity surface fire ignited these combustibles which eventually ignited the deck and, ultimately, the house. Aerial evidence showed that most of the vegetation between homes did not burn or burned only with a low intensity surface fire (Murphy et al., 2007).

Wheeler performed 6 (non-repeated) tests on various wood and Trex (a wood-plastic composite) decking materials. First, hot embers were placed on the wood members to see if the decking material ignited. Decking material smoldered, but did not transition to flaming. The lack of transition to flaming is likely due to the fact that no wind was applied, because wind is often necessary to initiate a transition to flaming (Manzello et al., 2006c). In another test, a pile of pine needles (debris) was lit underneath each deck and a 5-8 mph wind was applied. All decks ignited; however, wood ignited last and self-extinguished. Composite materials ignited quickly and produced large, severe fires. The slowest composite to ignite was Trex, which self-extinguished once pine needle fuel was consumed by fire. The authors recommend keeping the underside of decks clear of debris (Wheeler, 2004).

Manzello and Suzuki have performed tests on 1.2 x 1.2 m sections of wood decks in a reentrant corner assembly exposed to a continuous firebrand shower from the NIST Dragon under a 6 m/s wind. Decks were built out of western redcedar, douglas-fir and redwood, then exposed to a total firebrand mass flux of 17.1 g/m^{2}s. The deck boards were oriented perpendicularly to the airflow direction. Firebrands accumulated on the deck surface and every assembly was observed to ignite by flaming ignition. Average times for ignition were 437 s for Cedar, 934 s for Douglas-fir and 756 s for redwood. About 20% of the glowing firebrands ejected from the NIST Dragon accumulated on the top of the decks. There appeared to be a correlation between the firebrand mass required for sustained flaming ignition and the density of wood base boards; however, more information will be required to confirm this relationship in the future. (Manzello and Suzuki, 2014).

Sidings, Windows and Glazing

The ignition of materials on the exterior walls of structures is a major concern in WUI fires. Siding materials often ignite due to either direct flame contact or radiant heat exposure. Without proper clearance around the base of a structure, firebrand accumulation can lead to ignition of nearby vegetation or other fuels (e.g. mulch, wood piles, etc.), which can in turn lead to direct flame contact and radiant heat exposure on the exterior walls (IBHS, 2013). Under wind-driven conditions, re-entrant corners lead to the formation of a small recirculation zone which can attach the flame close to a wall (essentially mimicking a fire whirl) and lead to a higher vulnerability to ignition. Since such a configuration is also the worst-case situation for upward flame spread due to resulting air entrainment patterns (Drysdale, 2011) re-entrant corners are a significant hazard that are now thought to be a worst-case scenario for siding ignitions.

Manzello et al. used the NIST Dragon at BRI's FRWTF to study siding treatments (siding material on top of a layer of housewrap and OSB) in a re-entrant corner configuration under wind-driven conditions of 7 and 9 m/s (Manzello et al., 2012b). For experiments with vinyl siding, firebrands were observed to melt through the siding material to the point where holes were visibly observable through the material. Ignition of the OSB sheathing underneath the vinyl and Tyvek was only observed for vinyl siding with 9 m/s of wind applied and OSB that was oven-dried. During this ignition, the OSB burned through completely, eventually igniting the structural wood members underneath. Although polypropylene vinyl siding melted, it did not form holes and no ignition occurred. In an actual wildland fire, winds can be above 20 m/s, so this representative test illustrates some potential hazards in this configuration (Manzello et al., 2012b). A severe accumulation of firebrands was also found at the base of an OSB wall during eave experiments which can quickly lead to ignition of a structure (Manzello et al., 2012b).

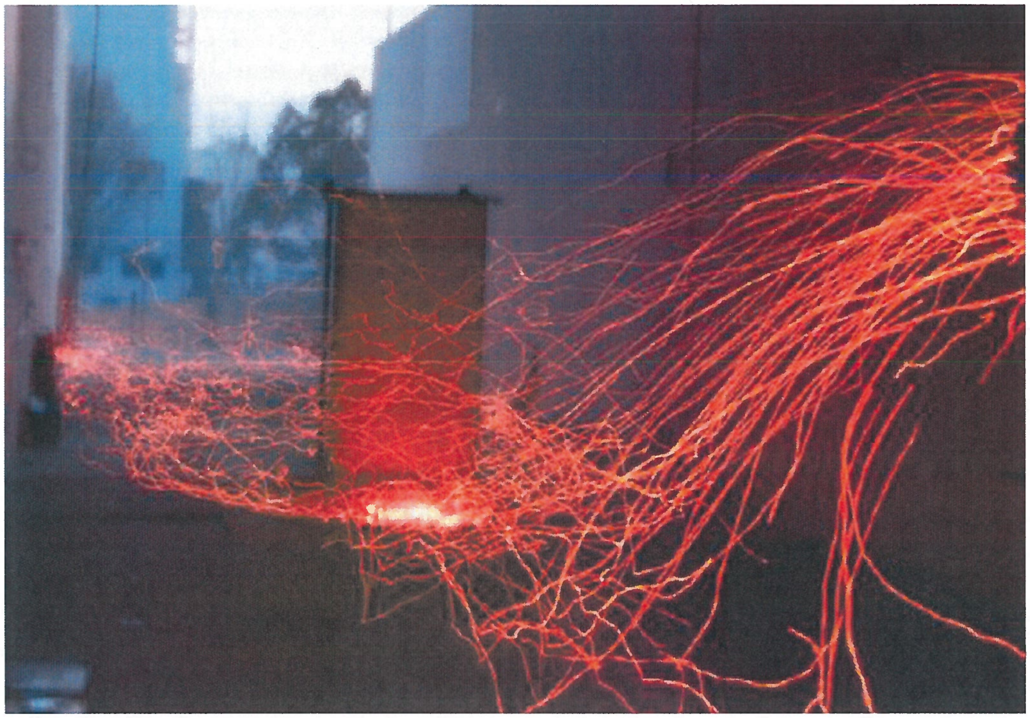

Figure 24: High-exposure time photograph showing firebrand accumulation in front of an obstacle from (Manzello et al., 2012a).

Firebrand accumulation around glazing assemblies surrounding windows has also been noted as a possible mechanism for window breakage which can contribute to fire penetration into a structure. Manzello et al. tested both horizontally and vertically sliding window assemblies. They were both double hung, as it was thought that this configuration might present the worst-case scenario for ember accumulation and ignition (Manzello et al., 2012b). Their experiments showed that embers could accumulate in the framing of the assembly, more so in the vertical wall assembly, but none sustained sufficient damage to break the glass or penetrate the structure.

Windows have also been tested for radiant exposure. In one test, a 50 by 63 inch (127 by 160 cm) panel with a radiant heat flux of 35 kw/m^2 was used to expose various window and wall assemblies (previous 1997 International Crown Fire Modeling Experiments in Canada showed that this heat flux is rarely achieved for more than 1 min) (Cohen, 2000b). These tests found that glass is the most vulnerable part of window – if it breaks, embers can directly enter a house; however, dual-pane tempered glass did not fail even with a 25 min exposure, showing that dual-pane glass is unlikely to fail due to radiative heating in a wildfire scenario. This conclusion supports code, such as NFPA 1144 5.7.2 which requires the use of tempered or other fire-resistant glass (NFPA, 2013). Screens were also shown in their tests to absorb radiant heat. Painted siding generally ignited more quickly than windows broke with times for all siding ignition ranging from 4 to 16 minutes. When vegetation is cleared at least 30 ft (9 m) from a building it does not appear that radiant heat fluxes could ignite siding within the short times a spreading vegetative fire will burn. A nearby detached garage, outbuilding or neighbor's house, however could provide a sustained source of radiation capable of igniting siding that should be carefully considered (Quarles et al., 2012). Assessment of siding ignition times from the preliminary results in the Northwest Territories proposed two story structures should be spaced about 39 feet apart based on expected radiant heat fluxes (Cohen, 1995). It is important to note these studies are based on a limited study, particularly, of siding materials and Quarles et al. (2012) does not have published, peer-reviewed data available on the tests.

Maranghides and Johnsson (2008) performed large-scale experiments at NIST where they compared a building clad with combustible materials against one with non-combustible underlying materials (such as fire-rated gypsum wallboard) and measured the time for fire to spread from one ignited assempy to another. They found that even with a 6-ft (1.8 m) separation between buildings, fire spread could be slowed down with a 1-hour fire rated assembly that incorporated gypsum wallboard. Flame spread resulting from penetrations at windows, whether from flames exiting from burning structures or entering/heating broken windows on an unignited assembly was most significant. Flames exiting the burning compartment contributed to total heat fluxes measured on the recipient wall (6 ft (1.8 m) from the burning compartment) that peaked between 60 - 110 kW/m^2 at the top of the wall. Around 20 kW/m^2 reached the window on the recipient wall. As a result, a one-hour fire-rated wall could increase the protection for closely spaced homes, but complete hardening of a home would require other protection methods (Quarles et al., 2012). Window assemblies appropriately protected for a presumed fire expsoure, such as double-paned windows with tempered glass, would also increase protection as a higher heat flux is required to break them.

While some literature highlights skylights as a point of entry for wind-blown embers or flames to penetrate a structure, no data seems to be available to back up the assessment (IBHS, 2013). Ignition of roofing or siding near skylights does seem feasible as accumulation of debris on the roof can cause glass to be broken by ignition around the window. Additionally, flammable plastic skylights can themselves ignite. Still no data in the literature shows them to be of particular hazard in the past.

Community Planning and Adjacent Structure Interactions

The location and arrangement of homes contributes to the overall fire risk within a community. For example, in the Waldo Canyon fire in Colorado, in areas where home-to-home ignition occurred, spacing between homes was typically only 12 feet to 20 feet (3 to 6 m) (Quarles et al., 2012). The spacing between homes — the housing density — and that interaction with surrounding vegetation has been reviewed by several authors below that all point to a significant impact on community-wide fire resilience simply by the arrangement and density of structures. A study of the implementation of Firewise zones around homes was also conducted in a study of the Witch Creek and Guejito fires which showed a clear correlation between the lack of vegetation near a home and the resulting number of structures destroyed. Spread within the community studied was primarily governed by structure-to-structure spread, the results of which are presented under the mitigation strategies section (Maranghides et al., 2013).

Spyratos et al. used a simplistic percolation-theory based fire model along with housing and vegetation data to show that fire risk can be strongly modified by the density and flammability of homes within the WUI (Spyratos et al., 2007). In particular, they found that there was a sharp increase in the probability of a greater fire size with the introduction of combustible housing into their models; this probability also increased when the typical landscape vegetation flammability found in most of the U.S. WUI was used. On the basis of their results, the authors suggest that homes should be additionally hardened against ignition from wildland fires, that nearby vegetation be similarly modified to reduce its flammability (i.e. landscape with lower flammability plants) and that the density and spacing of housing be taken into account when assessing fire risk in the WUI (Spyratos et al., 2007)

Syphard et al. (2012) has done a variety of work studying past fires and the effect of land use planning in the Southern California area. They focused on communities in California by using previous fire perimeter data compiled by the California Department of Forestry and Fire Protection (CAL FIRE) Fire and Resource Assessment Program (FRAP). For the study, Syphard et al. created a continuous raster map representing the number of times an area had burned from the beginning of record-keeping, 1878, until 2001. They focused on properties that had been lost in two Southern California regions prone to wildfires. Their work found that structures in areas with low to intermediate structure density in isolated clusters (with separation of 100 m or more separating clusters) were more likely to burn, rather than the highest density housing. Structures located at the edge of developments or in housing clusters on steep slopes, were also more susceptible. This result suggests that the interaction of both densely populated structures and wildland surrounding and within the community play a role in ignition and spread of fire between structures in the WUI. Arrangement of structures and their location also strongly affected their susceptibility to wildfire. The most important location-dependent variable found in the Santa Monica Mountains was historical fire frequency, which corresponded with wind corridors. Given that property surrounded by wildland vegetation, rather than urban areas were also more likely to burn hints at potential exposure conditions being a very pertinent variable. This relationship has impacts both for future housing planning and zoning as well as risk mapping – identifying regions of certain densities where mitigation strategies such as hardening structures may be most effective in reducing losses.

CASE STUDIES AND INVESTIGATIONS

Reviewed here are a series of WUI fire events (where post-fire reports are available) that have contributed to our understanding or framing of the WUI problem within the United States. There are many events not included in this listing; however, those events mentioned have shaped some of the discussion within this report, summarized in Table 1. Existing mitigation strategies deployed worldwide rely on both quantitative and anecdotal evidence of effectiveness, which in many cases has been compiled as a result of the investigations covered here.

Post-fire investigation remains a significant challenge, as reports of all fires described below reference deficiencies in available knowledge post-fire. Several workshops have been held to try and fulfill this need, including one specifically devoted to the topic hosted by the USFS (WFDRI, 2012) and a general NIST workshop on the WUI that also covered tools for post-fire evaluation (Pellegrino et al., 2013).

The USFS workshop was held to discuss the differing fire data reporting systems at the Federal, State, and local levels. The goal was to discover ways to improve fire data by making sure it is as accurate as possible. There was an information sharing session where different speakers discussed current systems and newer systems that are a work in progress. From these discussions, participants agreed that fire data is mostly inaccurate because of lack of clarity in terms of what defines a wildland fire, lack of reporting in general, and duplicate reports. One issue is that there is a Fire Module and a Wildland Fire Module in federal reporting systems, the latter of which is optional and has different data elements and definitions than the Fire Module. The issues discussed were categorized in the following categories: data and terminology standardization, analysis standardization, and data quality and completeness (WFDRI, 2012).

The data and terminology standardization group had two main focuses: creating a national definition of wildland fire, so everyone knows what events should be reported, and determining the minimum data element requirements for reporting (element definitions will be given to ensure clarity). The analysis standardization group focused on how to develop accurate statistical reports by creating a national estimates approach, producing historical data that contains no duplicate reports, and developing a system from current databases without incorporating all current databases in a new database. The data quality and completeness group was focused on improving incidents of non-reporting, improving the quality of what is reported, and training the entities responsible for reporting (WFDRI, 2012).

Table 1 A list of WUI fires under extreme conditions taking place after 1990. Unless otherwise indicated, reference taken from (Cohen, 2008).

Year	Incident	Location	Structure Loss	Investigations
1990	Painted Cave	Santa Barbara, CA	479	(Foote, 1994)
1991	Spokane "Firestorm"	Spokane, WA	108	
1991	Tunnel/Oakland	Oakland, CA	2900	(Trelles and Pagni, 1997)
1993	Laguna Hills	Old Topanga Laguna and Malibu, CA	634	
1996	Millers Reach	Big Lake, AK	344	
1998	Florida Fires	Flagler and Volusia counties, FL	300	
2000	Cerro Grande	Los Alamos, NM	235	(Cohen, 2000a)
2002	Hayman	Lake George, CO	132	
2002	Rodeo-Chediski	Heber Overgaard, AZ	426	
2003	Aspen	Summerhaven, AZ	340	
2003	Old, Cedar, etc.	Southern CA	3640	
2006	Texas-Oklahoma Fires	Texas and Oklahoma	723	
2007	Angora	Lake Tahoe, CA	245	(Manzello and Foote, 2014; Safford et al., 2009)
2007	Witch, Slide, Grass Valley, etc	Southern CA	2180	(Maranghides et al., 2013; Mell and Maranghides, 2009; IBHS, 2008; Cohen and Stratton, 2008)
2012	Waldo Canyon	Colorado Springs, CO	346	(Quarles et al., 2012)
2014	San Diego and Basilone Complex	San Diego County, CA	65+	(County of San Diego, 2014)

During the NIST symposium, the need to improve tools for post-fire evaluation was highlighted. Both NIST (Maranghides et al., 2013; Mell and Maranghides, 2009) and IBHS (Quarles et al., 2012) have examples of detailed post-response reports available in the literature; however, even these reports cite significant improvements that could be made. At the conclusion of the NIST workshop, it was recommended that more software and hardware training along with consistent standard operating procedures be available for post-fire methodologies and that consistent methodologies for post-fire mitigation be developed. Items such as characterizing firefighting or homeowner suppression efforts during the fire are particularly important and difficult to capture; nonetheless, both are essential for accurate post-fire analyses (Pellegrino et al., 2013).

Santa Barbara Paint Fire (1990)

On June 27, 1990 during a very hot and dry day in California, a fire broke out in the Painted Cave area and formed the "Paint" fire, which subsequently burned 5,000 acres, 440 houses and 28 apartment complexes. An investigation by Foote provided important information on the flammability of roofing. After the fire, 70% of houses with nonflammable roofs were found to have survived, while only 19% of houses with flammable roofs survived (Foote, 1994). Similar conclusions on the effect of flammable roofing on WUI fire spread were found after the 1923 Berkeley Hills fire (National Board of Fire Underwriters, 1923).

Oakland Hills/Tunnel Fire (1991)

The October 1991 Oakland Hills Fire (or Oakland Firestorm) was a significant WUI event that killed 25 people and injured 150 others. While only 1,520 acres were burned, over 3,354 homes and one apartment complex (about 5 buildings) were destroyed, resulting in a net loss of nearly 1.5 billion dollars (Pagni, 1993; Steckler et al., 1991). At the time, the fire was the worst fire loss from a wildland fire in California. Hot and dry Diablo winds contributed to rapid fire spread which trapped firefighters and residents as they tried to escape through narrow, winding roads.

Following the Oakland Hills Fire, several extensive studies were conducted at the University of California, Berkeley, including a study on fire-induced winds including the influence of mass fire effects (Trelles and Pagni, 1997) and studies on firebrand propagation (Pagni and Woycheese, 2000).

Cerro Grande Fire (2000)

There were approximately 200 structures that were completely destroyed or irreparably damaged during the May 2000 Cerro Grande Fire near Los Alamos, New Mexico. Although the fire was an intense crown fire, there were areas within several hundred yards or more of residential communities that burned as a surface fire. The occurrence of the transition to surface fire was discovered because tree canopies leading up to destroyed homes were not burned. Many of the homes burned due to home-to-home fire spread. Another important factor in this fire was an abundance of pine needles, dead leaves, cured vegetation, flammable shrubs, woods piles, etc. adjacent to or on homes, which were ignited by small surface fires or wind-blown firebrands. In several cases, a scratch line, such as the raking of pine needles from the base of a wood wall, prevented a house from igniting (Cohen, 2000b).

Grass Valley Fire (2007)

The 2007 Grass Valley Fire in the Lake Arrowhead area of California destroyed or damaged a total of 199 homes. The wildland fire started at 5:08 pm and transitioned to an urban conflagration after it started burning overlapping home ignition zones (HIZ) at 10:30 pm. From that point forward, homes were primarily ignited by flames and firebrands from other burning structures. The steep terrain of the area added to the intensity of the fire behavior. Most of the destroyed homes had unconsumed vegetation surrounding them, which suggests that homes ignited due to firebrands (Cohen and Stratton, 2008).

Figure 25: These homes near Lake Arrowhead, California, were destroyed on October 22, 2007, as part of the Grass Valley Fire, and serve as a WUI fire disaster example. Although the homes initially ignited from the wildfire, structures continued to ignite and burn after the wildfire had largely ceased its high-intensity spread. Taken from (Cohen, 2008).

For all but six homes, the advancing high intensity wildfire was not the direct cause of home ignitions (Cohen and Stratton, 2008). Instead, the structure ignition was the result of fire spread from surface fuels within the residential area in contact with homes, the result of firebrands generated by burning vegetation or thermal exposure directly related to burning residences.

Witch Creek and Guejito Fires (2007)

Among a complex of fires in California occurring in October 2007 were the Witch Creek and Guejito fires in San Diego County, California. As a result of the fires there were over 2000 structures lost, over 1 million persons evacuated (the largest in California history) and, through federal assistance, over 6,000 firefighters fought the blazes, including the United States Armed Forces and National Guard. Exacerbated by recent drought and low humidity, high wind Santa Ana conditions contributed to rapid fire spread.

A significant number of studies investigated isolated communities as well as whole regional areas to learn from these fires. Evidence determined that many homes were ignited via firebrands (IBHS, 2008). Overhanging trees played a large factor in the burning of homes, particularly due to built-up dead vegetative material. Two major implications from these fires were the importance of land use planning and the critical need for science-based data and research (Keeley, 2013).

An initial investigation into the Witch Creek and Guejito fires showed that ignitions due directly or indirectly to embers totaled 55 of 74 destroyed homes in the Trails community studied (Mell and Maranghides, 2009). Specific study of the Trails community showed embers from the wildland fire were reported in the community about 80 minutes before the fire front arrived. Through observations and discussions with home owners, it was determined that there was significant surface litter present on and around structures. The degree of damage was often dependent on surrounding structural and vegetative fuels, which varied with location. As new structures ignited in the community, the presence of embers also increased. Of the 16 damaged homes in the Trails community, the ignition location was most often a detached structure or decking (Mell and Maranghides, 2009).

Further investigation by NIST researchers found that a majority of defensive suppression activities by responding fire departments in the Trails community were very effective and that other defensive activities, such as those advocated by Firewise, were somewhat effective and that the level of effectiveness was correlated to fire and ember exposure. Defensive actions were also more than twice as effective at saving structures in low-exposure sections of the community in comparison to high-risk areas (Maranghides et al., 2013).

Waldo Canyon Fire (2012)

In investigation of the Waldo Canyon fire, there were multiple risks that contributed to home loss. Wooded slopes with overhanging decks created a large hazard. Windows were another hazard, as they allowed firebrands to enter the house. Home-to-home spacing where houses were destroyed was usually 12 to 20 feet (3.6 – 6 m). In high density situations, fire-rated wall construction could be helpful. Other hazards included near home combustibles, buildup of embers at the base of exterior walls, wood shake roofs and roof and exterior wall designs that were vulnerable to ember accumulation (Quarles et al., 2012).

Quarles et al. (2012) also found that fuel treatment efforts in Solitude Park near the Cedar Heights neighborhood were successful, particularly in assisting firefighting efforts in the neighborhood. However, there was evidence of potentially vulnerable conditions that may not have performed as well if conditions had changed. While the mitigation work conducted in the high risk areas of the community was credited with helping the fire department achieve an 82 percent save rate, further investigation particularly focusing on exposure conditions vs. the vulnerabilities of homes is necessary to help refine these conclusions. Reports on some of these ongoing investigations, particularly performed by NIST should be released soon.

MITIGATION STRATEGIES

The history of aggressive fire suppression has brought about changes to species and vegetation that have resulted in the high intensity wildfires of the present. During WUI fires, the necessities for combustion can be met through flames (radiation and convection heating) and firebrand ignitions. Models and testing have shown that large flames must be within 100-200 feet of the structure (the home ignition zone) in order to ignite it. Because this distance is rarely met for sufficient duration, small flames or firebrands ignite most homes (Cohen, 2008). In order to prevent disaster, WUI fires need to be thought of in terms of the potential for home ignition. Many approaches to minimize home ignition are possible, including regulation, community education programs, fire service intervention and fuel treatments. These tools may be applied at different scales, from the community, to the neighborhood or subdivision, individual lot or applying to components of an individual building (Figure 26). Fuel treatments themselves do not necessarily make homes less ignitable; rather, they facilitate successful suppression. The goal of decreasing home ignitability places much responsibility on the homeowner (Cohen, 2008). Post-fire analyses have shown that some mitigation strategies are effective in decreasing fire damage; these strategies will be reviewed throughout this section.

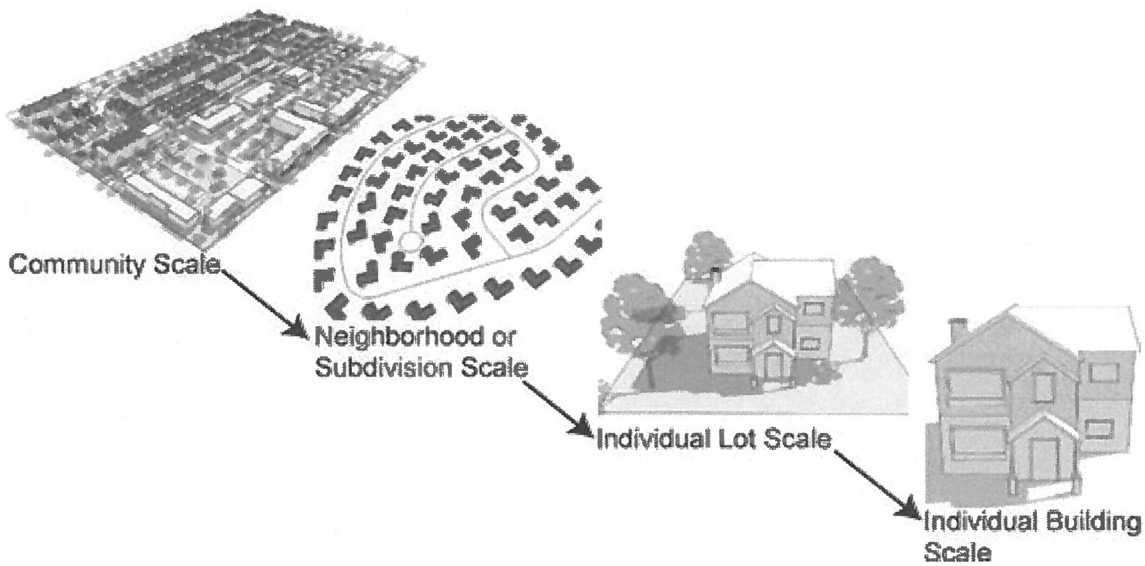

Figure 26: Different scales at which mitigation strategies can be applied from Duerkson et al. (2011).

Codes and Standards

Codes and standards are useful guidelines for regulatory bodies to adopt in order to help mitigate potential WUI home ignitions. A number of relevant codes and standards exist for the WUI. Regulatory standards specifically for the WUI include:

- NFPA 1141: Standard for fire protection infrastructure for land development in wildland, rural, and suburban areas (NFPA, 2012)

- NFPA 1142: Standard on water supplies for suburban and rual firefighting (NFPA, 2012b)
- NFPA 1144: Standard for reducing structure ignition hazards from wildland fire (NFPA 2013)
- NFPA 1143: Standard for wildland fire management (NFPA, 2014)
- ICC International Wildland-Urban Interface Code (ICC, 2012)
- California Building Code Chapter 7A: Materials and Construction Methods for Exterior Wildfire Exposure (CBC, 2009)

The standards set by NFPA 1141 - 1144, the ICC WUI code and CA CBC Chp. 7A can partially be used by AHJ's, planners, developers, and communities. NFPA 1141 primarily addresses means of access, building access and separation, fire protection, water supply, community safety, emergency preparedness and fire protection during construction. NFPA 1142 regulates water supplies required in rural areas which may include the WUI. NFPA 1143 applies to wildland fire management. NFPA 1144 applies more to home or property owners in the WUI, as it includes means of assessing fire hazards in the structure ignition zone (or HIZ), building design, location and construction and fuel loads around the defensible space around a home.

Section 701A of the 2009 California Building Code addresses topics in order to protect against WUI fires, including protection against intrusion of embers under roof coverings or into attics through attic ventilation, ignition-resistant exterior construction, use of tempered glass windows, and multiple decking requirements (CBC, 2009). In the aftermath of the 2007 San Diego fires, investigation showed that houses built between 2001 to 2004 following CA Building Code standards were much less likely to burn, with 2-3% of those houses exposed to WUI fires burning, as opposed to 13-17% of exposed homes built before 2001 burning (IBHS, 2008).

Many other standards are directly related to the above, primarily for the testing of materials referenced for use on components of structures in WUI communities such as:

- ASTM E108 - Standard Test Methods for Fire Tests of Roof Coverings (ASTM, 2011)
- ASTM E84 - Standard Test Method for Surface Burning Characteristics of Building Materials (ASTM, 2014b)

- ASTM E2726 – Standard Test Method for Evaluating the Fire-Test-Response of Deck Structures to Burning Brands (ASTM, 2012)
- ASTM D2898 – Standard Practice for Accelerated Weathering of Fire-Retardant-Treated Wood for Fire Testing (ASTM, 2010)
- UL 790 - Standard Test Methods for Fire Tests of Roof Coverings (UL, 2014)
- Testing Standards CA SFM 12.7A-1, Exterior Wall Siding and Sheathing (CBC, 2009)
- Testing Standards CA SFM 12.7A-2, Exterior Windows (CBC, 2009)
- Testing Standards CA SFM 12.7A-3, Under Eaves (CBC, 2009)
- Testing Standards CA SFM 12.7A-4, Decking (CBC, 2009)

In a Fire Protection Research Foundation (FPRF) review of WUI regulatory practices, Duerksen et al. outlined four levels of WUI Regulatory rules: community scale, neighborhood/subdivision scale, individual lot scale, and structure protection (Duerksen et al., 2011). In reviewing these rules and standards, Duerksen interviewed twelve WUI communities spread across the United States and asked nine questions to determine how the available tools are actually being used. Based on responses from the interview questions, several important lessons were learned, which are summarized below:

- Most communities were happy with the technical aspects of standards available to them
- Enforcement requires coordination between multiple departments.
- The greatest deficiencies found among the communities were a lack of coverage for existing development and a lack of enforcement of maintenance. The reason for the second problem is that *enforcing long-term maintenance of defensible space is labor and cost intensive*.
- Flexibility in administration of WUI regulations is critical.

The study suggested that new technical codes are probably not needed, but that the reorganization of the material to reflect their actual use would be beneficial. This recommendation is given because the authors found that many communities “cherry-pick” what is most useful to them. A WUI Best Practices Guide for local governments was also a suggestion for communities that do not want to fully adopt a set of standards (Duerksen et al., 2011).

Through the evaluation of 12 independent variables, including vegetation density, area of defensible space, adjacency of a parcel to public lands, proximity of a house to the nearest fire station, road width, road type, parcel size, subdivision morphology, assessed value, elevation, slope and aspect, Bhandary and Muller (2009) evaluated risk factors that influence the probability that a house will burn from a wildfire. Logistic regression was used to study data gathered from pre and post-fire IKONOS images as well as other geo-referenced data. Both the Healthy Forests Restoration Act (HFRA) and NFPA 1144 standard and policy variables were tested over the test area located in Colorado with elevations ranging from 6000 to 8000 feet. It was found that 8 of the 12 variables were statistically significant. These 8 variables included: vegetation density, area of defensible space, adjacency of parcel to federal land, road width, and subdivision morphology, proximity of a house to a fire station, assessed value, and parcel slope. They also stated that both the full and reduced models presented in this paper lend general support to the standard risk mitigation strategy represented by the NFPA 1144 guidelines and the results of the full model also support use of landscape treatments as a mitigation strategy both on private lots and surrounding undeveloped lands (Bhandary and Muller, 2009).

Other programs, such as Firewise, provide checklists and guidelines for communities and homeowners to perform preventative procedures to prevent WUI disasters. These programs are outlined in a following section.

Vegetation, Separation, Defensible Space and Fuel Treatments

Extensive work by Cohen et al. (2000b), including experiments with large crown fires in the Northwest Territories has, confirmed that separating homes from surrounding vegetation by at least ~120 ft will almost always prevent radiant ignition of the home. If radiant ignition is prevented, other sources of ignition around a home become more significant. The propagation of small flames through local vegetation can ignite small debris and other flammable material near a home, such as wood piles or collected dead vegetation, to cause radiant or direct flame contact ignition of the home. Firewise, NFPA 1141 and the ICC WUI Code all define the home ignition zone within the first 200 feet of a home. Some details on how this zone is defined in each specific code is listed in the appendix; however, details from Firewise will be presented here, as that is the only program which has been quantitatively assessed in the aftermath of a WUI fire.

Zone Concept

As part of an appropriate scheme for structure protection, fuel modification in zones around a structure in the WUI is advised by educational programs such as Firewise, as well as by standards such as NFPA 1141 and the ICC WUI Code[13]. Firewise specifically calls for limiting the amount of flammable vegetation and materials surrounding the home and increasing the moisture content of remaining vegetation. The home itself and everything around it up to 100 – 200 feet is known as the 'home ignition zone' (HIZ), as described by Cohen (2008). The HIZ is typically divided into three zones, shown illustratively in Figure 27 (NFPA, 2014b).

Figure 27: Diagram of three zones recommended by Firewise (Firewise, 2015b).

The **first zone** encircles the structure and all its attachments (wooden decks, fences, and boardwalks) for at least 30 feet on all sides. Within this area, Firewise recommends to:

- Mow the lawn regularly. Prune trees up 6-10 ft from the ground.
- Space conifer trees 30 ft between crowns. Trim back trees with overhanging branches within ten feet of the roof.

[13] Note that these zones are clearly designed to mitigate ignitions by radiation or direct flame contact as firebrands are known to travel up to several miles and cannot be stopped by breaks in vegetation.

- Create a 'noncombustible zone within 5 feet of the home, using non-flammable landscaping materials and/or high-moisture-content annuals and perennials [14].
- Remove dead vegetation from under deck and within 10 ft of house.
- Consider fire-resistant material for patio furniture, swing sets, etc.
- Remove firewood stacks and propane tanks; they should not be located in this zone.
- Water plants, trees and mulch regularly.
- Consider xeriscaping if you are affected by water-use restrictions.

The **second zone** is 30 to 100 feet from the home, and plants in this zone should be low-growing, well irrigated and not very flammable. In this area it is recommended to:

- Leave 30 feet between clusters of two to three trees, or 20 feet between individual trees.
- Encourage a mixture of deciduous and coniferous trees.
- Create 'fuel breaks', like driveways, gravel walkways and lawns.
- Prune trees up six to ten feet from the ground.

The **third zone** is 100 to 200 feet from the home, and this area should be thinned, although less spacing between trees is required than in Zone 2. NOTE: Because of other factors such as topography, the recommended distances to mitigate for radiant heat exposure actually extend between 100 to 200 feet from the home – on a site-specific basis. In this area:

- Remove smaller conifers that are growing between taller trees. Remove heavy accumulation of woody debris.
- Reduce the density of tall trees so canopies are not touching.

Similar guidelines are espoused in NFPA 1141, such as recommendation of three zones from the home between 100 – 200 ft. The standard also recommends spacing between tree crowns (preventing crown fires and reducing potential fire severity and radiant exposure), as shown in Figure 28. Implementing mitigation strategies to further distances is sometimes recommended

[14] Note the closest area near the home in this diagram is not a "fire-free" area.

depending on the fuel loading and potential fire severity that might be encountered (which varies as a function of fuel, weather, and terrain).

Table A.6.2.5 Recommended Tree Crown Spacing to Prevent Structural Ignition from Wildland Fire Radiant Heat

Zone	Distance from Structure	Recommended Tree Crown Spacing
1	0–30 ft (0–9 m)	18 ft (5.5 m)
2	30–60 ft (9–18 m)	12 ft (3.7 m)
3	60–100 ft (18–30 m)	6 ft (1.8 m)
4	Beyond 100 ft (30 m)	No restrictions

Figure 28: Recommended spacing between tree crowns from NFPA 1141.

Some confirmation of the effectiveness of these treatments has been provided in surveys following the NIST investigation of the Witch Creek and Guejito Fires. As shown in Figure 29, the percent of structures destroyed with wildland vegetation within zone 1 (0 – 30 ft from the structure) increased drastically to 67%, compared to only 32% of structure losses for homes without wildland vegetation (modified) in that zone (Maranghides et al., 2013). Similar results were found in zone 3 (100 – 200 ft from the structure) and even extended beyond this to other area surrounding the home (zone 4). Another issue associated with buffer zones that was observed is that some homeowners pushed fuel piles away from their homes to try and achieve the 100 ft separation but in the process, they pushed the fuel closer to their neighbor's home. The zone concept is most effective when the fuel is physically removed from the area, not just pushed to the edge of one's property and perhaps near someone else's structure. More data from this study is presented in a review of Firewise effectiveness in the following section.

Zone	With Wildland Vegetation	Without Wildland Vegetation
1	67%	32%
2	59%	27%
3	54%	27%
4	64%	17

Figure 29: Percent structure destroyed with and without wildland vegetation for Firewise zones 1 through 4 following the Witch Creek and Guejito Fires from Maranghides et al. (2013).

Defensible Space

Recent analysis of pre and post-fire imagery by Syphard et al. (2014) of 1000 structures burned between 2001 to 2010 in San Diego County, CA showed that structures were more likely to survive a fire with defensible space immediately adjacent to them. The most effective treatment distance was between 5 and 20 m (16-66 ft) from the structure, but distances larger than 30 m (100 ft) did not reduce the probability of burning, even when structures were located on steep slopes. The most effective action found was to reduce woody cover up to 40% immediately adjacent to structures and to ensure no vegetation was overhanging or touching the structure. While this recent analysis report is promising for current zoning and defensible space practices, information is missing in the model such as the specific types of construction, other mitigation undertaken, suppression efforts, etc. Only with more detailed pre and post-fire investigations could these questions be answered, as some effects may be associate with one another, such as firefighters choosing to perform suppression only on homes that already had defensible space, but this new technique may be able to provide data on a larger scale to supplement more intensive investigative efforts.

Fuel Treatments

Fuel treatments involve physically altering vegetation (e.g. removing, thinning, pruning, mastication, etc.) on natural wildland with the intent of reducing the probability of extreme fire behavior, including reducing a potential fire's intensity, flame lengths and rates of spread (Hudak et al., 2011). Mechanical treatments often involve removing ladder fuels, reducing surface fuels or removing densely spaced trees to reduce the probability of transition to a crown fire in the tree canopy. Mechanical treatments can be accomplished by hand or machine and may include chipping or pile burning of removed fuels. Grazing is another option for smaller-vegetation; in this case, goats or other animals can reduce the fuel loading (Hood and Wu, 2006). When performed in accordance with local ecological fire regimes, prescribed burning is an important option for reducing fuel loads and thus the intensity of a potential wildland fire (Wiedinmyer and Hurteau, 2010). Continued maintenance is important in order to retain fuel treatment effectiveness. The reduction of intensity is sometimes designed along with protection of WUI communities; however, it can be used to reduce the intensity of fire behavior regardless of the presence of a community.

For fuel treatments to be successful, site-specific fuel treatments are necessary. Agee and Skinner suggest four guidelines to develop fire resilient stands in dry forests. These recommendations include reducing surface fuels, increasing the ground to canopy height, decreasing crown density, and retaining big trees of fire resistant species (Agee and Skinner, 2005). Despite the benefits of fuel treatments, caution must be exercised in regards to the amount of thinning, because too much thinning can increase surface wind speed, cause drier surface fuels, and increase the flammability of fuels over time. All of these factors result in increased surface fire behavior. An understanding of the changes to fuel models, and their effects on the fire behavior of the specific landscape, must be accomplished before conducting a fuel treatment plan. Treating fuels is an ongoing venture that will be costly; however, biomass from fuel treatments can serve as a resource that can increase local economic development and help to cover the cost of fuel treatments (Reinhardt et al., 2008). The strategy of using fuel treatments near WUI communities and collecting the discarded biomass has been effective in some communities such as Flagstaff, AZ. There they have observed improved access for fire fighters and apparatus, easier location and suppression of spot fires and overall improved public safety (Farnsworth et al., 2003).

Most research on fuel treatments has focused on fuel treatments in the wild rather than in the WUI; therefore, current assessments do not include their effectiveness in reducing structure ignition potential. There is general consensus (Hudak et al., 2011) that fuel treatments are effective in lowering fire severity in both forests and rangelands, where effectiveness is determined by whether the treatments reduced fire behavior to improve firefighter safety, protect people and property and whether they mitigated severe fire effects important to vegetation and soil resources. In almost all cases, Hudak et al. (2011) found that fires with appropriate fuel treatments reduced fire behavior from a crown fire to a surface fire in forest stands. Prescribed burns were found to vary in effectiveness. The treatments became less effective over time without maintenance. Topography and wind also affected treatment effectiveness (i.e., resulting fire intensity) in Hudak's study.

Syphard et al. (2011a) studied the effectiveness of fuel breaks in Southern California, the main approach used in the region to mitigate wildfire risk. They referred to two studies, one done over a 28 year period by the USGS and the other conducted over a 30 year period by the Conservation Biology Institute. Both studies concluded that fuel breaks were only effective in stopping fire spread through wildland when they provided firefighter access. Among the forests studied, only 22% to 47% of fires stopped at fuel breaks, even when firefighters were present (Syphard et al., 2011b). The authors believed that it would be useful to have a fire model which accurately determines the effectiveness or size of a needed fuel break; however, such models are not yet available (Syphard et al., 2011a).

In an assessment of the 2007 Angora fire which burned under extreme conditions in the forests surrounding South Lake Tahoe, California, investigators found that area fuel treatments were effective in reducing fire behavior from a crown fire to a surface fire (Murphy et al., 2007). For example, Figure 30 shows the effect of fuel treatments around a single lot which locally reduced a crown fire into a surface fire. Fuel treatments located adjacent to subdivisions provided important safety zones for firefighters, increasing suppression effectiveness which saved structures. Urban lot treatments were also qualitatively shown to reduce ember production and reduce heat and smoke, allowing firefighters to be more effective at suppression efforts. Still, a large number of houses were observed to burn from firebrands generated from other burning structures, rather than from wildland fuels (Murphy et al., 2007). Fuel treatments on steep slopes burned at higher intensity than those on flat ground, both because they were adjacent to untreated units and because fire severity is increased with increasing slope. Therefore, the authors recommend further study as to appropriate fuel treatments on steep slopes and the balance between runoff management and fire severity (Murphy et al., 2007; Safford et al., 2009).

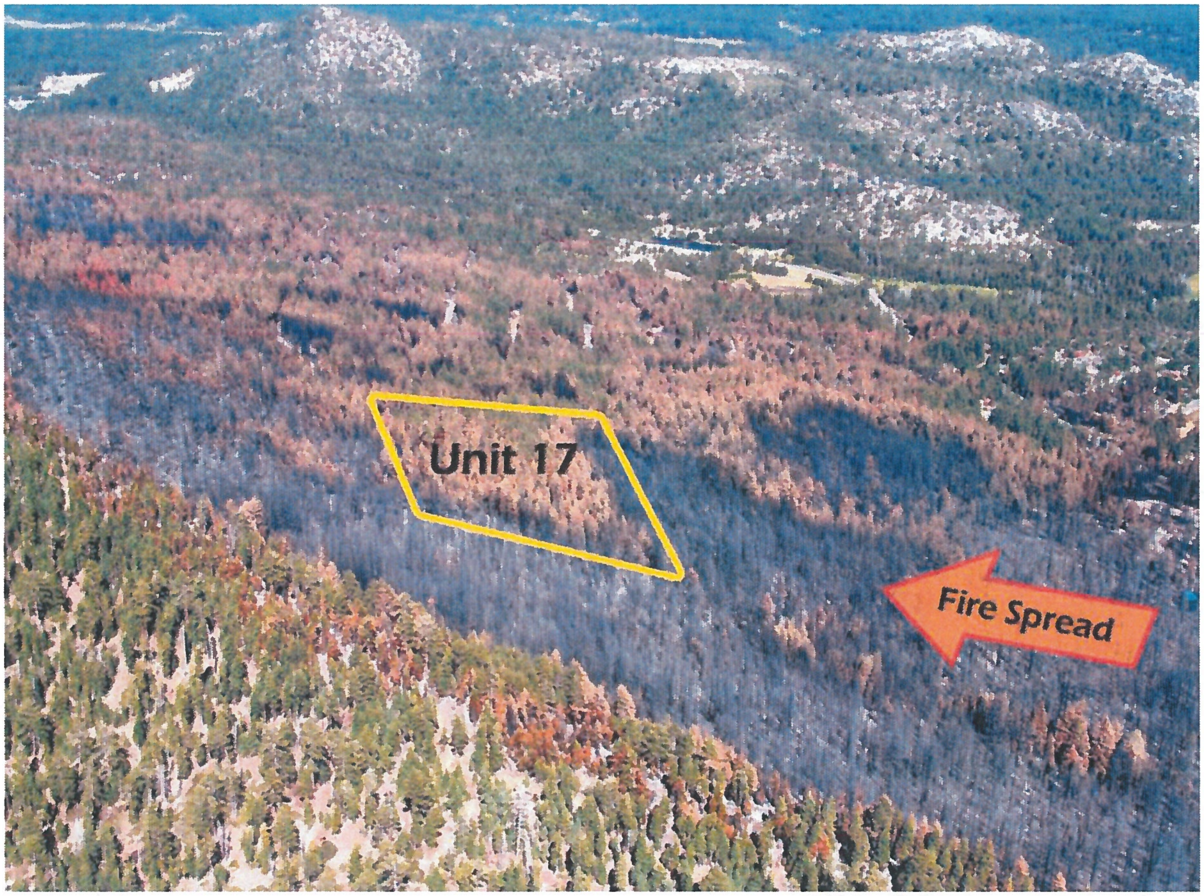

Figure 30: This telling photo from (Murphy et al., 2007) shows one fuel treatment area which met the full force of a crowning headfire, torching trees along the southern edge of the unit. After penetrating the treated area, the crown fire lost momentum and transitioned to a lower intensity surface fire due to a greatly reduced amount of surface fuel, limited ladder fuels, and wider crown spacing.

There is some information available in the literature regarding the placement of fuel treatments in order to optimize their effectiveness in reducing fire severity. Using tools such as FARSITE, Finney (2004, 2006) has computationally investigated methods to optimize fuel treatment locations, particularly to reduce the spread rate of a fire and its intensity or propensity for crowning. Massada et al. (2011) studied the most efficient approach for community or organizational scale fuel management. Their simulation approach's goal was to protect a group of clusters to minimize treatment area and reduce costs. It was acknowledged that different types of fuel treatments should be explored (they only tested 30 m wide fuel breaks) and that minimizing treatment area is not necessarily the best method for protection. Their research provides a starting point for studies on fuel breaks, but must be continued to explore other options. Unfortunately, these approaches only apply to protection where fire spread by spotting (firebrands) is minimal; however, many documented severe fires include spotting as a method of spread (Albini, 1988).

Long term simulations have also been run to assess the effectiveness of proper fuel treatment maintenance. Ager et al. (2007) modeled fire scenarios of thinning and fuel treatments in Eastern Oregon where repeated thinning, thinning with underburning and maintenance burns were performed every 10 years and compared these results to those where treatments stopped after some time period. They found that even without continued maintenance, some thinning and fuel treatment effects are long lasting (20-40 years). Some treatments, such as one-time thinning without continuous treatments may also result in less desirable fire conditions (larger fires) than no treatment at all.

A special case for fuel treatments involves the large swath of beetle-killed forests across North America which present some potential for increased fire severity, due to the accumulation of dead, dry fuel. Aronson and Kulakowski (2013) investigated the intersection of these beetle-killed forests and the WUI. They found that the majority of beetle killed areas (>98%) occurred far from the WUI and, therefore, only 1-2% of affected areas would require mitigation efforts (such as fuel treatments to create defensible space) to reduce the risk of structure ignition. They concluded that if the focus is solely on protection in the WUI, costs for this reduction would be minimal in comparison to managing entire forests.

Benefits of Treatment

Despite the obvious benefits of reduced fire severity and lower probabilities of ignition after developing and maintaining fuel treatments around WUI communities, there are sometimes drawbacks to prescribed burning, with residents complaining about air pollution and a risk of uncontrolled fires. In Florida, results from an air quality study measured amounts of particulate matter from both prescribed burns and wildfires (Harvey and Fitzgerald, 2004). After comparing results from uncontrolled wildfires and prescribed burns, the wildfires were found to have a higher health risk because they produced higher particulate amounts for longer periods of time; however, neither prescribed nor wildfires exceeded the 24-hour standard of 150 micrograms per cubic meter exposure. Florida burns 125,000 acres per year, one of highest prescribed burning rates in the country.

Another concern has been the effect of prescribed burning on carbon emissions from forested areas. Carbon sequestration by forested ecosystems offers a potential climate change mitigation benefit; however, wildland fires have the potential to reverse this benefit. One potential means of reducing carbon emissions from wildland fires is the use of prescribed burning, which consumes less biomass and, therefore, releases less carbon to the atmosphere. Wide-scale prescribed fire application can reduce CO_2 fire emissions for the western U.S. by 18-25% in the western U.S., and by as much as 60% in specific forest systems. (Wiedinmyer and Hurteau, 2010).

Homeowner Educational and Outreach Programs

Programs such as Firewise, Ready Set Go!, Fire Adapted Communities, Fire Safe Council (CA), Living with Fire (NV) and many others offer resources to homeowners to help them prepare for eventual WUI fires, by performing defensive procedures on and near their property as well as encouraging community-wide interactions as a way to prepare for WUI fires. These programs are a key component of WUI fire mitigation, as much of the problem resides within the home ignition zone, which homeowners must independently maintain. Studies, such as one recently conducted in Florida, have begun to show that increased spending on education efforts can reduce spending on wildfire losses and suppression efforts (estimated to be a 35:1 benefit to cost ratio) (Prestemon et al., 2010).

In the few WUI fires with detailed investigations, community-based approaches seem to be effective in reducing structure loss (Maranghides et al., 2013). This effectiveness is mostly due to the fact that small changes, such as clearing brush and reducing home vulnerabilities that could lead to ignition, are most important to reducing structure vulnerability; however, this fact places responsibility on the homeowners (Cohen, 2008). Whereas the built environment tends to be heavily regulated with little responsibility on the homeowner, WUI fire protection involves continual maintenance that requires active homeowner participation. Even small homeowner retrofits can significantly decrease fire damage, as was shown in a study of the 2007 California Wildfires (IBHS, 2008). The effect of small changes suggests that the approach to WUI fires needs to change from what it traditionally was, with less focus on broader changes such as fuel treatments and increased focus on the home ignition zone (Cohen, 2008). This should not discount the development of engineering solutions that, while never a complete solution, may significantly assist the problem via reducing burdens on homeowner maintenance, etc. by providing more fire-safe designs to begin with.

Many community-based programs are available to homeowners. Reams et al. (2008) provided the results of a survey of non-federal fire protection programs for the WUI. State and local programs were taken from the USFS National Wildfire Programs website (http://www.wildfireprograms.usda.gov/)[15], which provides a search engine for programs in local areas. The survey focused on how managers approached these programs, rather than the programs' specific effectiveness. In general, many homeowners expressed apathy and lack of responsibility or belief in wildland fire risk. Public education has been the most effective way to combat this problem and is an action taken by most of the surveyed programs (Reams et al., 2008). A summary of nationwide programs is provided in the Appendix of this report.

Firewise

Firewise is a program of the National Fire Protection Association, which "encourages local solutions for safety by involving homeowners in taking individual responsibility for preparing their homes from the risk of wildfire" (NFPA, 2014b). A collection of tools for homeowners and communities including landscaping guides, community assessment resources and recommendations for firefighter safety in the WUI is provided. Some tools are also useful for land managers, outreach coordinators and public information officers. Details on some elements of Firewise, such as the "Zone Concept" were provided earlier in this report.

Through an extensive investigation of the Trails community by NIST after the 2007 Witch Creek and Guejito fires, the effectiveness of several Firewise treatment strategies in reducing home ignition were, for the first time, able to be quantitatively assessed (Maranghides et al., 2013). Figure 31 shows the Firewise treatments assessed as related to items recommended off of a Firewise checklist. Data was collected on nearly all checklist items, but investigators found the Firewise checklists difficult to interpret, in terms of effectiveness, in a scientific manner. No

[15] Note, the USDA National Wildfire Programs Directory stopped being updated after January, 2010.

treatments were found to be ineffective. Not all treatments could be statistically evaluated due to lack of data, while many that were evaluated had different levels of effectiveness. The statistically significant effective treatments included having an irrigated area around the house, pruning and clearing vegetation, clearing out leaf clutter and overhanging branches, and avoiding wood use (roofs, fences, decks, etc.) (Maranghides et al., 2013).

Treatment Number	Treatment Description	Treatment Number	Treatment Description
1a	**Zone 1**[vii]. This well-irrigated area encircles the structure for at least 30' on all sides. *(If one section does not meet this it is a "fail")*	12	Set your single-story structure at least 30 feet back from any ridge or cliff; increase distance if your home will be higher than one story.
1b	**Zone 1.** Provide space for fire suppression equipment in the event of an emergency.	13	Use construction materials that are fire-resistant or non-combustible whenever possible. **(The presence of a wood roof, siding, eave, deck, pergola, fence or wood pile receives a "no")**
1c	**Zone 1.** Plantings should be limited to carefully spaced low flammability species.	14	Roof construction from materials such as Class-A asphalt shingles, slate or clay tile, metal, cement and concrete products, or terra-cotta tiles.
2	**Zone 2.** Low flammability plant materials should be used. Plants should be low-growing, and irrigation should extend into this zone.	15	On exterior wall facing, fire resistive materials such as stucco or masonry are much better choices than vinyl which can soften and melt.
3	**Zone 3.** Place low-growing plants and well-spaced trees in this area, remembering to keep the volume of vegetation (fuel) low.	16	Driveway 12 feet wide with a vertical clearance of 15 feet and a slope that is less than 5 percent and include ample turnaround space near the house.
4	**Zone 4.** This furthest zone from the structure is a natural area. Selectively prune and thin all plants and remove highly flammable vegetation.	17	Periodically inspect your property, clearing dead wood and dense vegetation at distance of at least 30 feet from your house.
6	Take out the "ladder fuels" — vegetation that serves as a link between grass and tree tops.	18	Move firewood away from the house or attachments like fences or decks. **(30 feet is defined as a minimum distance)**
7	Provide added protection with "fuel breaks" like driveways, gravel walkways, and lawns.	19	*Is the structure free of an attached wood fence?*
8	Keep vegetation pruned. Prune all trees so the lowest limbs are 6' to 10' from the ground.	20	Prevent combustible materials and debris from accumulating beneath patio decks or elevated porches.
9	Remove leaf clutter and dead and overhanging branches.	21	Screen or box-in areas below patios and decks with wire screen no larger than 1/8 inch mesh.
10	Store firewood away from the house. **(30 feet is defined as a minimum distance)**	22	Elevated wooden deck not located at top of hill where in direct line of a fire.
11	Slope of terrain; build on the most level portion of the land.		

Figure 31: Firewise checklist treatments from Maranghides et al. (2013) used to assess treatment effectiveness following the 2007 Witch Creek and Guejito fires.

By statistically analyzing data following investigation of the Witch Creek and Guejito fires, NIST was able to show that there were relationships between some preventative measures and a decreased probability of structure damage or destruction. The statistical analysis included a Chi-Square test to determine whether the null hypothesis was true or not, in essence determining whether preventative measures listed in the Firewise Treatments in Figure 31 had an association with damage to a property's primary structure. They found the following treatments proved to be significant to a p-value of 0.001 (very strong presumption against null hypothesis)

- Treatment 1a is present (pass) if an irrigated area encircles the structure for 9 m (30 ft) feet on all sides.
- Treatment 7 is present (pass) if fuel breaks like driveways, gravel walkways and lawns are present.
- Treatment 8 is present (pass) if vegetation on the property is pruned to 6 to 10 feet from the ground.
- Treatment 9 is present (pass) if leaf clutter and dead and overhanging branches are removed from the property.
- Treatment 13 is present (pass) if there is no wood roof, wood siding, wood eave, wood deck, wood pergola, wood fence or wood pile on the property.
- Treatment 17 is present (pass) if there dead wood and dense vegetation is cleared at least 30 feet from the house
- Treatment 19 is present (pass) if there is no wood fence attached to the house.

Only treatment 8 with a p-value of 0.01 (strong presumption against null hypothesis) and treatment 13 with a p-value of 0.05 (strong presumption against null hypothesis) did not meet the p-value of 0.001 (Maranghides et al., 2013). Firewise treatment 14 (roof construction) could not be tested for statistical significance due to the fact that all the structures that failed were destroyed, thereby, making the use of the Chi-Square test statistic invalid (i.e., all flammable wood shingle roofs were most likely destroyed). Results indicating the significant role roofing material plays in home ignition in the WUI are found from the same report reproduced here in Figure 17. For treatments 1C, 6, 11, 15, 18, 20, 21 and 22 not listed above, the treatments were not rejected, as the statistical testing by NIST found that there was no observable indication that they reduced a structure's potential for damage. This result may have been because damaged structures were completely destroyed (Treatment 14) or because insufficient data was available during the assessment (such as Treatment 10, whether there is no Firewood within 30 feet of the structure). These items may still play a role in preventing home ignitions, but more data will need to be collected to quantitatively inspect these results (Maranghides et al., 2013).

The NIST study also looked at the percentage of damaged homes at the perimeter of the Trails community affected by the fire versus those at the interior. They found that perimeter properties had 54% (43 of 80) of the residential structures damaged or destroyed, while interior properties had 29% (47 of 162) of the residential structures damaged or destroyed. In total, 37% (90 of 242) of the homes were damaged or destroyed across the entire Trails community (Maranghides et al., 2013).

The authors noted that Firewise does not explicitly recognize the hazard that an untreated property can have on adjacent properties (Maranghides et al., 2013), despite the importance of structure-to-structure or property-to-property interactions within a WUI community (Syphard et al., 2012). In these cases, the authors believed that the Firewise Zone Concept assumes a potential fire would burn through zones 3 and 4 at lower intensities compared to wildland adjacent to these zones. The low intensity burns, combined with treatments in Zone 1 and 2 that should result in no burning, are the essence of the Firewise Zone Concept. The authors wondered whether "*it is desirable for a wildland fire to burn through sections of the community, even if these sections are greater than 100 feet from a structure?*" (Maranghides et al., 2013). This may appear because the Firewise zone concept was developed as a result of studying fires that are in Intermix Communities where structure spacing is much greater than it was in the Trails community. The report notes that the Firewise zoning concept may not be ideal in its current form for WUI communities with closely built structures, as the concept could allow for spread through the community. Additionally, for Firewise treatments and the zoning concept to be most effective, community cooperation is necessary, because untreated properties may affect treated properties (Maranghides et al., 2013; IBHS, 2008; Quarles et al., 2012).

In another study of the Witch Creek fire by IBHS, fire effects on three shelter-in-place (SIP) communities[16] and three conventionally built communities were compared (IBHS, 2008). The most significant finding was that no homes in SIP communities were lost during the fire. Data was collected via aerial photos (for physical damage as well as community characteristics), site visits, and via interviews and focus groups (to understand community awareness, procedures, etc.). The investigators observed that houses along the edge of a community or densely placed within a community are most at risk for burning (the latter referred to as *cluster burning*). They recommended that the focus in mitigation shift to educating homeowners on a community basis as to what measures they can take to protect their homes. This recommendation was developed because residents were more aware of the risks and mitigation strategies for WUI fires, or because manual suppression was used by residents to prevent small firebrand-ignited fires or low intensity surface burns from igniting the structure. Interviews and focus groups with home owners found that owners do not wish for mandatory government stipulations on housing requirements in WUI zones, but want education on how to take care of their homes.

Fire Adapted Communities

Fire Adapted Communities (FAC) is a collaborative effort to bring together effective programs, tools and resources for reducing community wildfire risk. The collaborative nature of the program covers responsibilities and means for working together between various community members, from the individual homeowner to the city planner or policy maker, represented visually in Figure 32. These recommended collaborative actions are shown in Figure 32. The primary elements of a fire adapted community according to (Quarles et al., 2012) are:

1. An informed and active community that shares responsibility for mitigation practices.
2. A collaboratively developed and implemented Community Wildfire Protection Plan (CWPP).

[16] "SIP is a term used in San Diego County; however, the SIP restrictions and covenants that combine to protect homes community-wide could be referred to as "Wildfire Resistant Communities" for purposes of exporting the standards to other areas. They do serve as a useful comparison because every home must share the same fire-resistive design qualities, including a well-maintained fire district-approved vegetation management plan" (IBHS, 2008).

3. Structures hardened to fire and including adequate defensible space practices; advocated by Firewise Communities, IBHS and others.
4. Local response organizations with the capability to help the community prepare and can respond to wildfire; advocated by Ready, Set, Go!
5. Local response organizations with up-to- date agreements with others who play a role in mitigation and response.
6. WUI Codes, Standards or Ordinances, where appropriate, which guide development
7. A visible wildfire reduction prevention program that educates the public about the importance of a communitywide approach and the role of individual homeowners.
8. Adequate fuels treatments conducted in and near the community, including development and maintenance of a fuels buffer or firebreak around the community.
9. Established and well-known evacuation procedures

Quarles et al. (2012) Fire Adapted Communities report on the Waldo Canyon fire in Colorado Springs provided mostly qualitative assessments on how effective these mitigation strategies were at preventing home ignitions and identifying vulnerabilities. Approximately 90% of homes ignited by the Waldo Canyon Fire were completely destroyed. Of those that were damaged (rather than destroyed), firefighter intervention was the likely reason the house was saved. The post-fire assessment in Colorado Springs credited mitigation work conducted in high risk areas of the community as helping the fire department achieve an 82% rate of saving homes.

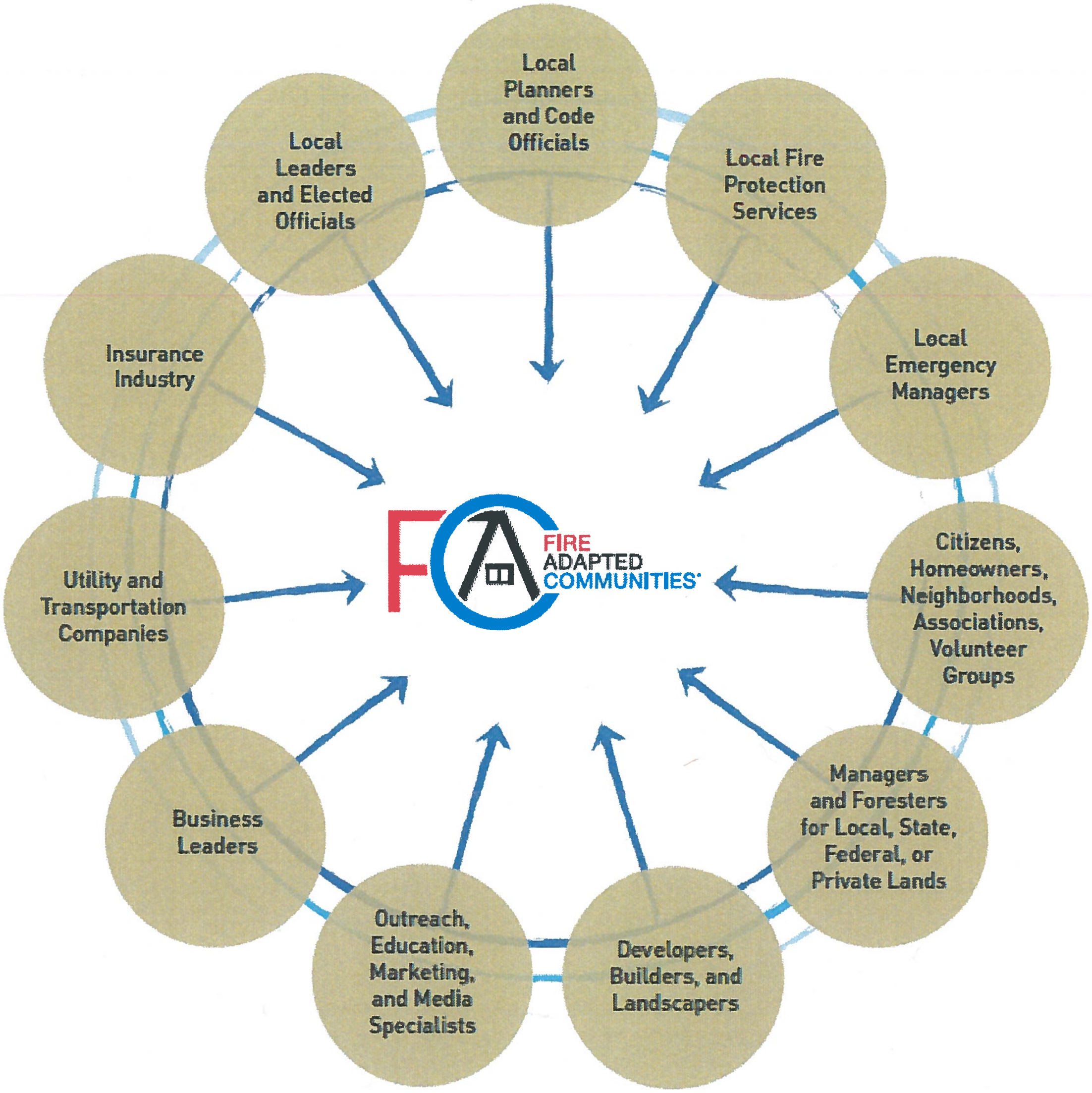

Figure 32: Fire Adapted Communities collaborative framework (Fire Adapted Communities, 2014).

Social Interaction and Response

There are various reasons why homeowners choose to take action or not to mitigate risk from WUI fires. Often WUI residents feel that government agencies, such as the USFS, need to take protective action on public lands to reduce wildland fire risk (Raish, 2011). This perception often may keep homeowners from taking action, though, because most WUI structure ignitions occur within the HIZ, where protection is primarily dependent on homeowner actions, and not on public lands, (Cohen, 2000b).

How residents react to and understand the risk to their homes from wildfire plays a crucial role in the means by which groups perform outreach. In a study of respondents in Boulder County, Colorado in 2007, only 33% of the respondents said they thought it was likely their home would be destroyed by a wildland fire, while 72% said they thought their trees and landscape would be destroyed (Champ et al., 2011). This result does not correlate with the effects of a fire, because homes are more likely than vegetation to ignite on a property, often due to firebrand ignition when defensible space is maintained around the home.

A recent study by Brenkert-Smith looked at the role informal social interactions have on WUI mitigation efforts. Information was gathered from six communities consisting of full-time and part-time residents (Brenkert-Smith, 2010). Full-time residents put more effort into mitigation and trying to develop pathways for informal communication between neighbors. Part-time residents explained that they received information from full-time neighbors that increased their mitigation efforts. They also felt that their full-time neighbors were looking out for them and would give them notice if something needed to be done. The study found that when the residents feel that they have strong ties to each other, even when the majority of the social interactions are informal, they are more educated.

A study by Gordon et al. was conducted comparing WUI communities in Pennsylvania and Minnesota (Gordon et al., 2010). The main result was a link between social barriers and a lack of community-based hazard planning and mitigation. Social barriers arose as a result of new and longtime residents with different values and lifestyles. Many new residents were unaware of wildland fire risk and, in Pennsylvania, did not believe that it was their responsibility to mitigate risk. In both Minnesota and Pennsylvania, long-term residents knew about and worked to mitigate the wildland fire risk; however, in Minnesota, most longtime residents had little interest in community programs to mitigate risk. In general, dealing with wildland fire risk on a community level is most effective. Social barriers in these communities with changing populations puts those communities at a higher risk because they do not approach mitigation on a community level. The authors recommended that such communities create grassroots and educational campaigns to teach about wildland fire risk, and that they engage in hazard mitigation and planning by building trust between longtime and new residents.

Risk Assessment Methodologies including Mapping

In the United States, the National Fire Danger Rating System (NFDRS) is used to provide a measure of the relative severity of burning conditions and the threat of fire during a particular time period (Cohen and Deeming, 1985). These assessments are based primarily on factors that affect a fire's steady rate-of-spread (fuel, weather and topography), but they miss important risk components if the goal is to evaluate risks to WUI communities (firebrands, structure ignition potential, structure-to-structure interaction, community features and suppression). Therefore, a number of different approaches have been taken to perform risk assessments of individual homes or communities, mapping everything from local areas to whole nations.

Mapping

Many approaches for determining fire risk to structures specifically focus on mapping the results of such risk assessments as a means to inform residents, first responders and local governments of specific risks. WUI risk maps vary depending on their purpose. A map could focus on vegetation and housing or have local purposes or national purposes Because of the different purposes of maps, it is important for map users to be aware of the map's purpose and data and analysis methods to use it as efficiently as possible (Stewart et al., 2009). There are limitations, for instance, to combining simple census-based data with vegetation mapping to map WUI risk; however, dasymetric mapping addresses this limitation. Wildfire simulations and burn probability models have been used to create risk matrices that allow for ranking of counties and local areas according to total area of risk and area of elevated risk (Haas et al., 2013).

Factors such as population density, potential fire exposure, and extreme fire weather potential are three layers that have been used to map the potential risk of a WUI fire. In a study by Menakis et al., a matrix was created and risk ratings were assigned based on the lowest class of risk of the three layers. Firebrands were taken into account by using buffer areas around high density housing. There were some anomalies in the methods used to develop the mapping, but the general classes of risk are meant to smooth over these (Menakis et al., 2000).

Risk Assessment Tools

Calkin et al. recently proposed a new risk management framework that could directly apply the principles of risk analysis to the WUI and provide information on fire loss reduction to land management agencies, first responders, and affected communities who face the possibility of wildland fires (Calkin et al., 2014). Their conceptual model (reproduced in Figure 33) highlights major objectives needed to prevent WUI disasters and the groups responsible for these actions (land management agencies, local governments and homeowners). By using this new risk framework, Calkin et al. investigated how pre-fire mitigation efforts failed to prevent significant structure loss during the Fourmile Canyon fire outside Boulder, CO (Calkin et al., 2014). They highlight the sequence of events that lead to WUI fires with large-scale losses (Figure 34). They highlight the importance of overcoming perceptions of WUI fire disasters as a wildfire control problem rather than a home ignition problem, as losses are primarily determined by home ignition conditions (Calkin et al., 2014). They propose strategic planning using risk management and decision concepts to guide cost-effective investments in risk mitigation efforts.

It has been suggested that a specific WUI fire inventory system should be created to address feedback on structure ignitability and suppression effectiveness, magnitude of risk in terms of loss and homeowner responsibility (Cohen and Saveland, 1997). The Structure Ignition Assessment Model (SIAM), developed by the USFS, addressed some of this need, using fire characteristics and location and a structures design to determine the structure's potential ignitability. The model includes structure design, topography, fire weather severity, fuels, and expert designated fire behavior to characterize exposure from flames, firebrands and radiation, then solves heat transfer equations and provides an ignition risk rating depending on the conditions (Cohen, 2000b). SIAM has been used to model high intensity crown fires where experimental data shows that SIAM provides an over estimate of heat transfer (worst case scenario). Through the studies, they concluded that unless flames or firebrands ignite within 40 m of the structure, the structure is not likely to ignite. (Cohen, 2000b). SIAM could help homeowners understand their risk and achieve a Firewise condition by making cost-benefit tradeoffs, however more fire effects (e.g. firebrands and home-to-home interactions) need to be included first.

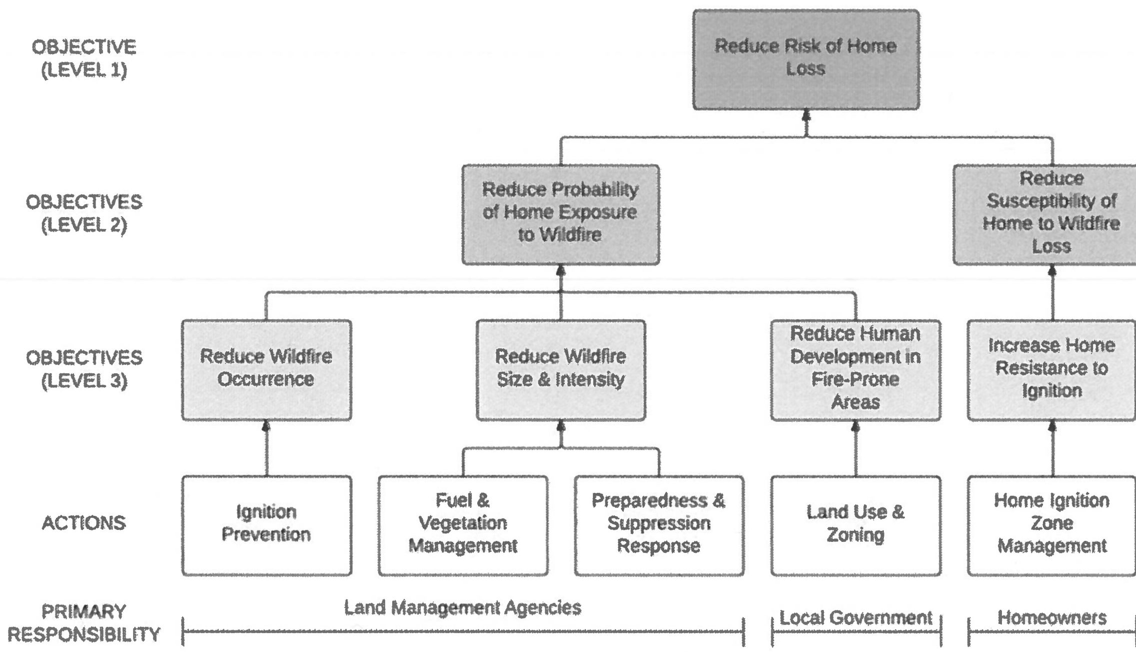

Figure 33: Conceptual model highlighting the major fundamental objectives (level 1), means-based objectives (levels 2 and 3), and actions for reducing the risk of home loss as a result of wildfire. The risk of home loss is jointly determined by the probability of home exposure to wildfire and the susceptibility of home to wildfire, which in turn are influenced by other factors. Actions and responsibilities for strategically managing risk factors vary across land management agencies, local government, and private landowner from (Calkin et al., 2014).

The CAL FIRE FRAP program produces Fire Hazard Severity Zone maps to demarcate WUI and non-WUI areas throughout the state of California in order to impose stricter codes for areas bordering wildland fuels (FRAP, 2015). The hazard mapping determines fire threat to WUI areas based on ranking fuel hazard, assessing the probability of wildland fire and defining areas of suitable housing density that lead to WUI fire protection strategy situations. Fuel hazards are determined as a function of rate of spread and heat-released per unit area (each functions of weather and slope). The probability of burning is taken from fire frequencies from past fire data. The urban interface was demarcated into urban (more than one house in 0.5 acres), intermix (from one house per 0.5 acres to one house per 5 acres), rural (from one house per 5 acres to one house per 50 acres) and wildland (less than one house per 50 acres). These three categories are then combined to an overall 3-category hazard ranking as described above.

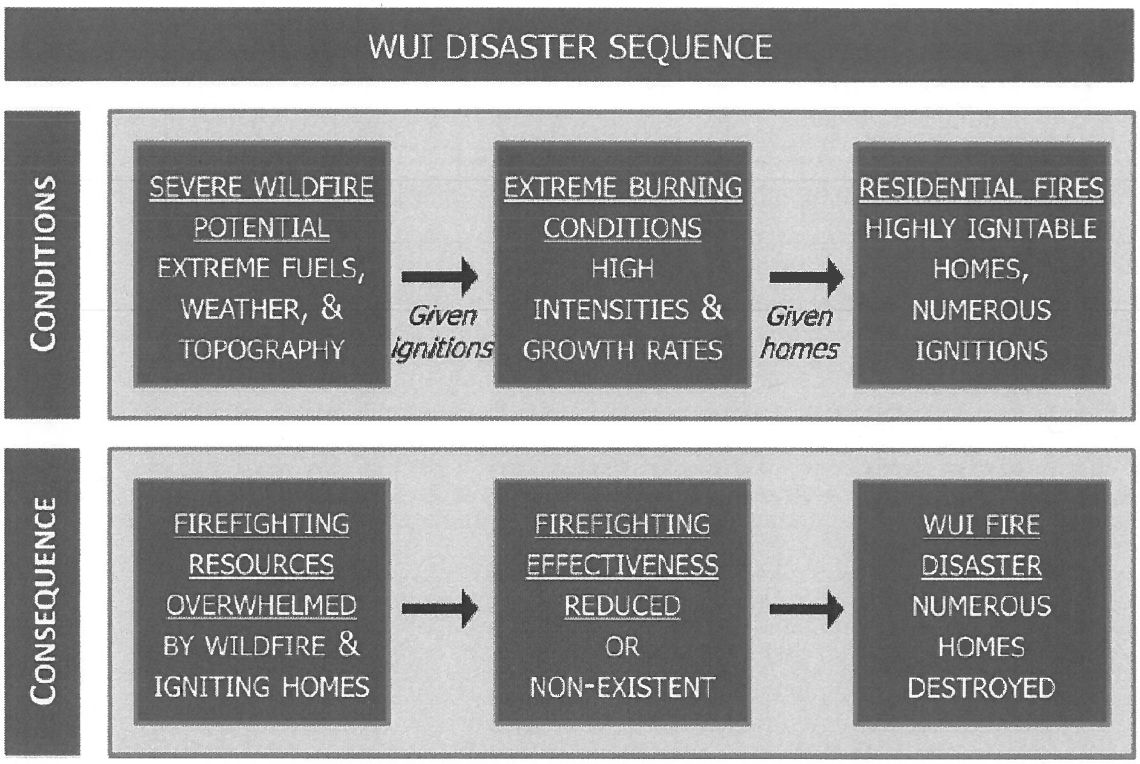

Figure 34: WUI disaster sequence. Each box corresponds to a factor that critically contributes to high numbers of destroyed homes during a WUI fire. Note that, if homes are ignition-resistant and numerous home ignitions do not occur (step 3), structure protection effectiveness is greater for home ignitions that do occur, thereby preventing disastrous losses from (Calkin et al., 2014).

More detailed risk assessments can be accomplished using additional methods such as ensemble fire modeling, historical weather data, probabilities of ignition, etc. Some open-source software tools such as Wildland Fire Hazard Modeling Tools (WFHMT) are available (Lautenberger, 2015). Other commercial tools are available that have performed assessments for corporations and government.

In Australia, the simulator PHOENIX RapidFire is able to provide a more realistic representation of fire behavior than using the Australian Standard Model, because it can take into account the hazard in terms of multiple impact mechanisms (Tolhurst et al., 2014). The PHOENIX RapidFire spread model has also been used in a risk-informed framework in Australia to determine fire risk for communities. Although more research still needs to be conducted, researchers suggest that moving to a more fire-centric view of the landscape (utilizing ensembles of modeled fires) as opposed to the static fuel-centric view (where static fuel maps are used) has the ability to improve landscape planning in multiple ways. Similar tools used in the United States for risk management, such as the Wildland Fire Decision Support System (WFDSS) or FARSITE, do not yet incorporate WUI hazards; however, they can useful in determining potential fire exposures to communities (Finney, 2004).

A variety of checklists are also available which attempt to determine the risk of destruction or damage of different components of structures or communities to WUI fires. These checklists often follow a framework similar to the reactions of components discussed in this report, including subdivision design, vegetation, topography, roofing materials, existing building construction, available fire protection, utilities, etc. These are often aimed at homeowners, inspectors or both. While there is a basis for many of these recommendations, there is little quantitative information which could be incorporated into a risk-informed model which predicts community or structure resilience. A selection of these checklists and rating forms from NFPA 1141, Firewise, IBHS and the ICC WUI Code are available in the Appendix of this report.

A recent NIST report addresses this point in more detail, suggesting a new framework for the assessment of WUI fire risk based on exposure conditions and vulnerabilities of structures to these exposure conditions (Maranghides and Mell, 2013). They propose a WUI fire and ember exposure scale to be used to form the basis of building codes that they suggest could prevent structure ignition at such exposure conditions. Their concept is to quantify the expected fire and ember exposures first; however, only limited information to fill this exposure and structure response database has been collected, though a technical plan to collect such data is outlined by Mell et al. (2010). Exposure conditions are grouped into four zones of differing severity, ranked by potential ember and incident radiant heat fluxes. Convective heat fluxes from smaller, local fires adjacent to structures are not considered. Structures in the zone must then follow appropriate guidelines for protection at that level of exposure for all components of a building.

Wetting/Covering Agents

Several new technologies have been suggested as a means to reduce the likelihood of structure ignition in the WUI. Some of these are mentioned in the 2012 International WUI Code (ICC, 2012); however, most have not been evaluated in actual-scale WUI events. Some means of protection include exterior sprinklers, gel and foam agents and full exterior blankets for structure protection.

Urbas et al. (2013) investigated the effectiveness of pre-wetting structural components, dead fuels, and landscaping plants using water, type A foam and gel agents in preventing fire spread from wildland fires to structures. Intermediate-scale radiant panel tests were conducted on 10 landscaping plants, mulch and four external materials (vinyl siding, plywood siding, asphalt shingle roofing, and cedar shake roofing) where their susceptibility to radiant ignition after 60 min of drying was evaluated. It was found that water and foam had very little effect in preventing radiant ignition of any material after prolonged radiant exposure. Gel agents did have some effectiveness in delaying ignition of some fuels and siding materials, particularly if those materials were not dried in advance. This test focused on radiant exposure only, which is unlike a realistic wildland fire where embers or small fires may contribute to ignition within the HIZ (Cohen, 2000b). There have been some reports (not documented) of mulch ignition in pockets not covered by gels which then smolder to the home and ignite the whole building. These do not appear in the literature, but are a serious concern needing substantiated investigation.

Glenn et al. (2012) also investigated material coatings for protection of exterior structure surfaces in the WUI. They examined sodium bentonite gel and foam coatings through burn tests and looked at their ability to protect a sample of commercial lap siding from radiant ignition (at 42 kW/m^2). Starch was added to some treatments to determine whether it stabilized the coating and prevented vertical slumping. Also included in the study was a commercial fire protection gel. Fire protective gel coatings studied (8 mm thick) were able to extend the time to ignition (determined at a critical temperature of 200°C) at fixed radiant heat fluxes for up to 30 minutes.

Takahashi et al. investigated blanket materials to protect structures in wildland fires with radiant exposures of up to 84 kW/m^2. These materials could be effective to prevent ignition from radiant exposure, direct flame contact or firebrands. How these will be deployed or remain cost effective is not yet known. Tests of over 50 materials were conducted, the best material being an aluminized insulation; however, weight concerns exist still. Future tests are planned to drape these materials as a blanket over outside walls of a house (Takahashi et al., 2013).

Following a severe wind event in 1999, a large number of exterior fire sprinklers were installed on homes in a heavily-wooded area to prevent ignition by wildfires (Johnson et al., 2008). It was found that the systems, when properly installed and maintained, were extremely effective in protecting not only structures, but also trees and surrounding vegetation. Of the threatened structures during a subsequent fire event that survived, 72% had working sprinklers. All but one structure with a working sprinkler system survived the fire. While the study provided only anecdotal evidence of the effectiveness of sprinklers, as other items such as hardening structures or defensible space were not be measured after-the-fact, it appears that the use of these systems may have had a positive effect on low to medium intensity fires experienced. Resources for maintenance of outdoor sprinkler systems were also provided (Johnson et al., 2008). If implemented in a larger, community-scale, issues such as water availability during a WUI fire emergency will need to be considered.

Fire Service Intervention

During the 2007 Witch Creek and Guejito fires, defensive actions by the fire service were found to be more than twice as effective in saving structures in low-exposure sections of the community as compared to in high-risk areas (Maranghides et al., 2013). Attempting to reduce the severity of fire behavior nearby homes is then an important approach. During the 2007 Witch Creek and Guejito fires, of 19 properties in areas of high fire intensity that were defended, 10 structures were destroyed and 4 damaged, whereas in low exposure areas, of the 66 defended properties, 10 were destroyed and 12 were damaged (Maranghides et al., 2013). Fire service intervention is also dependent on available resources, which often may be strained during a large-area fire.

While the application of firefighting during WUI fires is shown to decrease the numbers of structures lost, it can also put firefighters into a dangerous situation. The Yarnell Hill fire was an example of this, where 19 firefighters lost their lives in a burnover. There are many reasons for this loss, but the proper application of firefighting resources has recently been a subject of discussion. Appropriate first response activities, such as the number of resources to devote to a fireline versus structure protection is a question needing answers. Also, means of integrating wildland and structural firefighting crews, as they drastically differ in training and equipment, is another area of concern (Farris, 2005).

Rahn performed a staffing study on wildland firefighting initial attack effectiveness in San Diego (Rahn, 2010). Emergency response effectiveness was found to depend on four things: land management practices, existing environmental conditions, equipment and resources available to fight the fire, and the number of firefighters dispatched to an incident. This study observed varying firefighter staffing numbers on a 1,000 foot and 2,000 foot hose lay over 0% grade and 25% slope. Time efficiency to lay the hose-line 100 feet increased by 21 and 31 percent, for 0% and 25% slope, respectively, when increasing from 2 firefighters to 3 and by 49 and 47 percent, for 0% and 25% slope, respectively, when increasing from 3 firefighters to 4. In the 1,000 foot and 2,000 foot time trials similar patterns were observed, where going from 2- to 3- staffing showed the largest increase in time. It was found that a 2- person crew was between 15-40 minutes slower than a 3- person crew. Since the first 10-30 minutes of a wildland fire are the most crucial, this one person increase can make a significant difference. Another concern is the health safety of the firefighters. Firefighters' heart rates were measured before and after the hose-lay. The highest heart rate changes were found in the 2 person crews, and the difference decreased by about 34% when adding just one more person (Rahn, 2010).

Rhode performed a survey of incident management schemes used during the first several hours of response at six different WUI fires in Southern California (Rhode, 2002). Of the six fires studied, the most successful incident command structures were immediately organized into a unified command and ordering point. Incidents that included law enforcement in the unified command were highly successful in mounting evacuations. Nonetheless, all six fires studied resulted in significant injury to firefighters and half cost lives. General wildland fire factors such as abundant native chaparral fuels, conflagration behavior with mass structure involvement, high burning intensity, fire whirls, long range spotting, mass ignition and rapid rates of spread contributed to extreme fire conditions. Communities were also largely constructed of non-fire resistant materials such as wood shake roofs, lacked adequate fuel modification or brush clearing and used combustible landscaping. On all fires, public volunteerism proved unmanageable and an impediment to firefighting operations (Rhode, 2002).

During a WUI fire, two main firefighting strategies are possible: performing offensive perimeter control to keep the advancing fire front within a contained area and defensive structural prevention preventing ignition from firebrands and flames. A common strategy is to "pinch the flanks" through perimeter control to limit the width of the fire's head as it enters areas with structures. The ideal strategy found in Rhode's study was to provide both offensive perimeter control and defensive structural protection simultaneously. Abandoning perimeter control in favor of structural protection risked unabated fire expansion, increased structural risk, and difficulty of control. In some situations, perimeter control might have to be abandoned for a period of time, but it must be reestablished as soon as possible (Rhode, 2002).

Rhode stressed that organizational development and control can be as complex as the fire itself. Therefore, pre-fire planning can be critically important, including conceiving strategies and tactics, identifying values at risk, planning deployments and evacuations, calculating resource needs, and projecting fire behavior and spread. Some issues identified in firefighting included the presence of threatened or endangered species which served as obstacle to pre-suppression activities, water systems that were unable to provide adequate fire flow or failed during fires and egress and road access that was limited (Rhode, 2002).

PART II: GAP ANALYSIS

Summary

Despite the wide array of research presented above, there are still many areas related to the pathways to fire spread in the WUI in need of additional research. As part of this gap analysis, these areas have been broken down based upon both scientific and practical contexts. These contexts are divided into two areas, widely defined as those related to the quantification of risk and hazard and more practical and specific issues. This format is chosen as those areas related to the quantification of risk and hazard are ubiquitous to all practical and specific issues, necessary to provide a basis for future engineering design efforts. These include

- Quantification of Risk and Hazard
- Pre- and Post-Fire Data Collection
- Testing of Firebrands
- Understanding of Ember Fundamentals
- Understanding of Wildland Fire Fundamentals
- Structural Ignition

Each area under this category therefore relates to fundamental or applied research areas that have the ability to quantitatively inform risk mitigation efforts, and are not listed in a specific order. There are also many other practical issues, which relate to specific areas of code and standard development, WUI community protection or firefighting that are in need of rapid research and development. The overarching goal of these items is to reduce the fire exposure to communities, harden them to resist ignitions and improve the effectiveness of evacuation and suppression once a fire is in progress. We defined these practical and specific issues to include

- Fuel Management, Defensible Space and Community Planning
- Test Standards and Design of WUI Materials
- Effectiveness of Mitigation Strategies
- Impact of Wildland Fires on Health and Environment
- Firefighting Techniques
- Identification of Educational Needs

These categories represent a wide spectrum of subjects within possible WUI research. Some needs are directly related to a specific goal (i.e. to develop test standards for materials to be used in the WUI), while others lend more to the modeling of wildland fires or to a better general understanding of fire. These latter categories may indirectly or directly affect applications.

It's important to recognize that, throughout this review most work has focused on important test scenarios but has not *quantified* effects in a repeatable manner. While it is useful to identify vulnerabilities and best practices, protection of WUI communities cannot evolve without more quantitative analyses to optimize protection schemes. Codes and standards rely on precise thresholds, such as separation distances between homes, which must be defined for a wide variety of exposure conditions and standardized for a known worst-case scenario. Many studies reviewed here have also been presented without peer review and/or are not available in the open literature. It is critical that test and analyses supporting codes and standards be available to the public, while peer review ensures the technical credibility of the work. An effort has been made in the references section to link referenced studies to their most recent sources.The overarching research categories below help to describe some major gaps identified throughout the review, however they should not limit other future areas of research. The order does not reflect a particular higher or lower ranking on each topic but is simply used to organize the topics in a logical presentation. Surely through additional investigation and research new priority areas will be recognized and should be added to this list in the future.

Quantification of Risk and Hazard

In the era of performance-based design many design choices in the built environment are based upon knowledge of fire behavior and its effects on risk. Such an understanding of wildland fire behavior coupled with its impact on WUI communities, however, does not yet exist. Two main areas are necessary to inform risk and hazard quantification, data collection from real fires and expanded fundamental understanding. A statistical representation of data from previous fires, when carefully collected and analyzed, has the ability to inform our understanding of how fires will affect real structures and, with enough data, quantify these effects in a risk model. These risk models can then be used to perform cost-benefit analyses for fire mitigation that optimize resources available and estimate potential impacts of decisions made. The amount of data needed for such an approach, however, is most likely a limiting factor. Fundamental research, on the other hand, has more potential to provide simplified tools for the design of WUI communities. Most of the following sections describe some means in which we can inform the quantification of risk and hazard.

Several frameworks are available to perform risk and hazard analysis in order to optimize protective strategies or fire management, however most would be greatly improved with additional information on the response of structures in the WUI to fire (Calkin et al., 2014; Maranghides and Mell, 2013). This type of data does not exist; so, for the most part risk modeling today only incorporates features of surrounding wildland fire behavior (fuel, slope, weather, etc.) and the density of structures (Maranghides and Mell, 2013; Tolhurst et al., 2015; Lautenberger, 2015; FRAP, 2015).

Maranghides and Mell (2013) laid out what they thought were the missing components by defining a WUI hazard scale broken up into fire and ember exposure, shown in Figure 33. While such a defined structure is not necessarily absolute, their description of how most every "box" of possible fire exposure conditions has yet to be studied highlights the lack of data currently available, shown in Figure 35. The necessary step of connecting these exposures to the response of specific structural components will require additional effort. Since all components are hazards, it is necessary to include exposure from nearby structures and surrounding fuels, not just those directly intimate with the main structure.

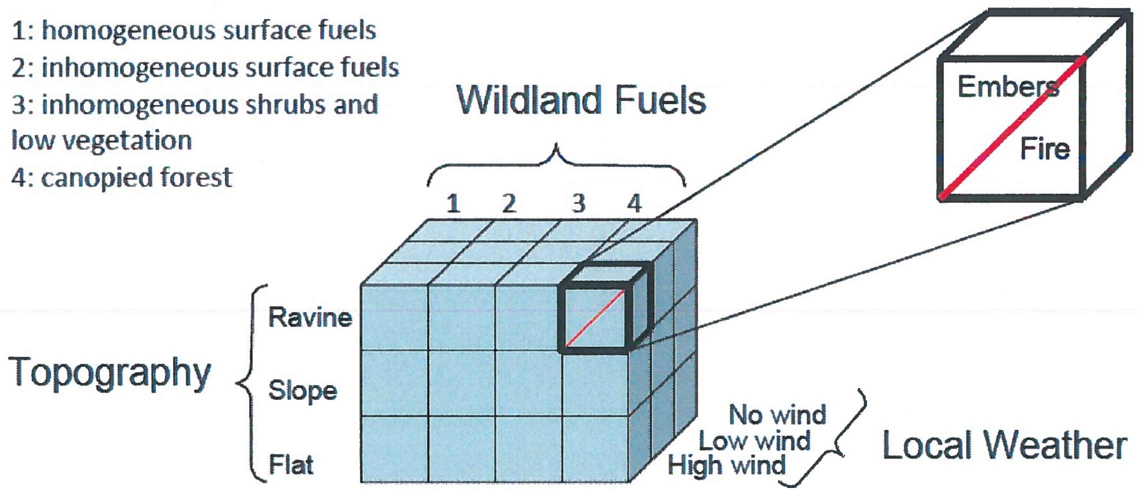

Figure 35: Capturing exposure from wildland fuels from Maranghides and Mell (2013).

Pre- and Post-Fire Data Collection

While so much about the spread of wildland fires into WUI communities is still not known, an effective means of increasing our knowledge is to assess the effects of WUI fires on real communities. For this data to be repeatable and applicable between many different communities, especially if used in the context of hazard and risk analysis, some standardization of pre- and post-fire data collection is necessary. This data could greatly enhance our current understanding of how WUI fires spread to help better address the problem. Currently there is some WUI data collection after fires, but this is not mandatory or standardized.

Some guidelines and tools for WUI data collection have been proposed by NIST (Pellegrino et al., 2012), however these are not yet widely distributed or used. Teams or organizations responsible for collecting data should be consistent in specific regions or states, so that incidents are not double counted or missed during both pre- and post-fire assessments. Terminology that is necessary for the data collection also needs to be uniformly understood by all involved. If these topics are not all standardized, then the pre- and post-fire data will not be as effective. With clearer guidelines for data collection, it is likely that there will be more data available to help researchers understand WUI fires and better characterize their risk or hazard based on exposure conditions and the reaction of components or systems.

Testing of Firebrands

Although only limited fundamental knowledge is available on firebrands, many tests have recently been performed to observe their effects on specific structural components and measure the distribution of firebrands from real fires from both vegetative and structural fuels (Manzello, 2014). These tests have been a good first step; however, future tests can consider additional aspects. There are many potential fuel types, from large pine stands to Mediterranean chaparral that may invariably generate different ember fluxes that should be studied and compared. Higher winds speeds have yet to be approached in order to create a more realistic WUI fire situation. Most experiments have been conducted with wind speeds up to 10 m/s, while wind speeds in excess of 20 m/s are often observed during WUI fires (Manzello, 2014). Along with these higher wind speeds, real WUI fires have up to several hours of continuous firebrand generation. Therefore, experiments need to incorporate longer firebrand exposure to simulate actual WUI fires.

To further understand ignition from firebrands, testing should consider different elevations and higher velocities of firebrand generation. Testing that includes the combined influence of firebrands and radiative heat flux is another area that should be further investigated as both may be present during WUI fires. It is also important to test multiple building components, observing their interaction. Single component testing alone would not have been able to reveal firebrand collection spots, such as re-entrant corners (Manzello et al., 2012b), however these appear to play a critical role in structure ignition. Important components that need test standards will be discussed in another section.

Understanding Firebrand Fundamentals

The lifetime of a firebrand has been separated into three stages, generation or production of a firebrand, lofting and transport, and finally deposition and subsequent ignition of recipient fuels. In terms of generation, some research has been conducted to measure firebrand generation from both vegetation and structures, presented as mass or size distributions collected downstream (Manzello and Foote, 2014; Suzuki et al., 2013, 2014). Research should continue on collection of firebrands from real and simulated fires, including different vegetation, structures, winds, etc. Very limited research appears in the literature on the actual process of firebrand generation and how it relates to the materials which generate firebrands. If more understanding can be garnered from specific fuel types, perhaps these distributions can be better understood *a priori*.

Lofting and transport of firebrands has been the best-studied aspect of the problem. While there is still work to do, several models exist which are adept at incorporating firebrands and investigating their transport through a fire plume (Sardoy et al., 2007; Koo et al., 2012) or statistically investigating their transport numerically (Tolhurst et al., 2014).

The least-understood process is ignition by firebrands. Ignition of a recipient fuel by a firebrand may depend on many characteristics: firebrand properties (i.e. size), ambient winds, fuel moisture content, geometry, whether the ember is flaming or smoldering on landing, and how many embers land in a particular recipient fuel (Mell et al., 2010). Little is known on how these various characteristics interact and the actual effect they have on how and when ignition occurs.

Recent studies on ignition behavior by Hadden et al. (2010) and Zak et al. (2014) have looked at the simplified problem of hot particles landing on a cellulose fuel bed, however this configuration more closely resembles firebrand ignition of vegetative fuels. The relative influence of solid-phase chemistry, re-radiation, brand size, configuration, etc. must be determined before better models for ignition can be developed. Some of these should focus on denser materials, such as wood or plastic often found on structures in the WUI. Most studies which have taken a closer look at ignition phenomena by firebrands have been somewhat restricted to loose, vegetative fuels (Viegas et al., 2012; Manzello et al., 2006) which may behave differently than the higher density, varying geometries found on or near structures.

Understanding of Wildland Fire Fundamentals

While fire dynamics is a fairly developed field used to analyze the built environment (Quintiere, 2006; Drysdale, 2011), such knowledge is limited or non-existent applied specifically to WUI fires. Tools are available to predict the spread of wildland fires, their intensities, and expected radiative fluxes (Andrews, 2003; Finney, 2004), however these tools are based on steady assumptions of flame spread that have limited or no physical basis (Finney et al., 2013). This leaves gaps as no tool can assess whether a fire will accelerate, decelerate or stop, critical elements when looking at the effectiveness of fire breaks in protecting a community. There is also no way to incorporate the influence of structures or fire suppression. New tools under development such as WFDS (WUI Fire Dynamics Simulator) hope to bridge some of these gaps but still require significant advancement in fundamental understanding of fire behavior to be accurate enough to further enhance our picture of the problem. Enhanced research on wildland fire behavior and its coupled effect on structures in the WUI, such as recent numerical efforts (Porterie et al., 2007) could enhance our understanding of structure-wildland and structure-structure interactions. Development of software with a firm technical and scientific basis could be a valuable tools in a WUI community designer's toolbox.

Other research needs include those surrounding firebrands, as discussed above. The mechanisms governing transition from smoldering to flaming combustion is not well-understood. This transition is of particular importance in determining whether ignition will occur in a fuel (whether vegetative or structural) due to a firebrand. Ignition due to flames and firebrands needs to be more completely characterized. How fire behavior influences the WUI in different ecosystems, e.g. tall pine stands, Mediterranean chaparral, etc. should be studied. Additionally, research on fire behavior and smoke transport is necessary, with the latter affecting health and environmental concerns.

Structural Ignition

Cohen has described the WUI problem as a structural ignition problem (Cohen 2004). While there is still an influence of the exposure conditions on structures, if ignition of structures can be prevented in whole, WUI fires would not pose as severe a threat to residents and communities. While some aspects of ignition from the fire front to target structures (primarily based on radiative exposure) are understood, structure to structure ignition is less well defined (Cohen 2004). Nonetheless, structure to structure ignition can be a significant or sometimes primary form of fire spread once a wildland fire enters a community (Maranghides et al., 2013). Participants of a recent WUI fire workshop (Pellegrino et al., 2012) also highlighted hardening of structures as their top research priority. Research needs to include greater detail on the effect of radiation and embers from nearby structures and the components which are most vulnerable to exposure.

While several anecdotal cases have been mentioned in reports, only one detailed study on a scaled configuration was found on structure-to-structure ignition (Maranghides and Johnsson, 2008). This test could not measure the influence of embers and was too limited to truly characterize realistic radiant heat fluxes, which should be characterized for a variety of potential fires. Additional testing at many scales, culminating in measurements during full community structural burns would be invaluable at determining means to prevent home-to-home spread which drastically increases damages during WUI fires.

If more research is conducted on how exactly firebrands ignite a structure (as suggested above) that may guide design of future structures hardened from ignition from firebrands from both vegetative and wildland fuels. Investigations of actual WUI fires may also help to better-determine the fraction of ignitions that are due to firebrands or, indirectly, by direct flame contact from nearby fuel sources originally ignited by a firebrand. These may similarly help future development of WUI community design.

While many authors have recognized a need to harden structures against embers (Pellegrino et al., 2013), there is little information on what hardening tactics might be effective. At a building level, there is little information on the response of different *types* of buildings (i.e. how the response of homes differs from that of commercial occupancies, warehouses, etc.) Finally, although specific components have been studied (Manzello, 2014), there is a great need for research on the interaction between coupled components under realistic WUI fire conditions. For example, a Class A roof might survive ignition from embers, but ignite as a result of direct flame impingement if flammable siding is ignited. Research on coupled systems will better represent how a structure reacts to hazards of WUI fires.

Fuel Management, Defensible Space and Community Planning

Fuel or fire breaks are a common feature in wildland areas and may either be deliberately provided in the design of a WUI community or subconsciously developed. The theory behind a fuel break is to introduce a discontinuity into the fuel that an approaching wildland fire would consume, thus slowing the fire or ceasing further spread. Recent analyses of past fire data, however, have shown that these breaks are not as effective as once thought (Syphard et al., 2011b), however the overall layout of communities (land-use planning) appears to greatly affect a building's probability of ignition (Syphard et al., 2012). Their primary effectiveness appears to be in providing working space for suppression efforts. Adequate fuel breaks allow access for active fire suppression which has been shown to be very effective (Syphard et al., 2012). Fuel breaks also provide an added measure of safety, forming safety zones which allow them to operate in a wider region. Still, active fire suppression by fire crews has the potential to put them in harm's way.

Fuel treatments have been shown to reduce the intensity of a crown fire, typically reducing the crown fire to a surface fire (Murphy et al., 2007). This does not prevent ignition from firebrands, but does have the potential to remove the radiative exposure component to nearby homes. While some work has suggested that fuel treatments far outside the WUI are effective in reducing potential fire effects (Schoennagel et al., 2009), more research is needed to support these conclusions. The effectiveness of fuel treatments is an ongoing research area that requires more research, particularly on its impact to WUI communities. The influence of a fuel treatment on fire behavior in a nearby WUI community has not been well studied (instead focusing on the wildland) and specific means are lacking. Different fuel types must also be assessed, as much work is toward large pine stands which support crowning. Many communities are located in scrub or chaparral (California, etc.) and little guidance is available for these fuel types. How to place these fuel breaks in terms of their effectiveness to WUI communities must be further studied to come up with appropriate and economic or risk-optimized guidelines.

Because land-use planning appears to significantly influence home survivability in the WUI (Syphard et al., 2012), additional research should be undertaken to understand exactly what features are most significant and guidelines for future community planning assembled. Recent work investigating defensible space (Syphard et al., 2014) appears to show that clearing the area around a home also increases home survivability. This research should be continued over larger sample sizes, however it needs to start being coupled to other features on the home and related to suppression efforts to narrow down exactly what mitigation strategies are effective. Because the analysis to date is focused on overhead observations instead of detailed assessments on the ground, they can't be coupled to specific recommendations on the use of retaining walls, landscaping choices, etc.

Very little work has been done to develop strategies to design a WUI community. As it stands now, no publication was found in which a strategy was proposed to aid in the design of a WUI community. The incorporation of greenbelts, parks, walking/bike paths or other defensible spaces may be particularly effective design strategies, however no guidance appears available for their use (Pellegrino et al., 2013). Guides aimed toward professional engineers, architects and AHJs could be very effective at improving community resilience once general guidelines are established via peer-reviewed research.

Test Standards and Design of WUI Materials

Many building components are considered possible ignition sources in WUI fires. One major research need is to create test standards for specific components in order to ensure future designs are ignition and fire resistant. Development of these standards will require additional study on possible exposures (ember flux and radiating heating from vegetative and structural fuels) to reflect realistic conditions encountered during extreme fire behavior. The goal of these test standards should be to ensure that all test components can resist ignition from an approaching wildfire or a burning nearby structure. Enough, perhaps is already known to start designing some test methods that can critically assess the ability of a structural component to resist ignition from some exposure level, however more research must be conducted to determine what specified exposure levels will be encountered in different environments. It is therefore recommended all future test development involve a quantitative measures of material or component performance (e.g. flame height, flame spread rate, heat-release rate, etc.) so that as exposure conditions are better understood these effects on existing features can be estimated without massive re-testing campaigns.

Some specific components in need of standards include roofing assemblies, gutters, vents, eaves, fences, sidings, and mulch. Specifically for roofs, more realistic ignition from embers needs to be considered. Roofs that are currently Class A rated by UL 790, ASTM-E108 or NFPA 276 have failed wind-tunnel firebrand shower tests (Manzello et al., 2013) highlighting the need for testing under conditions more representative of WUI fires. These tests should ideally be conducted with roofs as a system, including construction and joining techniques as these have been found to be specific vulnerabilities during WUI fires (Pellegrino et al., 2013).

Gutters and other roofing products also need to be developed to keep debris accumulation minimal or nonexistent. Test methods or observed performance should be understood to evaluate these new products. The size of vents and vent meshes are a concern where development needs to be made because firebrands, even small ones, can penetrate the meshes. Recent code developments such as ASTM E2886 have started to address this issue (ASTM, 2014a), but its effectiveness will need to be verified with more large-scale testing.

Fences and sidings are both areas where research is very minimal and needs to be conducted in order to create test standards. The mechanisms of ignition of fences and siding and the means by which these fires spread to ignite the rest of a structure are a critical area for research after reports from the Waldo Canyon Fire (Manzello, 2014), as they will be needed to design an appropriate test standard.

There is very little work done quantifying the flammability of different mulches, however a new test method (Beyler et al., 2014) may serve as a basis from which to standardize the process. Still, these tests should eventually go further to quantify limits of what distance away ignited mulches should be used from a structure under worst-case conditions. Embers also should not be produced by any ignited mulch that could be transported, especially under winds to spread to other nearby fuels. These conditions may serve as a pass/fail line, however its important the test still numerically ranks the fuels based on each aspect of performance as knowledge on exposure conditions is evolving.

Decks, porches and patios have, similar to fences, been identified as a significant source of structure ignitions (Mell and Maranghides, 2009; Quarles et al., 2012). Some test standards exist for decking materials (e.g. CBC 12-7A-4), however these tests have not been corroborated with exposure conditions that might occur under realistic WUI fires. The exact conditions so that they do not ignite an adjacent house are mostly incorporated into the test standard through measurements of the heat-release rate, however this is not directly applicable to home ignition and more studies on the coupled deck-home should be undertaken to see how previous decks may have ignited a home and minimize those effects. Observed accumulations of firebrands over long timescales on decks (Manzello and Suzuki, 2014) may or may not be represented by the relatively crude wood crib "brand" used in testing.

It is also necessary to consider materials testing in light of weathering. Weathering protocols for different materials and coatings, especially fire retardant materials is another major research need, since the components are all exterior building features which could experience significantly varied weather conditions in different parts of the country and drastically affect performance. Test methods to simulate accelerated weathering should be incorporated on materials that may adversely change in fire performance (Pellegrino et al., 2013). On a similar note, short-term coatings such as gels or foams are an area of significant research need if they are to be operationally used by homeowners or firefighters. While limited testing has been conducted (Urbas, 2013; Glenn, 2012), this has not been corroborated at larger scales with realistic WUI fire conditions to show that they are operationally effective. The same goes for exterior home sprinklers that have been shown to be effective in one case (Johnson, 2008), however the practicality of their use on a large scale or applicability to different fire scenarios is unknown.

An enhanced understanding of how firebrands ignite materials may greatly assist in the development of new standards and new component designs that can resist firebrand showers. A better means to incorporate firebrands in all testing strategies is desirable. Only one test method uses anything similar to a firebrand (ASTM, 2014a); however, this does not incorporate behavior such as the accumulation of firebrands in crevices or corners observed in experimental tests(Manzello, 2014), therefore research and development should work toward a rigorous test standard that incorporates more realistic elements in an economical manner.

If more test methods are coupled with quantitative measures of fire performance in the future it may also be possible to use this data to better evaluate hazard and risk modeling in the WUI, enhancing its usefulness.

Identification of Educational Needs

Often, residents of at-risk WUI communities do not understand areas vulnerable to ignition near their homes or in their broader communities. It is important to provide education on mitigation strategies to different stakeholders within these communities, i.e. home and business owners, community groups, local government, developers, firefighters, etc. So far, a variety of resources such as how-to guides and checklists for home protection are available as part of community education and awareness programs, several of which are provided in the appendix of this report.

Even relatively small education efforts, such as one performed in Florida between 2002 to 2007 have been shown to be a cost-effective way to limit damages from wildfires (Harvey et al., 2004). Increased understanding of people's perceptions of risk may assist in communicating research on effective local and community-wide mitigation strategies to homeowners and other stakeholders within the WUI. Community-wide mitigation efforts such as Firewise or Fire Adapted Communities should continue as they have been seen to be effective in encouraging active participation in mitigation strategies (Harvey et al., 2004). As the science of WUI fires increases, this knowledge must trickle down through various stakeholders. One piece that has only recently started to appear in literature is the influence of firebrand showers on ignition of buildings. As this mechanism appears to be a significant source of losses, it may be worth finding ways to emphasize its effect and ways to minimize ignition from firebrands.

A cultural shift to self-enforcement, and inspections at the local level is also needed. A discontinuity of opinion and enforcement of fuel placement and building practices amongst local officials can provide a lack of public trust and confusion amongst citizens of the community. Unifying codes will certainly assist with this effort.

Finally, guidelines for overall design of WUI communities were hard to come by. Development of these guidelines, especially geared toward professional engineers and architects will enable communities to be better equipped to handle the devastating effects of wildland fires in the WUI from their inception.

Impact of Wildland Fires on Health and Environment

The effects of wildland fires on human health, including respiratory effects, water quality and air pollutants have only started to be explored. The majority of this work focuses on respiratory effects due to small particulate matter (smoke) exposure (Bowman et al., 2005; Kunzli et al., 2006; Fowler et al., 2003). There may be other, unexplored aspects of exposure not yet assessed, such as impacts from water quality or other airborne pollutants. A special focus should be devoted toward effects on firefighters, which are often in close proximity to these fires without any breathing apparatus.

Research continues on the effect of wildland fires on the environment, however no resources were found that coupled the unique influence of WUI fires, where structure losses may contribute a different fraction or spectrum of emissions than vegetative fuels alone (Bryner and Mulholland, 1991). Other recent work indicating that proper prescribed fire use and management practices could sequester 18-25% of CO_2 emissions in the Western US, or as much as 60% in some ecosystems (Widinmyer and Hurteau, 2010) may provide additional motivation for responsible ecosystem fire management.

Firefighting Techniques

While tactics for structural and wildland firefighting are better developed, little guidance is available for operations in the WUI where these two techniques intersect. Further research on best practices for reducing structural losses in a variety of scenarios as well as ways to ensure firefighter safety should be conducted to develop best practices and, perhaps, supplemental training for wildland firefighters tackling WUI fires and vice versa. Guidelines for many factors, especially aimed at optimizing resources such as crew size, water capacity and where to distribute crews during fire spread could be improved. Recent work by Rahn (2010) has shown that the efficiency of a three-person crew fighting a wildfire increses 50% with the addition of a fourth crew member. These types of studies may help to improve the efficiency of suppressing fires in the WUI as well as safety of crews in the future, but need to go beyond just the size of the crew and inspect many other tactics and techniques. Improvement in coordination and planning both for firefighter response and resident evacuation may also improve the effectiveness of suppression efforts.

The virtue of protecting property at the risk of human life should continue to be debated in the community while mitigation efforts which don't require active suppression are pursued to the fullest extent possible.

Effectiveness of Mitigation Strategies

Several recommendations exist for homeowners in terms of strategies to mitigate risks from WUI fires to homes. Many organizations produce check lists for homeowners to follow to decrease risk (provided in the appendix), as well as standards which encourage or require certain mitigation strategies however there is not much literature data to support these changes. Investigations from the Witch and Guejito fires (Maranghides et al., 2013) does cite some effective and ineffective components of Firewise which are incorporated in several other standards and guidelines, however the majority of regulations for WUI homes and communities have not been assessed due to a lack of reliable data. Increased pre- and post- event investigation should be conducted, as recommended above, to address these gaps in communities where such standards have already been implemented such as California's CBC Chapter 7A requirements (CBC, 2009).

Specific requirements, such as the implementation of home fire sprinklers, which is offered to decrease home separation distance from 30 ft to 15 ft in NFPA 1141 have no data in the literature to support them. This is potentially a very high hazard if such fire sprinklers are not installed in the attic and could therefore contribute to firebrand production and increased home-to-home spread. This could be made worse if water supply shortages occur during power outages and firestorms.

Despite the fact that many recommendations are available to homeowners and community planners, few of these recommendations have been scientifically validated. There is a need for research on defensible space: both to quantify the effectiveness of current recommendations and then to standardize the recommendations for defensible space across wildland fire-prone areas (Pellegrino et al., 2013). The size of the fuel modification area and exactly how to treat it at the moment is debatable and certainly dependent on worst-case weather conditions. While standards may not want to explicitly define these spacings, more guidance and tools are necessary based on solid science, such as approvals for specific mulch, vegetation, etc. compared with relative exposures and home construction. Other areas include guidelines for home spacing, access routes, proper storage of nearby flammable materials, effectiveness of fuel breaks, etc.

Roof requirements in NFPA 1144 5.3.1 require compliance with ASTM E 108 for the class that relates to expected wildland fire behavior, however there is no guidance or scientific basis with which to support what types of surroundings may provide different exposure conditions to structures. With recent research showing smoldering ignition of some Class A roofs with accumulated vegetative debris to firebrand showers (Quarles, 2012; Manzello, 2013) highlights the need for further insight to design specific protections and assess them in real wildland fire situations. Vents, eaves, roof and attic components similarly have only limited data to support their design, d construction and location.

The provisions for overhanging buildings or projections from buildings constructed with heavy timber construction, noncombustible material, fire-retardant-treated wood, other ignition-resistant materials or be a 1-hour fire-rated assembly is not based on any WUI-specific research that assesses real hazards from firebrands or convective heating from nearby flames. While some tools exist to calculate radiative ignition between homes, more research and data on actual expected conditions is needed.

Best practices for design, such as those that relate to preventing firebrand accumulation and penetration should be developed and better spelled out to engineers, authorities having jurisdiction (AHJ) and homeowners. Currently most home assessment guides are meant for existing construction, where a design guide is not available for new construction. This is a serious deficiency in the field. Ideally, these may be updated to include more quantitative suggestions that are based on some specific research, testing or defined estimations that engineers could modify for their specific conditions. Detailed pre and post-fire data collection can also help to show the impact these types of changes can make, but only when carefully collected.

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REFERENCES

Agee, J.K., Skinner, C.N., 2005. Basic principles of forest fuel reduction treatments. For. Ecol. Manage. 211, 83–96. doi:10.1016/j.foreco.2005.01.034

Ager, A.A., McMahan, A.J., Barrett, J.J., McHugh, C.W., 2007. A simulation study of thinning and fuel treatments on a wildland–urban interface in eastern Oregon, USA. Landsc. Urban Plan. 80, 292–300. doi:10.1016/j.landurbplan.2006.10.009

Albini, F.A., 1979. Spot fire distance from burning trees: a predictive model. USDA Forest Service, General Technical Report INT-56, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture. Ogden, Utah. https://www.frames.gov/rcs/8000/8153.html [Last Accessed Feb. 13, 2015]

Albini, F.A., 1983. Transport of Firebrands by Line Thermals. Combust. Sci. Tech. 32, 277–288. doi:10.1080/00102208308923662

Albini, F.A., 1981. Spot fire distance from isolated sources—extensions of a predictive model Res. Note INT-309. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. https://www.frames.gov/rcs/8000/8157.html [Last Accessed Feb. 13, 2015]

Albini, F.A., 1983. Potential spotting distance from wind-driven surface fires. Res. Pap. INT-309. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. https://www.frames.gov/rcs/8000/8155.html [Last Accessed Feb. 13, 2015]

Andrews, P., Bevins, C., Seli, R., 2003. BehavePlus Fire Modeling System: Version 2.0: User's Guide. Gen. Tech. Rep. RMRS-GTR-106WWW. Ogden, UT: Department of Agriculture, Forest Service, Rocky Mountain Research Station. http://www.fs.fed.us/rm/pubs/rmrs_gtr106_ver2.pdf [Last Accessed Feb. 13, 2015]

Arno, S., Allison-Bunnell, S., 2002. Flames in our forest: disaster or renewal?, Island Press, Washington, D.C. ISBN: 978-1559638838

Aronson, G., Kulakowski, D., 2013. Bark beetle outbreaks, wildfires and defensible space: how much area do we need to treat to protect homes and communities? Int. J. Wildl. Fire 22(2), 256–265. doi:10.1071/WF11070

ASTM, 1969. ASTM E-286-69: Method of Test for Surface Flammability of Building Materials Using an 8-Ft. (2.44-M) Tunnel Furnace (Withdrawn 1991), ASTM International, West Conshohocken, PA.

ASTM, 2010. ASTM D2898-10: Standard Practice for Accelerated Weathering of Fire-Retardant-Treated Wood for Fire Testing, ASTM International, West Conshohocken, PA. doi: 10.1520/D2898-10ASTM, 2011. ASTM E-108-11: Standard Test Methods for Fire Tests of Roof Coverings, ASTM International, West Conshohocken, PA. doi:10.1520/E0108-11

ASTM, 2012. ASTM E2726-12a: Standard Test Method for Evaluating the Fire-Test-Response of Deck Structures to Burning Brands, ASTM International, West Conshohocken, PA. doi: 10.1520/E2726_E2726M-12A

ASTM, 2014a. ASTM E2886: Standard Test Method for Evaluating the Ability of Exterior Vents to Resist the Entry of Embers and Direct Flame Impingement, ASTM International, West Conshohocken, PA. doi:10.1520/E2886_E2886M-14

ASTM, 2014b. ASTM E84-14, Standard Test Method for Surface Burning Characteristics of Building Materials, ASTM International, West Conshohocken, PA, 2014. doi:10.1520/E0084

Babrauskas, V., 2003. Ignition handbook. Fire Science Publishers. Issaquah, WA. ISBN-10: 0-9728111-3-3

Bailey, D., 2013 WUI Fact Sheet, International Association of Wildland Fire and International Code Council. http://www.iawfonline.org/pdf/WUI_Fact_Sheet_08012013.pdf [Last Accessed Feb. 13, 2015]

Baum, H.R., Atreya, A., 2014. A Model for Combustion of Firebrands of Various Shapes. Fire Saf. Sci., 11, In Press. http://www.iafss.org/publications/fss/11/147/ [Last Accessed Feb. 13, 2015]

Baum, H.R. and Mccaffrey, B.J., 1989. Fire Induced Flow Field - Theory And Experiment. Fire Saf. Sci., 2: 129-148. doi:10.3801/IAFSS.FSS.2-129

Beyler, C., Dinaburg, J., Mealy, C., 2014. Development of test methods for assessing the fire hazards of landscaping mulch. Fire Tech., 50(1) 39-60. doi:10.1007/s10694-012-0264-y

Bhandary, U., Muller, B., 2009. Land use planning and wildfire risk mitigation: an analysis of wildfire-burned subdivisions using high-resolution remote sensing imagery and GIS data. J. Environ. Plan. Manag. 52, 939–955. doi:10.1080/09640560903181147

Bowman, D.M., Johnston, F.H., 2005. Wildfire smoke, fire management, and human health, EcoHealth 2(1), 76-80. doi:10.1007/s10393-004-0149-8

Brenkert-Smith, H., 2010. Building bridges to fight fire: the role of informal social interactions in six Colorado wildland–urban interface communities. Int. J. Wildl. Fire 19, 689. doi:10.1071/WF09063

Brown, H., 2004. The Air Was Fire: Fire Behavior at Peshtigo in 1871. Fire Manag. Today 64, 20–30. https://www.frames.gov/rcs/ttrs/17000/17406.html [Last Accessed Feb. 13, 2015]

Bryner, N.P., Mulholland, G.W. 1991. Smoke emission and burning rates for urban structures. Atmospheric Environment. Part A. General Topics, 25(11): 2553-2562. doi:10.1016/0960-1686(91)90172-4

Butler, B.W., 2014. Wildland firefighter safety zones: a review of past science and summary of future needs. Int. J. Wildl. Fire 23, 295–308. doi:10.1071/WF13021

Byram, G.M., 1959. Combustion of forest fuels. In: Davis, K.P., ed. Forest fire: control and use. Pgp. 61-89 New York, NY: McGraw Hill. https://www.frames.gov/rcs/9000/9652.html [Last Accessed Feb. 13, 2015]

Calkin, D.E., Cohen, J.D., Finney, M.A, Thompson, M.P., 2014. How risk management can prevent future wildfire disasters in the wildland-urban interface. Proc. Natl. Acad. Sci. U. S. A. 111, 746–51. doi:10.1073/pnas.1315088111

CBC, 2009 California Build Code, Materials and construction methods for exterior wildfire exposure Title 24, part 2, volume 1 of 2, Chapter 7A (Sacramento, CA: California Code of Regulations). Available at: http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_codes.php [Last Accessed Feb. 13, 2015]

Champ, Patricia A.; Brenkert-Smith, Hannah; Flores, Nicholas. 2011. Living with wildfire in Boulder County, Colorado, 2007. Res. Note RMRS-RN-47WWW. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 26 p. http://www.fs.fed.us/rm/pubs/rmrs_rn047.pdf [Last Accessed Feb. 13, 2015]

Chase, C.H., 1981. Spot fire distance equations for pocket calculators. Res. Note INT-310. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. https://www.frames.gov/rcs/8000/8158.html [Last Accessed Feb. 13, 2015]

Cheney, P., Sullivan, A., 2008. Grassfires: fuel, weather and fire behaviour. CSIRO Publishing, Collingwood, VIC, Australia. ISBN: 9780643093836

Cohen, J.D., 1995. Structure Ignition Assessment Model (SIAM), USDA Forest Service Gen. Tech. Rep. PSW-GTR-158. http://www.fs.fed.us/psw/publications/documents/psw_gtr158/psw_gtr158_05_cohen.pdf [Last Accessed Feb. 13, 2015]

Cohen, J.D., 2000a. Examination of the Home Destruction in Los Alamos Associated with the Cerro Grande Fire. http://www.treesearch.fs.fed.us/pubs/4686 [Last Accessed Feb. 13, 2015]

Cohen, J.D., 2000b. Preventing Disaster: Home Ignitability in the Wildland-Urban Interface. J. For. 98(3), 15–21. http://www.treesearch.fs.fed.us/pubs/4688 [Last Accessed Feb. 13, 2015]

Cohen, J., 2004a. Relating flame radiation to home ignition using modeling and experimental crown fires. Can. J. For. Res. 1626, 1616–1626. doi:10.1139/X04-049

Cohen, J., 2008. The Wildland- Urban Interface Fire Problem: A Consequence of the Fire Exclusion Paradigm. For. Hist. Today Fall, 20–26. http://foresthistory.org/Publications/FHT/FHTFall2008/Cohen.pdf [Last Accessed Feb. 13, 2015]

Cohen J.D., Butler B.W. (1998) Modeling potential structure ignitions from flame radiation exposure with implications for wildland–urban interface management. Implications for wildland–urban interface fire management. In 'Proceedings of the 13th Conference on Fire and Forest Meteorology'. 27–31 October 1996, Lorne, Vic., Australia. (Ed. R Weber) pp. 81–86. (International Association of Wildland Fire: Moran, WY). http://www.fs.fed.us/rm/pubs_other/rmrs_1998_cohen_j001.pdf [Last Accessed Feb. 13, 2015]

Cohen, J.D., Deeming, J.E., 1985. The national fire-danger rating system: basic equations. General Technical Report PSW-82. Berkeley, CA, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. https://www.frames.gov/rcs/ttrs/8000/8572.html [Last Accessed Feb. 13, 2015]

Cohen, J., Saveland, J., 1997. Stucture ignition assessment can help reduce fire damages in the W-UI. Fire Management Notes, 57(4) 19-23. 57. http://www.treesearch.fs.fed.us/pubs/4690 [Last Accessed Feb. 13, 2015]

Cohen, J.D., Stratton, R.D., 2008. Home Destruction Examination Grass Valley Fire. United States. Department of Agriculture. General Technical Report R5-TP-026b. http://www.fs.fed.us/rm/pubs_other/rmrs_2008_cohen_j001.pdf [Last Accessed Feb. 13, 2015]

County of San Diego, May 2014 San Diego County Wildfires After Action Report, 2014, http://www.readysandiego.org/aar/may-2014-san-diego-county-wildfires/May-2014-San-Diego-County-Wildfires.pdf [Last Accessed Feb. 13, 2015]

de Ris, J., 1979. Fire radiation-a review, Proc. Comb. Inst. 17(1) 1003–1016. doi:10.1016/S0082-0784(79)80097-1

de Ris, J., 2000. Radiation fire modeling. Proc. Comb. Inst. 28, 2751–2759. doi:10.1016/S0082-0784(00)80696-7

Dennison, P.E., Brewer, S.C., Arnold, J.D., Moritz, M.A., 2014. Large wildfire trends in the western United States, 1984-2011. Geophys. Res. Lett. 41, 2928–2933. doi:10.1002/2014GL059576

Drysdale, D., 2011. An introduction to fire dynamics. 3rd Edition, John Wiley & Sons, Ltd., West Sussex, UK, ISBN: 978-0-470-31903-1

Duerksen, C., Elliott, D., Anthony, P., 2011. Addressing Community Wildfire Risk : A Review and Assessment of Regulatory and Planning Tools, NFPA Fire Protection Research Foundation Report. http://www.nfpa.org/research/fire-protection-research-foundation/reports-and-proceedings/for-emergency-responders/fire-prevention-and-administration/addressing-community-wildfire-risk [Last Accessed Feb. 13, 2015]

Farnsworth, A., Summerfelt, P., Neary, D.G., Smith, T., 2003. Flagstaff's wildfire fuels treatments : prescriptions for community involvement and a source of bioenergy. Biomass and Bioenergy, 24(4-5) 269–276. doi:10.1016/S0961-9534(02)00174-5

Farris, J.K., 2005. Executive Analysis of Fire Service Operations in Emergency Management, Wildland Urban Interface Fires; Reducing the Commitment of Honolulu Fire Department Resources, Honolulu Fire Department, September 2005. http://www.usfa.fema.gov/pdf/efop/efo38375.pdf [Last Accessed Feb. 13, 2015]

Finney, M.A., 2004. FARSITE: Fire Area Simulator—model development and evaluation, Res. Pap. RMRS-RP-4, Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 47 p. http://www.treesearch.fs.fed.us/pubs/4617 [Last Accessed Feb. 13, 2015]

Finney, M.A., 2006a. A Computational Method for Optimizing Fuel Treatment Locations Assumptions And Methods, in: Andrews, Patricia L.; Butler, B.W. (Ed.), 2006. Fuels Management—How to Measure Success: Conference Proceedings. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Portland, OR. Proceedings RMRS-P-41, pp. 107–123. http://www.fs.fed.us/rm/pubs/rmrs_p041/rmrs_p041_107_123.pdf [Last Accessed Feb. 13, 2015]

Finney, M.A. 2006b. An overview of FlamMap fire modeling capabilities. Pages 213-220. In: Andrews, Patricia L.; Butler, Bret W. (comps.). Fuels Management-How to Measure Success: Conference Proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. https://www.frames.gov/rcs/2000/2152.html [Last Accessed Feb. 13, 2015]

Finney, M.A., Cohen, J.D., Grenfell, I.C., Yedinak, K.M., 2010. An examination of fire spread thresholds in discontinuous fuel beds. Int. J. Wildl. Fire 19, 163–170. doi:10.1071/WF07177

Finney, M.A., Cohen, J.D., McAllister, S.S., Jolly, W.M., 2013. On the need for a theory of wildland fire spread. Int. J. Wildl. Fire 22, 25. doi:10.1071/WF11117

Finney, M. A., Forthofer, J., Grenfell, I. C., Adam, B. A., Akafuah, N. K., & Saito, K. (2015). Section B Fire and Explosion-A Study of Flame Spread in Engineered Cardboard Fuel Beds

Part I: Correlations and Observations of Flame Spread. In Progress in Scale Modeling, Volume II (pp. 71-83). Springer International Publishing. doi:10.1007/978-3-319-10308-2_5

Fire Adapted Communities, 2014. Guide to Fire Adapted Communities. http://www.fireadapted.org/~/media/Fire%20Adapted/Files/FAC%20Reference%20Guide%202014%20FINAL%20reduced%202.pdf [Last Accessed Feb. 13, 2015]

Firewise, 2015. Firewise at NFPA: A Brief History. http://www.firewise.org/about/history.aspx?sso=0 [Last Accessed Feb. 13, 2015]

Firewise, 2015b. The basics of defensible space and the "home ignition zone." http://www.firewise.org/wildfire-preparedness/be-firewise/home-and-landscape/defensible-space.aspx?sso=0 [Last Accessed Feb. 13, 2015]

Foote, E., 1994. Structure survival on the 1990 Santa Barbara "Paint" Fire : a retrospective study of urban-wildland interface fire hazard mitigation factors. M.S. Thesis, University of California, Berkeley.

Foote, E., Liu, J., Manzello, S., 2011. Characterizing firebrand exposure during wildland urban interface fires. Proc. Fire Mater. 1–12. doi:10.1007/s10694-012-0295-4

Fowler, C.T. 2003. Human health impacts of forest fires in the southern United States: a literature review." Journal of Ecological Anthropology. 7(1) 39-63. doi:10.5038/2162-4593.7.1.3

Frankman, D., Brent W.W., Butler, B.W., Jimenez, D. Forthofer, J.M., Sopko, P., Shannon, K.S., Hiers, K.J., Ottmar, R.D. 2013. Measurements of convective and radiative heating in wildland fires. Int. J. Wildl. Fire, 22(2) 157-167. doi:10.1071/WF11097

FRAP, California Fire Hazard Severity Zone Map Update Project, http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_maps.php [Last Accessed Feb. 13, 2015]

Glenn, G.M., Bingol, G., Chiou, B.-S., Klamczynski, A.P., Pan, Z., 2012. Sodium bentonite-based coatings containing starch for protecting structures in wildfire emergency situations. Fire Saf. J. 51, 85–92. doi:10.1016/j.firesaf.2012.03.005

Gol'dshleger, U., Pribytkova, K., Barzykin, V., 1973. Ignition of a condensed explosive by a hot object of finite dimensions. Combust. Explos. Shock Waves 9(1) 99–102. doi: 10.1007/BF00740368

Gordon, J.S., Matarrita-Cascante, D., Stedman, R.C., Luloff, a. E., 2010. Wildfire Perception and Community Change. Rural Sociol. 75, 455–477. doi:10.1111/j.1549-0831.2010.00021.x

Gorham, D.J., Hakes, R., Singh, A.V., Forthofer, J., Cohen, J., McAllister, S., Finney, M.A., Gollner, M.J., 2014. Studying Wildfire Spread Using Stationary Burners, in: Xavier Viegas, D. (Ed.), VII International Conference on Forest Fire Research. Coimbra, Portugal. doi:10.14195/978-989-26-0884-6_47

Gude, P., Rasker, R., Noort, J. Van Den, 2008. Potential for Future Development on Fire-Prone Lands, Journal of Forestry. 106(4) 198-205.

Haas, J.R., Calkin, D.E., Thompson, M.P., 2013. A national approach for integrating wildfire simulation modeling into Wildland Urban Interface risk assessments within the United States. Landsc. Urban Plan. 119, 44–53. doi:10.1016/j.landurbplan.2013.06.011

Hadden, R.M., Scott, S., Lautenberger, C., Fernandez-Pello, a. C., 2010. Ignition of Combustible Fuel Beds by Hot Particles: An Experimental and Theoretical Study. Fire Technol. 47, 341–355. doi:10.1007/s10694-010-0181-x

Hall, J.R.. The Total Cost of Fire in the United States, National Fire Protection Association, Quincy, MA, 2014. http://www.nfpa.org/research/reports-and-statistics/fires-in-the-us/overall-fire-problem/total-cost-of-fire [Last Accessed Feb. 13, 2015]

Harvey, B., Fitzgerald, S., 2004. Is Florida's Prescribed Fire Program Something to get Choked up About?: Clean air standards, Fire Management Today, Vol. 64, Issue 4, Pg. 16-18. https://www.frames.gov/rcs/ttrs/17000/17404.html [Last Accessed Feb. 13, 2015]

Holmes, C.A. 1971. Evaluation of fire-retardant treatments for wood shingles. Res. Pap. FPL 158. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. http://www.fpl.fs.fed.us/documnts/fplrp/fplrp158.pdf [Last Accessed Feb. 13, 2015]

Holmes, C.A. 1973. Correlation of ASTM exposure tests for evaluating the durability of fire-retardant treatment of wood. Res. Pap. FPL 194. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. http://www.fpl.fs.fed.us/documnts/fplrp/fplrp194.pdf [Last Accessed Feb. 13, 2015]

Holmes, C.A., Knispel, R.O. 1981. Exterior weathering durability of some leach-resistant fire-retardant treatments for wood shingles: A 5-year report. Res. Pap. FPL 403. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. http://www.fpl.fs.fed.us/documnts/fplrp/fplrp403.pdf [Last Accessed Feb. 13, 2015]

Hood, S., Wu, R., 2006. Estimating Fuel Bed Loadings in Masticated Areas Field Measurements. In USDA Forest Service Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. RMRS-P-41, 333–340. http://www.treesearch.fs.fed.us/pubs/25959 [Last Accessed Feb. 13, 2015]

Hudak, A.T., Rickert, I., Morgan, P., Strand, E., Lewis, S.A., Robichaud, P.R., Hoffman, C., Holden, Z.A., Andrew, T., Sarah, A., Peter, R., Review, Z.A., 2011. Review of Fuel Treatment Effectiveness in Forests and Rangelands and a Case Study From the 2007 Megafires in Central Idaho USA. Gen. Tech. Rep. RMRS-GTR-252. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 60p http://www.treesearch.fs.fed.us/pubs/37405 [Last Accessed Feb. 13, 2015]

IBHS, 2008. MEGA FIRES: The Case for Mitigation. http://www.disastersafety.org. [Last Accessed Feb. 13, 2015]

IBHS, 2013. Wildfire Home Assessment and Checklist. http://www.disastersafety.org. [Last Accessed Feb. 13, 2015]

IBHS, 2014. IBHS website. http://www.disastersafety.org. [Last Accessed Feb. 13, 2015]

ICC, 2012. International wildlan-urban interface code. International Code Council, Country Club Hills, IL. Available at: http://www.iccsafe.org [Last Accessed Feb. 13, 2015]

Ito, A., Kashiwagi, T., 1988. Characterization of flame spread over PMMA using holographic interferometry sample orientation effects. Combust. Flame 71, 189–204. doi:10.1016/0010-2180(88)90007-7

Johnson, J.F., Downing, T., Nelson, K.C., 2008. External Sprinkler Systems and Defensible Space: Lessons Learned from the Ham Lake Fire and the Gunflint Trail. A report prepared for the Firewise Program, Minnesota Department of Natural Resources. https://www.frames.gov/rcs/ttrs/24000/24982.html [Last Accessed Feb. 13, 2015]

Jones, J.C., 1995. Improved Calculations Concerning the Ignition of Forest Litter by Hot Particle Ingress. J. Fire Sci. 13, 350–356. doi:10.1177/073490419501300502

Keeley, JE, AD Syphard, CJ Fotheringham., 2013. Ch. 5: The 2003 and 2007 wildfires in southern California. In: Boulter, S, J Palutikof, DJ Karoly, D Guitart (eds.). Natural Disasters and Adaptation to Climate Change. Oxford: Cambridge University Press. http://www.werc.usgs.gov/ProductDetails.aspx?ID=4971 [Last Accessed Feb. 13, 2015]

Koo, E., Pagni, P.J., Weise, D.R., Woycheese, J.P., 2010. Firebrands and spotting ignition in large-scale fires. Int. J. Wildl. Fire 19, 818. doi:10.1071/WF07119

Koo, E., Linn, R.R., Pagni, P.J., Edminster, C.B., 2012. Modelling firebrand transport in wildfires using HIGRAD/FIRETEC. Int. J. Wildl. Fire 21, 396. doi:10.1071/WF09146

Krawchuk, M.A., Moritz, M., Parisien, M.-A., Van Dorn, J., Hayhoe, K., 2009. Global pyrogeography: the current and future distribution of wildfire. PLoS One 4, e5102. doi:10.1371/journal.pone.0005102

Kunzli, N., Avol, E., Wu, J., Gauderman, W.J., Rappaport, E., Millstein, J., Bennion J., 2006. Health effects of the 2003 Southern California wildfires on children. American journal of respiratory and critical care medicine. 174(11) 1221-1228. doi:10.1164/rccm.200604-519OC

Lampin-Maillet, C., Jappiot, M., Long, M., Bouillon, C., Morge, D., Ferrier, J.-P.,2010. Mapping wildland-urban interfaces at large scales integrating housing density and vegetation aggregation for fire prevention in the South of France. J. Environ. Manage. 91, 732–41. doi:10.1016/j.jenvman.2009.10.001

Lautenberger, 2015. Wildland Fire Hazard Modeling Tools (WFHMT), http://reaxengineering.com/trac/wfhmt/ [Last Accessed Feb. 13, 2015]

LeVan, S.L., Holmes, C.A. 1986. Effectiveness of fire retardant treatments for shingles after 10 years of outdoor weathering. Res. Pap. FPL-474. Madison, WI: U.S. Dept. of Agriculture, Forest Service, Forest Products Laboratory. http://www.fpl.fs.fed.us/documnts/fplrp/fplrp474.pdf [Last Accessed Feb. 13, 2015]

Fahy, R.F., LeBlanc, P.R., Molis, J.L., 2014. Firefighter Fatalities in the United States -2013. NFPA No. FFD10 http://www.nfpa.org/~/media/Files/Research/NFPA%20reports/Fire%20service%20statistics/osfff.pdf [Last Accessed Feb. 13, 2015]

Linan, A., Williams, F.A., 1972. Radiant ignition of a reactive solid with in-depth absorption. Combust. Flame 18, 85–97. doi:10.1016/S0010-2180(72)80229-3

Manzello, S.L., Cleary, T.G., Shields, J.R., Yang, J.C., 2006a. On the ignition of fuel beds by firebrands. Fire Mater. 30, 77–87. doi:10.1002/fam.901

Manzello, S.L., Cleary, T.G., Shields, J.R., Yang, J.C., 2006b. Ignition of mulch and grasses by firebrands in wildland–urban interface fires. Int. J. Wildl. Fire 15, 427. doi:10.1071/WF06031

Manzello, S.L., Hayashi, Y., Yoneki, T., Yamamoto, Y., 2010a. Quantifying the vulnerabilities of ceramic tile roofing assemblies to ignition during a firebrand attack. Fire Saf. J. 45, 35–43. doi:10.1016/j.firesaf.2009.09.002

Manzello, S.L., Maranghides, A., Mell, W.E., 2007. Firebrand generation from burning vegetation. Int. J. Wildl. Fire 16, 458. doi:10.1071/WF06079

Manzello, S., Shields, J., Hayashi, Y., Nii, D., 2008. Investigating the Vulnerabilities of Structures to Ignition From a Firebrand Attack. Fire Saf. Sci. 9, 143–154. doi:10.3801/IAFSS.FSS.9-143

Manzello, S.L., Maranghides, A., Shields, J.R., Mell, W.E., Hayashi, Y., Nii, D., 2009. Mass and size distribution of firebrands generated from burning Korean pine (Pinus koraiensis) trees. Fire Mater. 33, 21–31. doi:10.1002/fam.977

Manzello, S.L., Park, S.-H., Cleary, T.G., 2009. Investigation on the ability of glowing firebrands deposited within crevices to ignite common building materials. Fire Saf. J. 44, 894–900. doi:10.1016/j.firesaf.2009.05.001

Manzello, S.L., Park, S.-H., Cleary, T.G., 2010b. Development of rapidly deployable instrumentation packages for data acquisition in wildland–urban interface (WUI) fires. Fire Saf. J. 45, 327–336. doi:10.1016/j.firesaf.2010.06.005

Manzello, S.L., Park, S.-H., Shields, J.R., Hayashi, Y., Suzuki, S. 2010c. Comparison Testing Protocol for Firebrand Penetration through Building Vents: Summary of BRI / NIST Full Scale and NIST Reduced Scale Results NIST Technical Note 1659 Comparison Testing Protocol for Firebrand Penetration through Building Vents : Summary. Gaithersburg, MD. http://www.nist.gov/manuscript-publication-search.cfm?pub_id=904793 [Last Accessed Feb. 13, 2015]

Manzello, S.L., Park, S.-H., Suzuki, S., Shields, J.R., Hayashi, Y., 2011. Experimental investigation of structure vulnerabilities to firebrand showers. Fire Saf. J. 46, 568–578. doi:10.1016/j.firesaf.2011.09.003

Manzello, S.L., Suzuki, S., Hayashi, Y., 2012a. Enabling the study of structure vulnerabilities to ignition from wind driven firebrand showers: A summary of experimental results. Fire Saf. J. 54, 181–196. doi:10.1016/j.firesaf.2012.06.012

Manzello, S.L., Suzuki, S., Hayashi, Y., 2012b. Exposing siding treatments, walls fitted with eaves, and glazing assemblies to firebrand showers. Fire Saf. J. 50, 25–34. doi:10.1016/j.firesaf.2012.01.006

Manzello, S.L., 2013. The Performance of Concrete Tile and Terracotta Tile Roofing Assemblies Exposed to Wind-Driven Firebrand Showers. NIST Technical Note 1794. Gaithersburg, MD. doi:10.6028/NIST.TN.1794

Manzello, S.L., Suzuki, S., 2014. Exposing Decking Assemblies to Continuous Wind-Driven Firebrand Showers. Fire Saf. Sci. 11. In Press. http://www.iafss.org/publications/fss/11/60 [Last Accessed Feb. 13, 2015]

Manzello, S.L., 2014. Enabling the Investigation of Structure Vulnerabilities to Wind- Driven Firebrand Showers in Wildland-Urban Interface (WUI) Fires. Fire Saf. Sci. 11. http://www.iafss.org/publications/fss/11/310 [Last Accessed Feb. 13, 2015]

Manzello, S.L., Foote, E.I.D., 2014. Characterizing Firebrand Exposure from Wildland–Urban Interface (WUI) Fires: Results from the 2007 Angora Fire. Fire Technol. 50, 105–124. doi:10.1007/s10694-012-0295-4

Maranghides, A., Johnsson, E., 2008. Residential Structure Separation Fire Experiments. NIST Technical Note 1600. Gaithersburg, Maryland, USA. http://fire.nist.gov/bfrlpubs/fire08/art034.html [Last Accessed Feb. 13, 2015]

Maranghides, A., McNamara, D., Mell, W., Trook, J., Toman, B., 2013. A case study of a community affected by the Witch and Guejito fires : report #2 - evaluating the effects of hazard mitigation actions on structure ignitions. Gaithersburg, MD. doi:10.6028/NIST.TN.1796

Maranghides, A., Mell, W., 2013. Framework for Addressing the NationalWildland Urban Interface Fire Problem – Determining Fire and Ember Exposure Zones using a WUI Hazard Scale. NIST, Gaithersburg, MD. doi:10.6028/NIST.TN.1748

Marney, D.C.O., Russell, L.J.. 2008, Combined fire retardant and wood preservative treatments for outdoor wood applications – a review of the literature. Fire Tech., 44, 1-14. doi:10.1007/s10694-007-0016-6

Marney, D.C.O., Russell, L.J., Mann, R. 2008, Fire performance of wood (Pinus radiata) treated with fire retardants and a wood preservative, Fire Mater. 32, 357-370. doi:10.1002/fam.973

Massada, A., Radeloff, V., Stewart, S., 2011. Allocating fuel breaks to optimally protect structures in the wildland–urban interface. Int. J. Wildl. fire 20, 59–68. doi:10.1071/WF09041

McArthur, A.G., 1966a. Prescribed burning in Australian fire control. Aust. For. 30, 4–11. doi:10.1080/00049158.1966.10675391

McArthur, A., 1966b. Weather and grassland fire behaviour. Forest Research Institute, Forestry and Timber Bureau, Canberra, Australia.

McArthur, A., 1967. Fire behaviour in eucalypt forests. Forestry and Timber Bureau, Paper submitted to the Ninth Commonwealth Forestry Conference, India.

Mell, W., Manzello, S., Maranghides, A., 2010. The wildland–urban interface fire problem– current approaches and research needs. J. Wildl. Fire 2005, 238–251. doi:10.1071/WF07131

Mell, W., Maranghides, A., 2009. NIST Technical Note 1635: A Case Study of a Community Affected by the Witch and Guejito Fires. http://www.nist.gov/manuscript-publication-search.cfm?pub_id=902864 [Last Accessed Feb. 13, 2015]

Menakis, J., Cohen, J., Bradshaw, L., 2000. Mapping wildland fire risk to flammable structures for the conterminous United States, Pp. 41-49 in: K.E.M. Gallery, R.C. Clinger, and N.G. Sugihara (eds.). Proceedings of Fire Conference 2000: The First National Congress on Fire

Ecology, Prevention and Management. Miscellaneous Publication No. 13, Tall Timbers Research Station, Tallahassee, FL.

Morris, G.A., 1987. A simple method for computing spotting distances from wind-driven surface fires. Res. Note INT-374. U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. https://www.frames.gov/rcs/14000/14031.html [Last Accessed Feb. 13, 2015]

Murphy, K., Rich, T., Sexton, T., 2007. An assessment of fuel treatment effects on fire behavior, suppression effectiveness, and structure ignition on the Angora Fire, US For. Serv. Tech. Pap. R5-TP-025. http://www.cnpssd.org/fire/angorafireusfsfullreport.pdf [Last Accessed Feb. 13, 2015]

National Board of Fire Underwriters, 1923. 'Report on the Berkeley, California, Conflagration of September 17, 1923.' (The National Board of Fire Underwriters: New York)

National Fire Protection Association (NFPA) 2012. NFPA 1141: Standard for fire protection infrastructure for land development in wildland, rurual and suburban areas. Retrieved from http://codesonline.nfpa.org [Last Accessed Feb. 13, 2015]

National Fire Protection Association (NFPA) 2012b. NFPA 1142: Standard on water supplies for suburban and rual firefighting. Retrieved from http://codesonline.nfpa.org [Last Accessed Feb. 13, 2015]

National Fire Protection Association (NFPA) 2014. NFPA 1143: Standard for wildland fire management. Retrieved from http://codesonline.nfpa.org [Last Accessed Feb. 13, 2015]

National Fire Protection Association (NFPA) 2013. NFPA 1144: Standard for reducing structrual ignition hazards from wildland fire. Retrieved from http://codesonline.nfpa.org [Last Accessed Feb. 13, 2015]

National Fire Protection Association (NFPA), 2015. NFPA 276: Standard method of fire test for determining the heat release rate of roofing assemblies with combustible above-deck roofing components. Retrieved from http://codesonline.nfpa.org [Last Accessed Feb. 13, 2015]

NIFC, 2015 National Interagency Fire Center. www.nifc.gov/nicc [Last Accessed Feb. 13, 2015]

Pagni, P. J. (1993). Causes of the 20 October 1991 Oakland Hills Conflagration. *Fire Safety Journal*, *21*(4), 331-339. doi:10.1016/0379-7112(93)90020-Q

Pagni, P. J.; Woycheese, J. P. (2000). Fire Spread by Brand Spotting. U.S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 15th Joint Panel Meeting. Volume 2. Proceedings. March 1-7, 2000, San Antonio, TX, Bryner, S. L., Editor(s), 373-380 pp, 2000. http://fire.nist.gov/bfrlpubs/fire00/art131.html [Last Accessed Feb. 13, 2015]

Pagni, W., 1999a. Combustion Models for Wooden Brands, International Conference on Fire Research and Engineering (ICFRE3), Third (3rd). Proceedings. Society of Fire Protection Engineers (SFPE), National Institute of Standards and Technology (NIST) and International Association of Fire Safety Science (IAFSS). October 4-8, 1999, Chicago, IL, Society of Fire Protection Engineers, Boston, MA, 53-71 pp, 1999. http://fire.nist.gov/bfrlpubs/fire99/art110.html [Last Accessed Feb. 13, 2015]

Pechony, O., Shindell, D.T., 2010. Driving forces of global wildfires over the past millennium and the forthcoming century. Proc. Natl. Acad. Sci. U.S.A. 107, 19167–70. doi:10.1073/pnas.1003669107

Pellegrino, J.L., Bryner, N.P., Johnsson, E.L., 2013. Wildland-Urban Interface Fire Research Needs: Workshop Summary Report, NIST. May 2013. doi:10.6028/NIST.SP.1150

Porterie, B., Consalvi, J.L., Loraud, J.C., Giroud, F., Picard, C., 2007. Dynamics of wildland fires and their impact on structures. Combust Flame., 149, 314-328. doi:10.1016/j.combustflame.2006.12.017

Prestemon, J.P., Butry, D.T., Abt, K.L, Sutphen, R., 2010, Net benefits of wildfire prevention education efforts, Forest Science 56 (2): 181-192. http://www.srs.fs.usda.gov/pubs/ja/ja_prestemon029.pdf [Last Accessed Feb. 13, 2015]

Pyne, S.J., 2008, Spark and sprawl: A world tour. Forest History Today, Fall, 2008. https://www.frames.gov/rcs/13000/13500.html [Last Accessed Feb. 13, 2015]

Quarles, S. and Smith, E., 2004, The combustability of landscape mulches. University of Nevada Cooperative Extension. https://www.unce.unr.edu/publications/files/nr/2011/sp1104.pdf [Last Accessed Feb. 13, 2015]

Quarles, S., Leschak, P., Cowger, R., Worley, K., Brown, R., Iskowitz, C., 2012. Lessons Learned From Waldo Canyon: Fire Adapted Communities Mitigation Assessment Team Findings. http://www.fireadapted.org/~/media/Fire%20Adapted/Images/News%20Images/Waldo-Canyon-Rpt-FINAL-shrunk%203.pdf [Last Accessed Feb. 13, 2015]

Quarles, S.L., 2012. Vulnerabilities of Buildings to Wildfire Exposures. http://www.extension.org/pages/63495/vulnerabilities-of-buildings-to-wildfire-exposures/print/#.U5HVJ_mwLYg [Last Accessed Feb. 13, 2015]

Quintiere, J., Harkleroad, M., Hasemi, Y., 1986. Wall flames and implications for upward flame spread. Combust. Sci. Technol. 48, 191–222. doi:10.1080/00102208608923893

Quintiere, J.G., 2006. Fundamentals of fire phenomena. John Wiley & Sons, Ltd., West Sussex, England.

Radeloff, V.C., Hammer, R.B., Stewart, S.I., Fried, J.S., Holcomb, S.S., McKeefry, J.F., 2005. The Wildland-Urban Interface in the United States. Ecol. Appl. 15, 799–805. doi:10.1890/04-1413Radeloff, V.C., 2014, 2010 Wildland Urban Interface - Public Land Adjusted http://silvis.forest.wisc.edu/maps/wui/2010/download [Last Accessed Feb. 13, 2015]

Rahn, M., 2010. Initial Attack Effectiveness: Wildfire Staffing Study: Final report. San Diego State University. https://www.iaff.org/10News/PDFs/cdffirereport.pdf [Last Accessed Feb. 13, 2015]

Raish, C., 2011. Perspectives on Risk in the Wildland Interface. National Fire Plan Research Highlight. October, 2011. http://www.fs.fed.us/rm/science-application-integration/docs/national-fire-plan/wildland-urban-interface.pdf [Last Accessed Feb. 13, 2015]

Reams, M., Haines, T., Renner, C., 2008. An Examination of State and Local Fire Protection Programs in the Wildland-Urban Interface, in: Gonzalez-Caban, A. (Ed.), Proceedings of the Seoncd International Symposium on Fire Economics, Planning and Policy: A Global View. PSW-GTR-208. Albany, CA: USDA Forest Service, Pacific Southwest Research Station., pp. 495–504. http://www.fs.fed.us/psw/publications/documents/psw_gtr208en/psw_gtr208en_495-504_reams.pdf [Last Accessed Feb. 13, 2015]

Reinhardt, E.D., Keane, R.E., Calkin, D.E., Cohen, J.D., 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. For. Ecol. Manage. 256, 1997–2006. doi:10.1016/j.foreco.2008.09.016

Reszka, P., Borowiec, P., Steinhaus, T., Torero, J.L., 2012. A methodology for the estimation of ignition delay times in forest fire modelling. Combust. Flame 159, 3652–3657. doi:10.1016/j.combustflame.2012.08.004

Rhode, M.S., 2002. Command Decisions During Catastrophic Urban-interface Wildfire: A Case Study of the 1993 Orange County, California, Laguna Fire. M.S. Thesis, California State University, Long Beach.

Rothermel, R., Forest, I., 1972. A mathematical model for predicting fire spread in wildland fuels. Research Paper INT-RP-115. Ogden, UT: USDA Forest Service Intermountain Forest and Range Experiment Station. https://www.frames.gov/rcs/6000/6152.html [Last Accessed Feb. 13, 2015]

Safford, H.D., Schmidt, D. a., Carlson, C.H., 2009. Effects of fuel treatments on fire severity in an area of wildland–urban interface, Angora Fire, Lake Tahoe Basin, California. For. Ecol. Manage. 258, 773–787. doi:10.1016/j.foreco.2009.05.024

Sardoy, N., Consalvi, J.-L., Porterie, B., 2007. Fernandez-Pello, A.C., Modeling transport and combustion of firebrands from burning trees, Combust. Flame. 150(2) 151-169. doi:10.1016/j.combustflame.2007.04.008

Sardoy, N., Consalvi, J.-L., Kaiss, A., Fernandez-Pello, A.C., Porterie, B., 2008. Numerical study of gournd-level distribution of firebrands generated by line fires. Combust. Flame. 154(3) 478-488. doi:10.1016/j.combustflame.2008.05.006

Scott, J.H., 2012. Introduction to Fire Behavior Modeling. https://www.frames.gov/files/8413/4643/5159/Intro_to_Fire_Behavior_Modeling_Guide_2012.06.25.pdf [Last Accessed Feb. 13, 2015]

Short, K.C., 2014. A spatial database of wildfires in the United States, 1992–2011. Earth Syst. Sci. Data 6, 1–27. doi:10.5194/essd-6-1-2014

Simeoni, A., Mueller, E., Skowronski, N., Clark, K., Krememns, R., Gallagher, M., Thomas, J., El Hossamni, M., Filkov, A., Butler, B. 2014. Experimental study of fire behavior during prescribed fires in New Jersey, 2014 GSA Annual Meeting, Vancouver, British Columbia.

Spyratos, V., Bourgeron, P.S., Ghil, M., 2007. Development at the wildland-urban interface and the mitigation of forest-fire risk. Proc. Natl. Acad. Sci. U. S. A. 104, 14272–6. doi:10.1073/pnas.0704488104

Steckler, K.O., D.D. Evans, J.E. Snell, 1991, Preliminary Study of the 1991 Oakland Hills fire and its relevance to woodframe, multi-family building construction, NISTIR4724, USDOC National Institute of Standards and Technology, Gaithersburg, MD.

Stein, S.M., Menakis, J., Carr, M.A., Comas, S.J., Stewart, S.I., Cleveland, H., Bramwell, L., Radeloff, V.C., 2013. Wildfire, wildlands, and people: understanding and preparing for wildfire in the wildland-urban interface - a Forests on the Edge report. Gen. Tech. Rep. RMRS-GTR-299. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. http://www.fs.fed.us/rm/pubs/rmrs_gtr299.html

Steward, L.G., Sydnor, T.D., Bishop, B., 2003. The ease of ignition of 13 Landscape Mulches. Journal of Aboriculture 29(6) 317-321. http://ucanr.edu/sites/UrbanHort/files/117293.pdf

Stewart, S. I., B. Wilmer, R. B. Hammer, G. H. Aplet, T. J. Hawbaker, C. Miller, and V. C. Radeloff. 2009. Wildland-Urban Interface maps vary with purpose and context. Journal of Forestry, 107(2):78-83

Stewart, S.I., Wilmer, B., Hammer, R.B., Aplet, G.H., Hawbaker, T.J., Miller, C., Radeloff, V.C., 2009. Wildland – Urban Interface Maps Vary with Purpose and Context. Journal of Forestry, March 2009, pp. 78-83.

Stocks, B., Alexander, M., Van Wagner, C., McAlpine, R., Lynham, T., Dube, D., 1989. The Canadian Forest Fire Danger Rating System: An Overview. For. Chron. 65, 258–265. doi:10.5558/tfc65258-4

Stocks, B.J., Alexander, M.E., Wotton, B.M., Stefner, C.N., Flannigan, M.D., Taylor, S.W., Lavoie, N., Mason, J. a, Hartley, G.R., Maffey, M.E., Dalrymple, G.N., Blake, T.W., Cruz, M.G., Lanoville, R. a, 2004. Crown fire behaviour in a northern jack pine – black spruce forest. Can. J. For. Res. 34, 1548–1560. doi:10.1139/x04-054

Stokes, A., 1990. Fire ignition by copper particles of controlled size. J Electr Electron Eng Aust 10, 188–194.

Stoll, A.M., Chianta, M.A., 1971. Heat transfer through fabrics as related to thermal injury. Trans. N. Y. Acad. Sci. 33, 649–670. doi:10.1111/j.2164-0947.1971.tb02630.x

Sullivan, A.L., 2009a. Wildland surface fire spread modelling, 1990–2007. 1: Physical and quasi-physical models. Int. J. Wildl. Fire 18, 349. doi:10.1071/WF06143

Sullivan, A.L., 2009b. Wildland surface fire spread modelling, 1990–2007. 2: Empirical and quasi-empirical models. Int. J. Wildl. Fire 18, 369. doi:10.1071/WF06142

Sullivan, A.L., 2009c. Wildland surface fire spread modelling, 1990–2007. 3: Simulation and mathematical analogue models. Int. J. Wildl. Fire 18, 387. doi:10.1071/WF06144

Suzuki, S., Manzello, S.L., Lage, M., Laing, G., 2012. Firebrand generation data obtained from a full-scale structure burn. Int. J. Wildl. Fire 21, 961. doi:10.1071/WF11133

Suzuki, S., Manzello, S.L., Hayashi, Y., 2013. The size and mass distribution of firebrands collected from ignited building components exposed to wind. Proc. Combust. Inst. 34, 2479–2485. doi:10.1016/j.proci.2012.06.061

Suzuki, S., Brown, A., Manzello, S.L., Suzuki, J., Hayashi, Y., 2014. Firebrands generated from a full-scale structure burning under well-controlled laboratory conditions. Fire Saf. J. 63, 43–51. doi:10.1016/j.firesaf.2013.11.008

Syphard, A.D., Keeley, J.E., Brennan, T.J., 2011a. Factors affecting fuel break effectiveness in the control of large fires on the Los Padres National Forest, California. Int. J. Wildl. Fire 20, 764. doi:10.1071/WF10065

Syphard, A.D., Keeley, J.E., Brennan, T.J., 2011b. Comparing the role of fuel breaks across Southern California national forests. For. Ecol. Manage. 261, 2038–2048. doi:10.1016/j.foreco.2011.02.030

Syphard, A.D., Keeley, J.E., Massada, A.B., Brennan, T.J., Radeloff, V.C., 2012. Housing arrangement and location determine the likelihood of housing loss due to wildfire. PLoS One 7, e33954. doi:10.1371/journal.pone.0033954

Syphard, A.D., Brennan, T.J., Kelley, J.E., 2014. The role of defensible space for residential structure protection during wildfires., Int. J. Wildland Fire. doi:10.1071/WF13158

Takahashi, F., Abbott, A., Murray, T.M., T'ien, J.S., Olson, S.L., 2013. Thermal response characteristics of fire blanket materials. Fire Mater. 38(6), 609-638. doi:10.1002/fam.2202

Tarifa, C.S., Notario, P.P. Del, Moreno, F.G., 1965. On the flight paths and lifetimes of burning particles of wood. Symp. Combust. 10, 1021–1037. doi:10.1016/S0082-0784(65)80244-2

Theobald, D., Romme, W., 2007. Expansion of the US wildland–urban interface. Landsc. Urban Plan. 83, 340–354. doi:10.1016/j.landurbplan.2007.06.002

Thomas, P.H., 1963. The size of flames from natural fires. Symp. Combust. 9, 844–859. doi:10.1016/S0082-0784(63)80091-0

Thomas, P.H., 1964. A Comparison of Some Hot Spot Theories. Combust. Flame. 9(4), 369-372. doi:10.1016/0010-2180(65)90025-8

Tolhurst, K., Duff, T., Chong, D., 2014. Using fire simulations to assess house vulnerability at the urban interface, Fire Note 126, Bushfire CRC, Australia.

Tran, H., Cohen, J., Chase, R., 1992. Modeling ignition of structures in wildland/urban interface fires, in: 1st International Fire and Materials Conference. Inter Science Communications Limited, London, UK, Arlington, VA, pp. 253–262.

Trelles, J. and Pagni, P.J., 1997. Fire-induced Winds In The 20 October 1991 Oakland Hills Fire. Fire Safety Science 5: 911-922. doi:10.3801/IAFSS.FSS.5-911

Trelles, J., Pagni, P., 1992 Ð› Practical Scheme for Calculating the Fire-Induced Winds in the October 20, 1991 Oakland Hills Fire. U.S./Japan Government Cooperative Program on Natural Resources (UJNR). Fire Research and Safety. 12th Joint Panel Meeting. October 27-November 2, 1992, Tsukuba, Japan, Building Research Inst., Ibaraki, Japan Fire Research Inst., Tokyo, Japan, 297-305 pp, 1992.

UL, 2014. UL 790: Standard Test Methods for Fire Tests of Roof Coverings, Underwriter Laboratories, Northbrook, IL.

Urbas, J., 2013. Effectiveness of pre-applied wetting agents in prevention of wildland urban interface fires. Fire Mater. 563–580. doi:10.1002/fam

USFS, 2013. Fiscal Year 2014 Budget Overview, United States Department of Agriculture, Forest Service. April, 2013. http://www.fs.fed.us/aboutus/budget/2014/Overview%20%28COMPLETE%29.pdf [Last Accessed Feb. 13, 2015]

WFDRI, 2012. Wildland Fire Data Reporting Initiative Workshop Meeting Report. November 14-15, 2012, Denver, CO. http://www.nfpa.org/~/media/Files/Wildland/wfrdi_meeting_report_nov12.pdf [Last Accessed Feb. 13, 2015]

Van-Wagner, C.E., 1977. Conditions for the start and spread of crown fire. Can. J. For. Res. 23–34. doi:10.1139/x77-004

Viegas, D.X., Almeida, M., Raposo, J., Oliveira, R., Viegas, C.X., 2012. Ignition of Mediterranean Fuel Beds by Several Types of Firebrands. Fire Technol. doi:10.1007/s10694-012-0267-8

Viegas, D.X., Simeoni, A., 2010. Eruptive Behaviour of Forest Fires. Fire Technol. 47, 303–320. doi:10.1007/s10694-010-0193-6

Vodvarka, F., 1969. Firebrand field studies – Final report. Illinois Institute of Technology Research Institute.

Vodvarka, F., 1970. Ubran Burns - Full-Scale Field Studies - Final Report (IIT Research Institute: Chicago, IL).

Wang, H.-H., 2009. Analysis on Downwind Distribution of Firebrands Sourced from a Wildland Fire. Fire Technol. 47, 321–340. doi:10.1007/s10694-009-0134-4

Waterman, T.E., 1969. Experimental study of firebrand generation, IIT Research Institute, Project J6130, Chicago, IL, 1969.Weir, J.R., 2004. Probability of Spot Fires During Prescribed Burns. Fire Manag. Today 64, 24–26.

Wheeler, J., 2004. Testing for Deck Material Flammability. Fire Manag. Today 64, 13–15.

Wiedinmyer, C., Hurteau, M.D., 2010. Prescribed fire as a means of reducing forest carbon emissions in the western United States. Environ. Sci. Technol. 44, 1926–32. doi:10.1021/es902455e

Woycheese, J.P., Pagni, P.J., Liepmann, D., 1999. Brand Propagation From Large-Scale Fires. J. Fire Prot. Eng. 10, 32–44. doi:10.1177/104239159901000203

Woycheese, J.P. 2000. Brand Lofting and Propagation for Large-Scale Fires, Ph.D. Thesis, University of California, Berkeley.

Xavier Viegas, D., 2004. A Mathematical Model For Forest Fires Blowup. Combust. Sci. Technol. 177, 27–51. doi:10.1080/00102200590883624

Yoshioka, H., Hayashi, Y., Masuda, H., Noguchi, T., 2004. Real-Scale Fire Wind Tunnel Experiment on Generation of Firebrands from a House on Fire. Fire Sci. Technol. 23, 142–150. doi:10.3210/fst.23.142

Zak, C., Urban, J., Tran, V.I., Fernandez-Pello, A.C., 2014. Flaming Ignition Behavior of Hot Steel and Aluminum Spheres Landing in Cellulose Fuel Beds, Fire Saf. Sci., 11. http://www.iafss.org/publications/fss/11/188 [Last Accessed Feb. 13, 2015]

APPENDIX

Homeowner Educational Resources and Programs on the Internet

http://www.wildfireprograms.usda.gov/

Comprehensive index of community wildfire programs anywhere in the United States. Note: this source stopped updating in January, 2010.

Firewise: http://firewise.org/

A project of the National Fire Protection Association which includes a recognition program for communities, online courses and education and wildfire preparedness resources. Resources include courses and documentation on proper documentation in the WUI, how to conduct a community assessment and firefighter safety in the WUI.

Fire Adapted Communities: http://www.fireadapted.org/

Fire Adapted Communities (FAC) is a collaborative effort to bring together effective programs, tools and resource for reducing community wildfire risk. Includes a guide to fire adapted communities they recently published:

Ready, Set, Go! http://www.wildlandfirersg.org/.

The Ready, Set, Go! (RSG) Program, managed by the International Association of Fire Chiefs (IAFC), seeks to develop and improve the dialogue between fire departments and the residents they serve. Launched nationally in March 2011 at the Wildland-Urban Interface (WUI 2011) Conference, the program helps fire departments to teach individuals who live in high risk wildfire areas – and the wildland-urban interface – how to best prepare themselves and their properties against fire threats.

IBHS http://www.disastersafety.org/wildfire/

A service of the Insurance Institute for Business & Home Safety. Includes wildfire home assessment, wildfire fact sheet and many other resources and research results.

National Wildland Fire Coordinating Group: http://www.nwcg.gov/

The NWCG is an operational group designed to coordinate programs of the participating wildfire management agencies. They have several resources including fire prevention and education on the WUI.

Missoula Fire Sciences Laboratory http://firelab.org/applications

A collection of software applications including BehavePlus, FARSITE and FlamMap used for wildland fire simulation and assessment.

Living with Fire http://www.unce.unr.edu/blogs/livingwithfire/

A University of Nevada program that provides a set of consistent wildfire threat reduction recommendations for Nevadans.

eXtension Learn www.extension.org/surviving_wildfire

eXtension is an interactive learning environment delivering research-based information emerging from America's land-grant university system. This section provides information on wildfire with lessons and information for WUI residents.

UC Berkeley Center for Fire Research and Outreach http://ucanr.edu/sites/cfro/

The CFRO provides a forum for coordination on emerging research and tools regarding wildland fire in California. The center facilitates working groups devoted to a specific field or topic of research and management that relates to fire. The Center also addresses areas with Mediterranean climates world-wide.

Fire Hazard Checklists

A. ICC IWUIC Fire Hazard Severity Form

APPENDIX C

FIRE HAZARD SEVERITY FORM

The provisions contained in this appendix are not mandatory unless specifically referenced in the adopting ordinance.

When adopted, this appendix is to be used in place of Table 502.1 to determine the fire hazard severity.

A. Subdivision Design Points

1. Ingress/Egress
   - Two or more primary roads 1___
   - One road 3___
   - One-way road in, one-way road out 5___

2. Width of Primary Road
   - 20 feet or more 1___
   - Less than 20 feet 3___

3. Accessibility
   - Road grade 5% or less 1___
   - Road grade more than 5% 3___

4. Secondary Road Terminus
   - Loop roads, cul-de-sacs with an outside turning radius of 45 feet or greater 1___
   - Cul-de-sac turnaround
   - Dead-end roads 200 feet or less in length 3___
   - Dead-end roads greater than 200 feet in length 5___

5. Street Signs
   - Present 1___
   - Not present 3___

B. Vegetation (IWUIC Definitions)

1. Fuel Types
   - Light 1___
   - Medium 5___
   - Heavy 10___

2. Defensible Space
   - 70% or more of site 1___
   - 30% or more, but less than 70% of site 10___
   - Less than 30% of site 20___

C. Topography

- 8% or less 1___
- More than 8%, but less than 20% 4___
- 20% or more, but less than 30% 7___
- 30% or more 10___

D. Roofing Material

- Class A Fire Rated 1___
- Class B Fire Rated 5___
- Class C Fire Rated 10___
- Nonrated 20___

E. Fire Protection—Water Source

- 500 GPM hydrant within 1,000 feet 1___
- Hydrant farther than 1,000 feet or draft site 2___
- Water source 20 min. or less, round trip 5___
- Water source farther than 20 min., and 45 min. or less, round trip 7___
- Water source farther than 45 min., round trip 10___

F. Existing Building Construction Materials

- Noncombustible siding/deck 1___
- Noncombustible siding/combustible deck 5___
- Combustible siding and deck 10___

G. Utilities (gas and/or electric)

- All underground utilities 1___
- One underground, one aboveground 3___
- All aboveground 5___

Total for Subdivision

- Moderate Hazard 40–59
- High Hazard 60–74
- Extreme Hazard 75+

B. NFPA 1141 Structure Assessment Rating Form

Table A.4.1.2 Example of Structure Assessment Rating Form

Rating Values by Areas Assessed	Overview of Surrounding Environment (4.2.1)	From Chimney to Eaves (4.2.2)	From Top of the Exterior Wall to Foundation (4.2.3)	From Foundation to Immediate Landscaped Area (4.2.4)	From Immediate Landscaped Area to Extent of Structure Ignition Zone (4.2.5)
Topographical Features					
(1) Topographical features that adversely affect wildland fire behavior (4.2.1)	0–5				
(2) Areas with history of high fire occurrence (4.3.4)	0–5				
(3) Areas exposed to unusually severe fire weather and strong, dry winds (4.2.1.3)	0–5				
(4) Local weather conditions and prevailing winds (4.2.1.2)	0–5				
(5) Separation of structure on adjacent property that can contribute to fire spread/behavior (4.2.1.3)	0–5			0–5	0–5
Vegetation — Characteristics of predominant vegetation					
(1) Light (e.g., grasses, forbs, sawgrasses, and tundra) NFDRS Fuel Models A, C, L, N, S, and T	5			15	5
(2) Medium (e.g., light brush and small trees) NFDRS Fuel Models D, E, F, H, P, Q, and U	10			20	5
(3) Heavy (e.g., dense brush, timber, and hardwoods) NFDRS Fuel Models B, G, and O	15			25	15
(4) Slash (e.g., timber harvesting residue) NFDRS Fuel Models J, K, and L	15			30	20
Topography (4.2.1.1, 4.2.4, 4.2.5)					
(1) Slope 5–9%				1	1
(2) Slope 10–20%				4	2
(3) Slope 21–30%				7	3
(4) Slope 31–40%				10	6
(5) Slope >41%				15	10
Building Setback, relative to slopes of 30% or more (4.2.1.5, 5.1.3.2)					
(1) ≥30 ft (9.14 m) to slope	1				
(2) <30 ft (9.14 m) to slope	5				
Roofing Materials and Assembly, nonrated (4.2.2.1, 4.2.2.3)		50*			
Ventilation Soffits, without metal mesh or screening (4.2.3.4)		20			
Gutters, combustible (4.2.2.4, 4.2.2.5)		5			

Table A.4.1.2 *Continued*

Rating Values by Areas Assessed	Overview of Surrounding Environment (4.2.1)	From Chimney to Eaves (4.2.2)	From Top of the Exterior Wall to Foundation (4.2.3)	From Foundation to Immediate Landscaped Area (4.2.4)	From Immediate Landscaped Area to Extent of Structure Ignition Zone (4.2.5)
Building Construction (predominant)† (4.2.4)					
(1) Noncombustible/fire-resistive/ignition-resistant siding and deck			Low		
(2) Noncombustible/fire-resistive/ignition-resistant siding and combustible deck			Medium		
(3) Combustible siding and deck			High		
Fences and Attachments, combustible (4.2.4.3)				15	
Placement of Gas and Electric Utilities					
(1) One underground, one aboveground	3				
(2) Both aboveground	5				
Fuel Modification within the structure ignition zone (4.2.4, 4.2.5)					
(1) 71–100 ft (21–30 m) of vegetation treatment from the structure(s)					5
(2) 30–70 ft (9–21 m) of vegetation treatment from the structure(s)				7	
(3) <30 ft (9 m) of vegetation treatment from the structure(s)				15	
No Fixed Fire Protection (NFPA 13, 13R, 13D sprinkler system)			5		
TOTALS (if numerical ranking is desired)					
Hazard Rating Scale (Compare with above totals)					
Slight Structure Ignition Hazards from Wildland Fire	0–14	0–14	0–14	0–14	0–14
Moderate Structure Ignition Hazards from Wildland Fire	15–29	15–29	15–29	15–29	15–29
Significant Structure Ignition Hazards from Wildland Fire	30–49	30–49	30–49	30–49	30–49
Severe Structure Ignition Hazards from Wildland Fire	50+	50+	50+	50+	50+

*Nonrated and combustible roof assemblies are predominantly structural exposures and severely increase the ignition hazard from wildland fire.

†The table provides both numerical and value rankings (low, medium, high). The user is urged to assign the value ranking of low, medium, or high based on the other ignition factors prevalent at the assessment site. For example, a deck made of combustible materials might rank low if it is small in size and the rest of the site is in a low fuel loading area that will not promote a large amount of firebrands. That same deck might rate high if it is in an area of high fuel loading that will promote numerous firebrands. Numeric values can be substituted as a local option.

HOME IGNITION ZONE ASSESSMENT MITIGATION GUIDE

Date of Assessment:________________ Property address: ____________ Resident Name: ______________ Property Owner:____________

	ASSESSMENT ITEMS	MITIGATION RECOMMENDATIONS
1.	**OVERVIEW OF SURROUNDINGS:**	
	How is the structure positioned in relationship to severe fire behavior?	
	Type of construction:	
2.	**CHIMNEY TO EAVES:**	
	Inspect the roof – noncombustible? Shingles missing? Shingles flat with no gaps?	
	Gutters – present? Noncombustible?	
	Litter on roof, in gutters, and crevices:	

3.	**Eaves to Foundation:**	
	Attic, eave, soffit vents, and crawl spaces:	
	Inspect windows and screens – metal screens? Multi-paned windows? Picture windows facing vegetation?	
	Walls and attachments: noncombustible? Will they collect litter?	
	Decks (combustible materials?)	
	Fences:	
	Flammable material next to or under the structure:	
	Combustible materials near or on the structure where walls meet roof or decking surfaces:	
	Crawl space, attic vents, soffits:	
	Nooks and crannies and other small spaces : All appear to be in excellent condition and protected.	

4.	**FOUNDATION TO IMMEDIATE LANDSCAPED AREA:**	
	Landscaped (*Managed*) vegetation – separation distances, maintenance, plant selection; Firewise landscaping zones?	
	Propane Tanks:	
	Vehicle and RV use and parking, including lawn mowers, etc.:	
5.	**IMMEDIATE LANDSCAPED AREA EXTENT OF THE HOME IGNITION ZONE:**	
	Inspect vegetation clearance and crown separation:	

D. IBHS Wildfire Home and Property Checklist

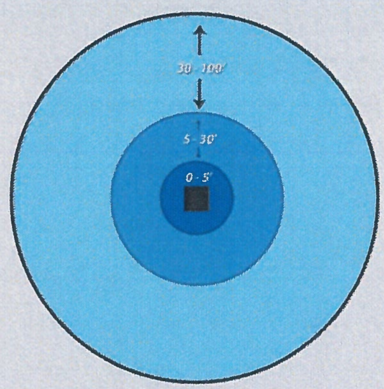
Wildfire Home and Property Checklist

Use the following checklist to help determine what parts of a home and the surrounding property may be most vulnerable during a wildfire. Reduce those risks with the guidance provided in the following pages.

Insurance Institute for Business & Home Safety

PROPERTY

- ❑ Slope / Terrain
- ❑ Location of home on parcel
- ❑ Defensible space
  - ❑ 0-5'
  - ❑ 5-30'
  - ❑ 30-100'



Know Your Space

Create defensible space to keep wildfire from getting too close to your property.

HOME

- ❑ Roof
  - ❑ Fire rating of covering
  - ❑ Shape
  - ❑ Edges
  - ❑ Skylights
- ❑ Exterior Wall
  - ❑ Type
  - ❑ Foundation type / clearance
  - ❑ Eave type (under-eave construction)
  - ❑ Windows / Doors

- ❑ Vents and Other Openings
  - ❑ Face perpendicular to wind
  - ❑ Face parallel to wind
  - ❑ Ridge vents
  - ❑ Mesh screens
- ❑ Attachments
  - ❑ Deck
  - ❑ Enclosure
  - ❑ Garage
  - ❑ Fence

Assessment:

WHAT TO KNOW TO BETTER PROTECT YOUR HOME FROM WILDFIRE

SLOPE

The slope of the land around your home is a major consideration in assessing wildfire risk. Wildfires burn up a slope faster and more intensely than along flat ground. A steeper slope will result in a faster moving fire, with longer flame lengths.

Homes located mid- or top of a slope (without set back) are generally more vulnerable because of increased flame length and intensity of a fire moving up the slope. Depending on the location of your home, defensible space may need to be increased.

ZONE 1

0-5 ft. around the perimeter

The objective of this zone is to reduce the chance of wind-blown embers from a nearby fire landing near the home, igniting combustible debris or materials and exposing the home to flames. This zone is closest to the house, so it requires the most careful selection and management of vegetation and other materials.

ZONE 2

5 ft.–30 ft. around the perimeter (or to the property line)

The objective of this zone is to create and maintain a landscape that, if ignited, will not readily transmit fire to the home. Trees and shrubs in this zone should be in well spaced groupings and well maintained. Ladder fuels (i.e., shorter vegetation or shrubs under taller trees) should be avoided to prevent the fire from climbing into the crown or upper portions of trees. If these groupings were to be ignited by wind-blown embers, the resulting fire should not be able to threaten the home by a radiant heat exposure or by flames being able to touch the exterior surfaces of your home.

ZONE 3

30 ft. - 100 ft. (or to the property line)

The objective of vegetation management in this zone is to reduce the energy and speed of the wildfire. Tree and brush spacing should force the fire in the tops of the tree, brush or shrub crowns to drop to the ground. Flame length should decrease.

Assessment:

WHAT TO KNOW TO BETTER PROTECT YOUR HOME FROM WILDFIRE

TREE BRANCHES OVERHANGING OR WITHIN 10 FT. OF THE ROOF

Branches overhanging your roof will result in more debris accumulation on your roof, in your gutters and near your home.

OTHER COMBUSTIBLE ITEMS/STRUCTURES

A fire in close proximity to a propane tank can result in gas releasing at the pressure relief valve, potentially resulting in a column of flame. Flames impinging on the upper surface of the tank can result in an explosion, particularly when the fuel level is low.

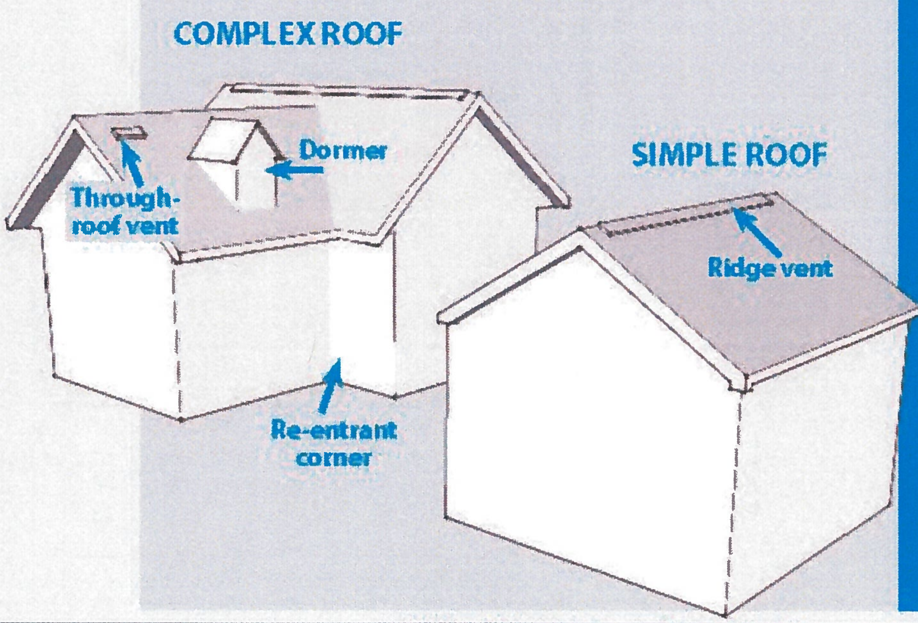
If ignited, other combustible items on your property, such as a tool storage shed or gazebo, could expose your home to radiant heat and flames.

ROOF SLOPE

Roof slope is important because it will affect the amount of debris that accumulates and will also influence the radiant exposure to the roof if nearby vegetation or buildings ignite.

ROOF MATERIAL

Your roof is a large, relatively horizontal surface where debris from trees and other vegetation can accumulate. When a wildfire is threatening your home, wind-blown embers can also land on your roof and ignite this debris, potentially putting your home at risk. Your roof must be able to resist the burning embers from the wildfire and flames from ignited debris. Roof coverings are rated as Class A, B, or C. A Class A fire-rated roof covering offers the best protection.



Assessment:

WHAT TO KNOW TO BETTER PROTECT YOUR HOME FROM WILDFIRE

ROOF DESIGN

Even with a Class A roof, locations where the roof covering meets another material can be vulnerable. Debris can accumulate at these locations, and so can wind-blown embers. It is important to inspect these locations as they are potential "weak links" on your roof (for example, wood shingle siding on a dormer next to a Class A roof covering), or areas where the Class A roof can be by-passed (for example, non-bird stopped tiles at the roof edge).

SKYLIGHTS

During a wildfire, skylights could be an entry point for wind-blown embers and flames if the glass or Plexiglas opening were to fail. Operable skylights would also be vulnerable if left open when a wildfire threatens. Debris accumulation on top of and around skylights will be greater on flat or lower-sloped roofs. Dome-type skylights use an acrylic glass product and flat-type skylights use tempered or other specialized glass. Performance differences between acrylic and glass would make the flat-type skylights less vulnerable to wildfire exposures. All skylights incorporate metal flashing at the base, where it integrates with the roof.

VENTS

Most homes have enclosed spaces that are vented, including attics and crawl spaces. Other openings in an exterior wall include those for dryer vents and vents to supply make-up air for rooms where gas appliances are operating (e.g., furnace and/or water heater). Wind-blown embers that enter the attic or other enclosed spaces can ignite combustible materials that have either accumulated there or have been stored there.

Vents on vertical walls or surfaces have been shown to be vulnerable to the entry of embers. For the attic, these vents would include gable end vents, through-roof vents with a dormer face and under-eave vents used in open-eave construction. Crawl space vents (also called foundation vents), dryer vents and vents to supply make-up air would also be vulnerable to the entry of embers.

Some attic and foundation vents that have been specifically designed to resist the entry of embers and flames are commercially available. Your local fire or building department would know if any of these vents have been approved for use in your area.

Consider using closure devices. There are commercially available options or you can make your own and store in a place where they can be easily retrieved and installed when wildfire threatens. The commercial devices should be deactivated, or home-made covers removed, after the wildfire passes. Some gable end and crawl space vents have been designed to resist the entry of embers and flames - check with your local fire or building official to find out if any have been approved for use in your area.

EXTERIOR WALL - FOUNDATION

There are three basic types of foundations: concrete slab-on-grade, raised floor (i.e., one having a crawl space) and pier (or "post") and beam (unless a perimeter skirting has been installed, this one will be open underneath). An "open underneath" foundation will be vulnerable if combustible materials or vegetation and debris has accumulated or has been stored there. Raised floor and slab-on-grade foundations can be vulnerable if the distance from

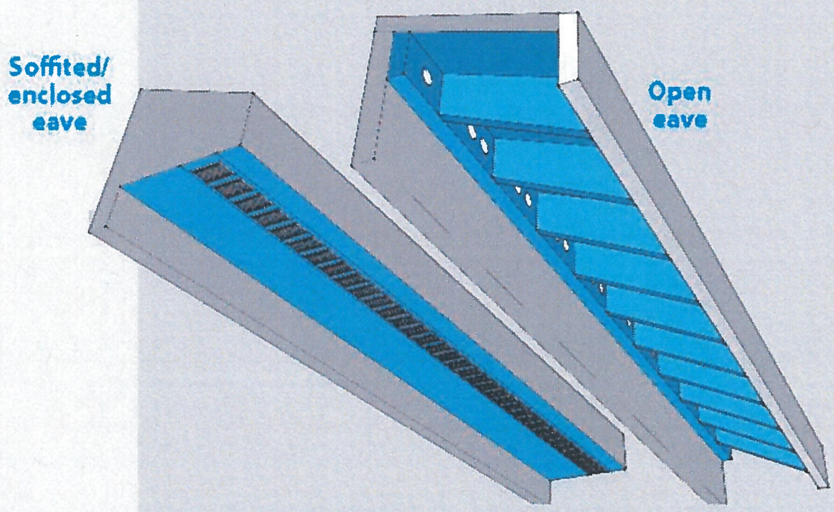
Assessment:

WHAT TO KNOW TO BETTER PROTECT YOUR HOME FROM WILDFIRE

the ground to the siding is much less than 6 in., or, in the case of a crawl space, ember entry occurs through a foundation vent. Combustible siding will be more vulnerable if the ground-to-siding clearance is less than 6-in. if embers can accumulate at the base of the wall. The use of combustible mulch and woody vegetation will make this area even more susceptible to ignition from wind-blown embers. Untreated wood shingle and vinyl siding are relatively more vulnerable to flame contact and radiant heat exposures that would result from an ember ignition of near-home debris or other combustible items.

UNDER-EAVE CONSTRUCTION

Under-eave construction consists of either "open-eave framing" or is enclosed with a "soffit" material (also called "boxing-in"). Vent openings are often found in this area. Vents in open-eave construction can be vulnerable to the entry of embers, and are more vulnerable to ember entry than vents located in a soffited eave. Open-eave construction can also trap heat if subjected to flames, resulting in more rapid ignition of combustible construction materials and lateral flame spread. Flames reaching the under-eave area would be more likely if combustible vegetation and mulch were included in the 0-5 ft "near-home" zone and similarly, if combustible siding were used.



EXTERIOR WALL - MATERIAL

Siding is vulnerable when it ignites and flames or embers get into the cavity behind it or if the flames spread vertically, impinging on windows and the eave. With inadequate ground-to-siding clearance, accumulated embers can ignite combustible siding directly. Ignition is more likely if combustible siding is exposed to a direct flame contact or extended radiant heat exposure. The chance of direct flame contact is greater if you haven't created

Assessment:

WHAT TO KNOW TO BETTER PROTECT YOUR HOME FROM WILDFIRE

and maintained a 0-5 ft. noncombustible zone around your home. An extended radiant heat exposure is possible if nearby combustible materials (for example, a firewood pile) or a nearby building ignite. Untreated wood shingle and vinyl siding are relatively more vulnerable to flame contact and radiant heat exposures.

RE-ENTRANT (INTERIOR) CORNER

An interior corner that is constructed using combustible siding and trim will be more vulnerable to flames. If ignited, flames will spread vertically more quickly.

WALL VENTS AND OPENINGS

Vents located on a vertical wall, including crawl space vents (also called foundation vents), gable end vents, and other openings such as a dryer vent, will be very vulnerable to the entry of wind-blown embers.

WINDOWS

An open window is the most vulnerable window when a wildfire threatens - embers can easily enter the home. Closed windows are vulnerable to radiant heat and direct flame contact exposures. If the frame ignites or melts, the fire may burn into the stud cavity and into the living space of the home. If glass breaks, embers and flame can easily enter the home. Of these, the glass is the most vulnerable component.

GARAGE (ATTACHED OR DETACHED)

Most people store combustible materials in their garage. Garage (vehicle access) doors, particularly on older garages, can have small gaps at the top, sides and bottom that can allow embers to enter. These embers can ignite combustible materials stored in the garage.

DECK

Your decks is a vulnerable part of your home when it ignites. A burning deck will expose the building to radiant heat and flames, potentially igniting combustible siding and breaking glass in windows and doors. The materials used to build the deck, combustible materials you store under your deck, vegetation around it and the location of your deck relative to the slope around your house all contribute to how vulnerable your deck will be. Debris that accumulates between deck boards and at deck-to-wall intersections can be ignited by embers. Rotted wood deck boards and structural support members are more easily ignited when they are dry.

Checklist:

MITIGATION ACTIONS OR RETROFIT OPTIONS

- $ < $500
- $$ $500 - $1,000
- $$$ $1,000 - $5,000
- $$$$ >$5,000

SLOPE

Is your home located in the middle of a steep slope or at the top of a slope with minimal setback?

- ❑ If yes, increase vegetation management in the 5 ft. to 100 ft. zones. Consider installing a noncombustible wall within 15-20 ft. of the down slope side of your home, particularly if you have a deck overhanging the slope.

YOUR DEFENSIBLE SPACE IS COMPRISED OF THESE THREE ZONES. THE SELECTION AND MAINTENANCE OF VEGETATION AND OTHER COMBUSTIBLE ITEMS IN THESE ZONES WILL DETERMINE HOW ADEQUATE YOUR DEFENSIBLE SPACE IS.

ZONE 1

0-5 ft. around the perimeter of the home

- ❑ Install hard surfaces in this zone, such as a concrete walkway, or use noncombustible mulch products, such as rock. Keep the lawn well irrigated and use low-growing herbaceous (non-woody) plants. Shrubs and trees are not recommended in this zone. Remove dead vegetation and implement a maintenance strategy to keep the area clear of dead plant materials. $-$$

ZONE 2

5 ft.–30 ft. around the perimeter (or to the property line)

- ❑ Create islands or groupings of vegetation to form a discontinuous path of vegetation to make it difficult for the fire to burn directly to your home. Remove dead plant material and tree branches. Remove lower tree branches and shrubs positioned under the tree line so that a surface fire cannot reach the tree crown. Trees located within this zone should be maintained with a minimum horizontal spacing of 10 ft. between crowns, with the distance increasing with slope. Prune limbs and branches to a height of up to 15 ft. For shorter trees, pruning should not exceed one-third of the tree height. Relocate propane tanks larger than 125 gallons (water capacity) at least 30 ft. from your house. Create 10 ft. of Zone 1 defensible space around the tank. Consider surrounding three sides with a noncombustible wall to help protect it. Free - $$$

ZONE 3

30 ft. - 100 ft. (or to the property line)

- ❑ Trees located in this zone should be maintained with a minimum horizontal spacing of 10 ft. between crowns, with this distance increasing with slope. Ladder fuels under taller trees should be eliminated. Separation between groupings of shrubs and bushes should be created and maintained. Remove dead plant material from all vegetation. Vegetation management beyond 100 ft. should be considered if the home is located on a steep slope. Free - $$$

Does your home have a tool shed, detached garage, play set or other structures in the yard?

- ❑ Create defensible space around secondary buildings or relocate them at least 30 ft. from your home. Consider a noncombustible material for a trellis. Carefully maintain vegetation used on trellis-type structures, pruning regularly to remove dead vegetation. Combustible materials used for play sets are typically larger dimensions (and therefore more difficult to ignite). Combustible wood/bark or rubber mulch that are more commonly used as surfacing materials around play sets are easily ignited by embers. Play sets with combustible mulch surfacing materials should be relocated at least 30 ft. from your home. Free - $$

ROOF COVERING

Do you have a Class A fire-rated roof?

- ❑ If not, choose a product rated Class A when it's time to re-roof. Non-rated products include untreated wood shakes or shingles. Other roof coverings may carry a Class B or C fire rating. A Class A fire-rated roofing product offers the best protection. $$$$

Checklist:

MITIGATION ACTIONS OR RETROFIT OPTIONS

$ <$500
$$ $500 - $1,000
$$$ $1,000 - $5,000
$$$$ >$5,000

ROOF EDGE(S)

Are your gutters full of debris?

- ❑ If yes and you have a *SIMPLE ROOF DESIGN*, clean out gutters and install a drip edge at the roof edge to protect any exposed roof sheathing or fascia. Free - $$
- ❑ If yes and you have a *COMPLEX ROOF*, clean out gutters and install a drip edge at the roof edge to protect any exposed roof sheathing or fascia. Remove any debris that has accumulated at roof-to-wall intersections, for example, near a dormer or a chimney. For added protection, consider replacing combustible siding at any "intersection" location with a noncombustible or ignition resistant siding product. Metal step flashing extending up from the roof a minimum of 6 in. can be installed at the base of combustible siding in lieu of replacing it (integrate with siding to avoid moisture-related degradation problems). If necessary, consult a roofing professional to get help with this. If windows are present, replace with ones that have dual / multi-pane, tempered glass. Free - $$$

Do gaps or openings exist between the roof covering and the roof deck? These gaps are common with clay barrel-style roofs and some types of metal and cement (flat) tile roof coverings. The gaps can occur at the roof eave or ridge.

- ❑ If yes, fill the space with either a commercially available "bird stop" material or plug with a mortar mix (the material used between layers of bricks). This material will minimize the accumulation of debris than can accumulate between the roof covering and the roof sheathing, and will also limit the intrusion of embers when a wildfire threatens your home. $-$$

VENTS ON YOUR ROOF

Are the attic vents located on your roof covered with screening that is free of debris?

- ❑ If there is no screening, install 1/8 in. metal mesh screening. $-$$
- ❑ If you have a turbine vent, enter the attic and inspect the location where the vent attaches to the roof. Attach 1/8 in. screening to the roof sheathing if none is present. $-$$
- ❑ If you have dormer-face vents, replace them with a low-profile vent. $-$$
- ❑ If you have ridge vents, they should be rated for high-wind / rain exposure, and specifically should be a Florida Building Code High Velocity Hurricane Zone approved ridge vent, regardless of where you are in the country. $-$$
- ❑ Consult your local fire or building department to find out if any vents designed to resist the entry of embers and flames have been approved for use in your area. Free

SKYLIGHTS

Are skylights installed on a flat or low-sloped roof?

- ❑ Remove accumulated debris next to and on the skylight. Free

Do you have a dome-type skylight?

- ❑ If yes, consider replacing it with a flat, tempered glass skylight. If the skylight is installed on a steep roof and if vegetation is at the same level, remove and prune vegetation, clear away debris, and trim overhanging limbs. Free - $$
- ❑ Keep operable skylights closed when a wildfire threatens. Free

FOUNDATIONS

Do you have a post-and-beam style foundation?

- ❑ If yes, enclose it with a noncombustible material–this process is sometimes called "skirting". Ventilate enclosed space according to your building code requirements. All foundation vents should have 1/8 in. corrosion-resistant metal screening that is in good condition. $-$$$
- ❑ Remove combustible materials stored in the crawl space, or from under the building if you have a non-skirted post-and-beam foundation. Free

Checklist:

MITIGATION ACTIONS OR RETROFIT OPTIONS

$ < $500
$$ $500 - $1,000
$$$ $1,000 - $5,000
$$$$ >$5,000

VENTS ON THE EXTERIOR WALLS

Do you have foundation vents that are closeable?

- ☐ Some foundation vents are closeable - these vents should be closed when a wildfire threatens, but should be opened after the wildfire has passed. Some foundation vents have been designed to resist the entry of embers and flames - check with your local fire or building official to find out if any have been approved for use in your area. Remove combustible materials stored in the crawl space. Free

Do you have vent covers for foundation and/or gable end vents?

- ☐ If not, consider using closure devices. There are commercially available options or you can make your own and store in a place where they can be easily retrieved and installed when wildfire threatens. The commercial devices should be deactivated, or home-made covers removed, after the wildfire passes. Some gable end and crawl space vents have been designed to resist the entry of embers and flames–check with your local fire or building official to find out if any have been approved for use in your area. $$

Do you have other vent openings on the wall?

- ☐ Dryer vents and wall-mounted make-up air openings for for furnaces should be screened with 1/8 in. corrosion resistant metal mesh. Consider installing a louver-type dryer vent that is closed unless the dryer is running. $

SIDING

Do you have combustible siding?

- ☐ If yes, create a 0-5 ft. defensible space zone next your home. Remove any accumulated debris as necessary. If siding extends to grade, consult with contractor to determine if your foundation would allow some siding at the base of the wall to be removed to obtain the 6 in. clearance. Moisture-related degradation and insect damage may be present in some siding products that have been installed such that it extends to grade. Free - $$
- ☐ Examine your siding for locations where embers could accumulate or lodge. Apply caulk at trim-to-siding locations where it is missing or has failed ($). $ - $$
- ☐ If you plan to re-side your house, use a noncombustible or ignition resistant material for the siding and corner trim. If you haven't already done so, create a 0-5 ft. noncombustible zone in this area. $$$$

EAVES

Do you have open-eave framing?

- ☐ If yes, consider converting open-eave framing to a boxed-in or soffited-eave design. Venting in the soffit material (and between the soffit and attic space) must be maintained. If you haven't already done so, create a 0-5 ft. noncombustible zone next your home. $$$

Do you have vents in the eaves?

- ☐ If yes, all vents should be covered with 1/8 in. mesh corrosion-resistant metal screening. If an open-eave construction is maintained: Closure devices for vents located in the blocking of open-eave framing are commercially available. Consider purchasing these or making them from 1/4-in. plywood or thin sheet metal. Install these devices when a wildfire threatens and remove or open them after the threat has passed. Under-eave vents have been designed to resist the entry of embers and flames–check with your local fire or building official to find out if any have been approved for use in your area. $-$$$

Checklist:

MITIGATION ACTIONS OR RETROFIT OPTIONS

$ <$500
$$ $500 - $1,000
$$$ $1,000 - $5,000
$$$$ >$5,000

WINDOWS

Do you have single-pane windows?

- ❑ If yes, replace single-pane windows with dual or multi- pane windows, preferably ones with tempered glass. $$$ - $$$$
- ❑ Install window screening to improve performance against radiant heat exposures and to minimize the size and number of embers that could enter the home. Both plastic-clad fiberglass and metal screening will reduce radiant exposure to the glass and protect against ember entry but neither will protect against flames. The fiberglass screen will fail if exposed to flames, thereby allowing embers to enter if the window glass has also failed. If you haven't already done so, create a 0-5 ft. noncombustible zone near your home. $-$$

GARAGE (DETACHED OR ATTACHED)

Do you have a garage door?

- ❑ If yes, weather seal the perimeter of garage doors. $
- ❑ If you do not have a garage door, consider installing one to help protect combustible materials stored there. $$

DECK

Do you have a deck?

- ❑ If your deck overhangs a steep slope, be sure your defensible space is sufficient to minimize flames spreading up the hill and reduce flame length to minimize the chance for a flame contact exposure to the underside of the deck. Consider building a noncombustible wall across the slope approximately 15–20 feet from the edge of the deck. Free - $$$
- ❑ Do not store combustible materials under your deck. If you have no other option, installing a noncombustible siding product around the deck perimeter may be an option. Be sure the enclosed space is adequately ventilated to minimize the chance of water-related damage (i.e., fungal decay, fastener corrosion, etc.). Free - $$$
- ❑ Most deck boards are combustible, including wood, plastic and wood-plastic composites. Solid surface decks, such as those made from lightweight concrete, are usually noncombustible, but are also more expensive. If you live in a wildfire-prone area anywhere in the country, when it's time to replace deck boards, choose a product that complies with the requirements of the California Building Code, as provided in the Office of the State Fire Marshal Wildland Urban Interface (WUI) Handbook (http://osfm.fire.ca.gov/strucfireengineer/strucfireengineer_bml.php). $$$
- ❑ Regularly clean out debris from between deck board joints and other areas where debris has accumulated. Check the condition of wood deck boards and structural support members–replace or repair rotted members. Free
- ❑ When a wildfire threatens, move combustible deck furniture and cushions inside or move as far away from the house as possible. Treat other combustible items, such as a broom, as your furniture and move them inside or far away from the house. Any LP tank for a grill should be moved off the deck and away from the home. Free

FENCE

Do you have a fence?

- ❑ Replace any combustible fencing that attaches directly to your home with a noncombustible section that is at least 5 ft. long. A chain link gate or fence, a wood frame fence with metal mesh infill, or other noncombustible material can be used. If metal wire is used, do not allow climbing vegetation to grow on the fence–this would defeat the purpose of the noncombustible material. $-$$

END

MEDFORD PLANNING

MEMORANDUM

To: Mayor and City Council *for October 10, 2019 study session*

From: Carla Angeli Paladino, Principal Planner & Kyle Kearns, AICP, Planner II

Date: October 3, 2019

Subject: Wildfire Risk Reduction Program (WRRP) including Defensible Landscaping Space (GF-19-006)

DIRECTION SOUGHT

Staff is asking Council to acknowledge the Planning Department's work plan to draft and bring forward code amendments related to development in the wildfire high risk areas.

PRESENTATION OUTLINE

- Presentation overview and information – Carla Paladino
- Discussion and Direction – Mayor and City Council

SUMMARY

The Long Range Planning Division's work plan for the biennium includes researching and drafting code amendments that specifically address how to better prepare for and regulate development in the wildfire high risk areas. The Division, in coordination with the Fire Department, proposes to address topics such as landscaping, subdivision access points, fuel breaks, and materials for fencing and accessory structures as the first phase of the project. The second phase would include evaluating limitations on specific land uses in these areas. The information below was presented and discussed with the Planning Commission at their August 26, 2019 study session. The Planning Commission agreed with staff working on the first phase of the project. Code language has not yet been drafted.

BACKGROUND

A Medford WUI fire, the Deer Ridge Fire, in 2009.

Medford, like much of the American West, has become hyperaware of the impacts that wildfires can have on cities and the residents who call these places home. The increased awareness is in large part due to the increased severity of wildfires within the wildland-urban interface (WUI; pronounced WOO-EE). The WUI, as defined by the American Planning Association (APA), "...refers to any developed area where conditions affecting the combustibility of natural and cultivated vegetation (wildland fuels) and structures or infrastructure (built fuels) allows for the ignition and spread of fire through these combined fuels." [1]

An analysis of the areas considered to be in the WUI was performed as a part of the City's Natural Hazards Mitigation Plan (2017). This analysis was driven by Oregon Senate Bill 360 which determined the areas most susceptible to wildfire damages in the City of Medford (see map below on page 4). The following are examples of the types of fires being referenced when discussing a wildland-urban interface fire.

- 2018 Camp Fire, which spread through the town of Paradise, CA (18,804 destroyed structures, 86 deaths, and was 153,336 acres in size)[2]
- 2018 CARR Fire which went down the hillsides into the City of Redding, CA (responsible for 1,604 destroyed structures, 8 deaths and 229,000 acres in size)[1]
- 2017 Tubbs Fire that burned portions of Napa and Sonoma Counties, impacting the City of Santa Rosa heavily (5,636 destroyed structures, 22 deaths and 36,807 acres)[2]
- 2014 Boles Fire, Weed, CA (150 homes destroyed, 516 acres)
- 2010 Oak Knoll Fire, Ashland, OR (11 homes destroyed in 45 minutes, one death)

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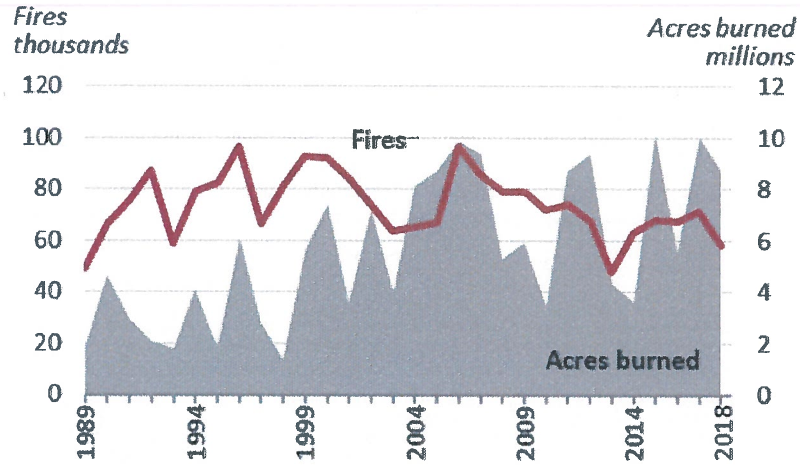
[1] Mowery, Molly, et al. "Planning the Wildland-Urban Interface." American Planning Association, Planning Advisory Service, Apr. 2019, www.planning.org/publications/report/9174069/.

[2] California Department of Forestry & Fire Protection, Cal Fire. "Fire.ca.gov." Fire.ca.gov, Cal Fire, 8 Aug. 2019. www.fire.ca.gov/media/5511/top20_destruction.pdf.

Other fires locally, like the Taylor Creek Fire (2018), Klondike Fire (2018) and the Chetco Bar Fire (2017), are examples of the damage, both from fire and smoke, which wildfires can have on the Rogue Valley. Examples of fires provide reminders of the local health and economic impacts that they cause. Furthermore, in the US, wildfires burn 7 million acres annually (as of 2017), in 2018 this number jumped to 8.8 million.[3]

Figure 1. Annual Wildfires and Acres Burned (1988-2017)



Source: NIFC.
Note: Data reflect wildland fires and acres burned nationwide, including wildland fires on federal and nonfederal lands.

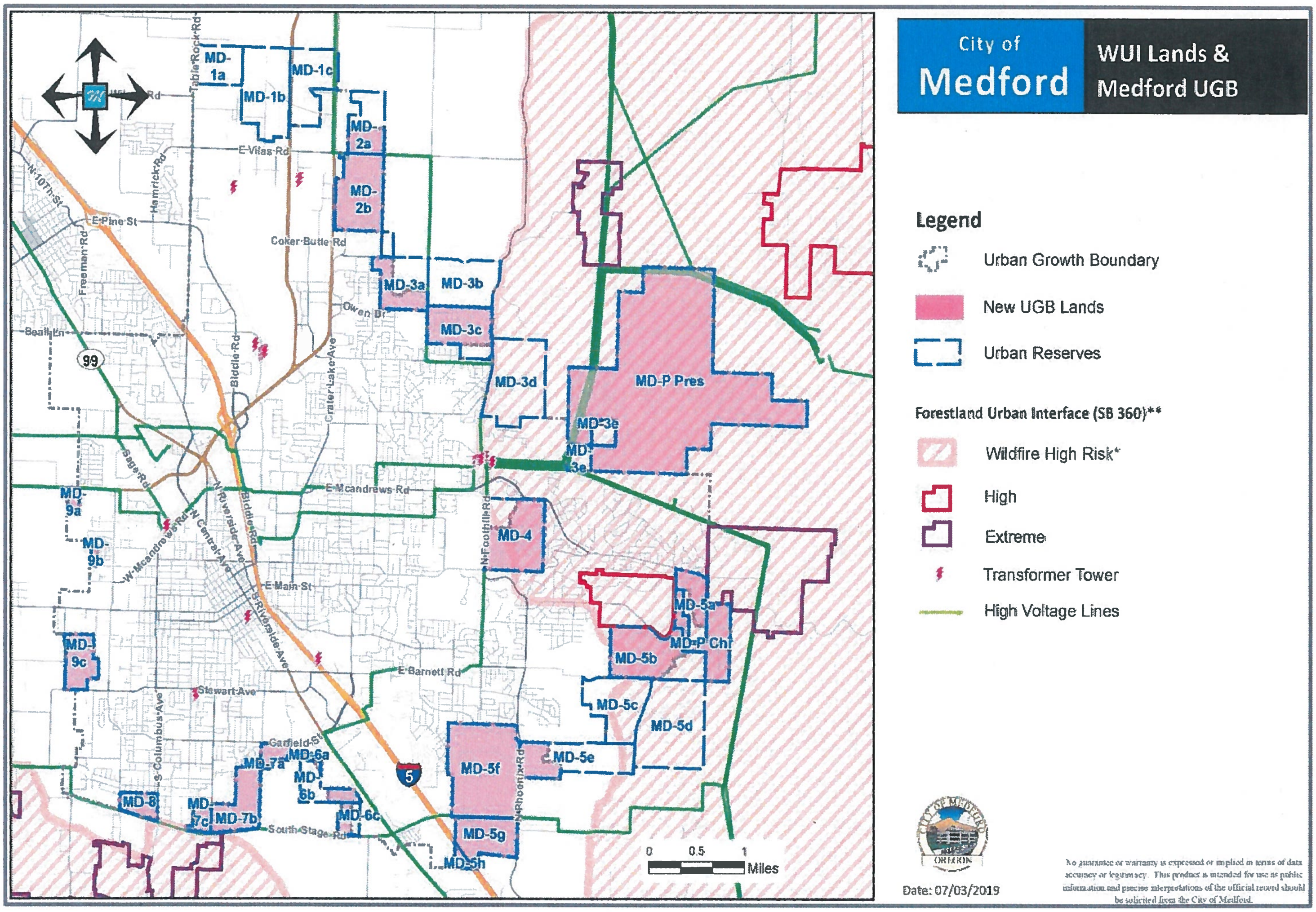
It is the intent of this memorandum to provide educational materials to the City Council in regards to wildfires and the WUI, inform of actions being taken by the Medford Fire-Rescue, Building and Planning Departments as well as to propose next steps on how the Medford Land Development Code (MLDC) might be amended to best address the wildland-urban interface.

Over the course of the past few decades, development that has encroached into the WUI has increased significantly as has the risk from wildfire to homes. "Between 1990 and 2010, new houses in the WUI increased from 30.8 to 43.4 million (41 percent increase) and land area of the WUI increased from 581,000 to 770,000 square kilometers [or 224,325 to 297,299 square miles] (33% growth), making it the fastest-growing land-use type in the conterminous United States."[4] Additionally, in the State of Oregon, 9% of households are at High or Extreme Risk from wildfire according to Verisk Analytics, an insurance research firm. Of the 33,568

[3] Hoover, Katie, and Laura Hanson. "Wildfire Statistics ." Fas.org, Congressional Research Service, 31 May 2019, fas.org/sgp/crs/misc/IF10244.pdf.
[4] Radeloff, Volker C., et al. "Rapid Growth of the US Wildland-Urban Interface Raises Wildfire Risk." PNAS, National Academy of Sciences, 27 Mar. 2018, www.pnas.org/content/115/13/3314.

residentially zoned addresses in Medford, 1,985 (6%) are at High or Extreme risk of wildfire. It is expected that this number will increase over time, as trends locally are indicating.

From 2010 to 2017 there has been an increase in Medford's structures in the wildfire hazard area from 1,098 to 2,187, respectively (nearly a 50 percent increase); in 2017 this was represented by a total improvement value of $314,524,970 (City of Medford Natural Hazards Mitigation Plan 2017, pg. 2.66). This increase in structures in the WUI should be expected to follow a similar pattern as many of the newly expanded UGB lands are within or adjacent to the WUI, this is in addition to already fast growing parts of Medford like the Southeast Plan area. Expanded UGB lands within the WUI include Prescott Park, Chrissy Park, MD-4, and MD-5; lands adjacent to the WUI include MD-3, MD-7 and MD-8. Additionally, 19% of the



*Note: This dataset represents High-Risk Wildfire Areas. Lands within this overlay are subject to Jackson County Planning & Development Requirements. The GIS data was created by Jackson County GIS.
**Note: Represents the 2010 State of Oregon Senate Bill 360 that was approved in 2011. The Forestland Urban Interface (SB360) was created by State and County representatives. The GIS data was created by Jackson County GIS.

City's Urban Growth Boundary is within the Wildfire High Risk Area (WHRA), while a bulk of the east, southeast and southwest portions of the City are adjacent to the WHRA. Lastly, looking further into the future, some of the City's Urban Reserves on the east side of the City are also within the Wildfire High Risk Area.

Although the path of a particular wildfire is hard to predict, the fact remains that there are particular areas of Medford that are more susceptible to damage from a wildfire. This provides the Planning Commission and City Council with the opportunity to be proactive in addressing some of the key factors that affect fire in the wildland-urban interface and the source of fuels available within the WUI.

FIRE & BUILDING DEPARTMENTS AMENDMENTS

On October 17, 2019, the City Council will consider changes to the Building Code requiring more ignition-resistant building materials/methods for new homes constructed in the wildfire high hazard area outlined on the above map. The changes include:

- Requiring roofing materials that meet a minimum Class B fire rating (e.g. asphalt, metal roofing, slate shingles, tile, clay and other similar materials; wood shingle or shake materials would be prohibited)
- Noncombustible rain gutters with provision to prevent the accumulation of leaves and debris in the gutter with leaf guards
- Attic and underfloor vents openings designed to prevent ember and flame intrusion
- Standards for non-combustible or ignition resistant materials used for exterior walls, decks, porches, etc.
- Dual glazing on windows and skylights

The Fire-Rescue department is preparing an update to the Emergency Operations Plan. An update to this plan will allow for the City of Medford to create evacuation plans for the City in the case of a wildfire and all other natural disasters. This will also come with better training for City staff to incorporate best practices when responding to a natural disaster.

Planning and Fire Department staff are working on submitting a grant application to the Community Planning Assistance for Wildfires (CPAW) organization due on October 18th. The organization works with communities to reduce wildfire risk through improved land use planning. Awarded communities receive free, customized technical consulting services and training for one year from CPAW's team of professionals. Other Oregon cities who have used CPAW's services include Ashland, Bend, and Sisters. There is no obligation to implement the identified recommendations if we are selected from the organization.

DEVELOPMENT CODE AMENDMENTS

In discussions with Fire Department staff, planning staff has identified several code amendments to pursue in order to try and reduce the loss of life and property in the event of a wildfire in the high risk areas. The proposed amendments include the following:

First Round

- Amend the Medford Land Development Code (MLDC) to prohibit the installation of highly flammable plants on the property (e.g. blackberries, juniper, sagebrush), prohibit organic combustible ground cover within five feet of the structure (e.g bark, wood chips) and require a mechanism for compliance (e.g. owner affidavit or landscape plan approved)
- Amend subdivision requirements to require two access points
- Amend ordinances to ensure sufficient roads are available to evacuate residents living in vulnerable areas during emergencies and maintain adequate road design that allows emergency responders to effectively get into these areas
- Amend MLDC to require fuel breaks on undeveloped land adjacent to developed land (largely achieved through weed/nuisance ordinances)
- Amend MLDC to require non-combustible or ignition-resistant building materials for fencing, decks, and accessory structures within 10 feet of house that are not regulated by Building and Fire codes;
- Setback of 20 feet or greater for wood piles during fire season

Second Round

- Limit land uses that concentrate vulnerable populations (e.g. retirement homes, hospitals, congregate care facilities) and high density residential
- Limit land uses that use combustible resources (e.g. gas stations, certain industrial uses, certain farm uses)

Outreach Activities

- Participate in outreach efforts to better inform the community, including industries directly affected by proposed changes
- Educate and promote the benefits of fire sprinkles in the wildfire risk area and elsewhere

NEXT STEPS

The City will be informed about the CPAW award by the end of November 2019. If the City is selected, Fire and Planning staff will work alongside CPAW in 2020. The amendment topics above will be researched and drafted and may be modified based on CPAW suggestions and information if applicable.

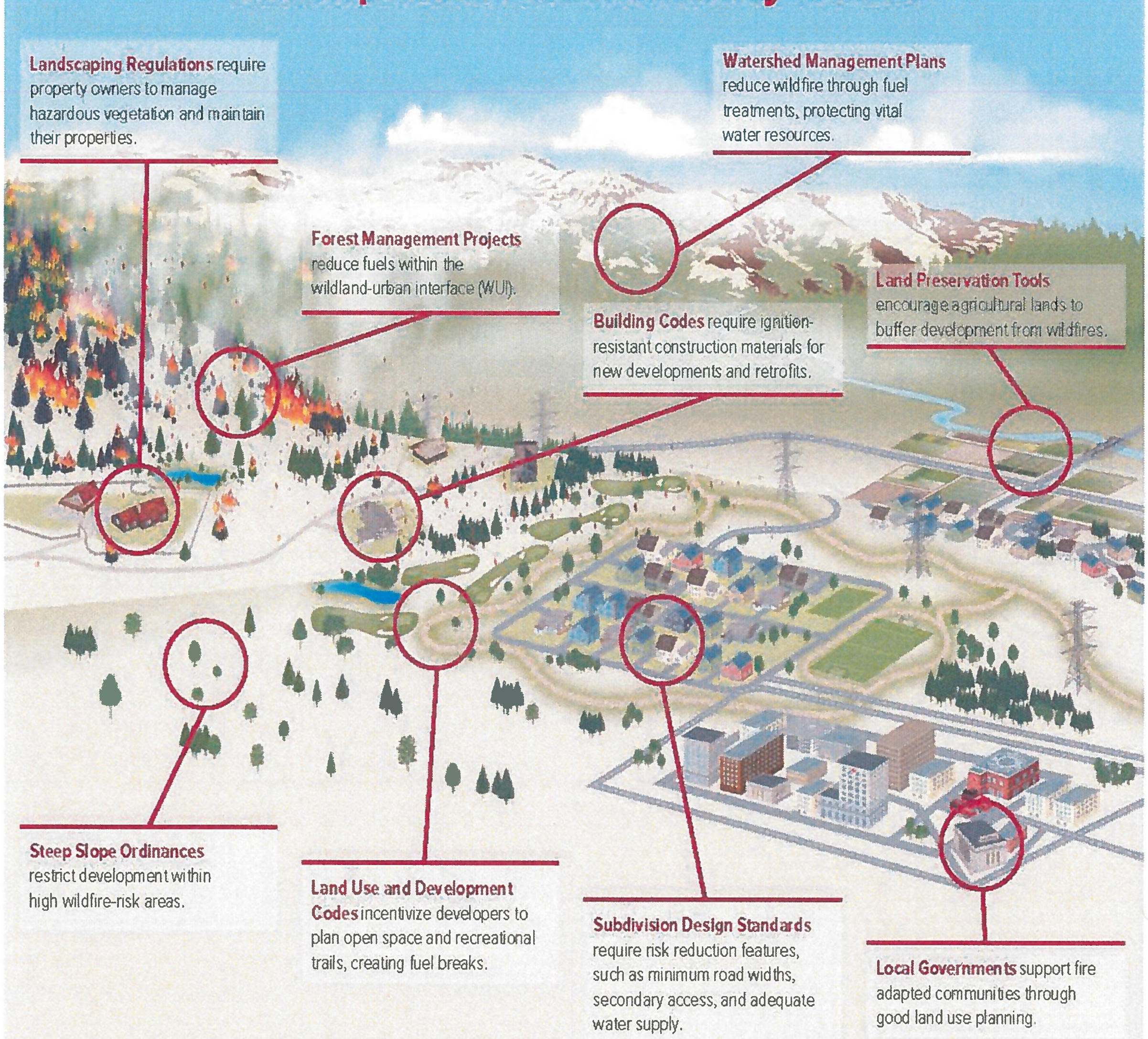
EXHIBIT

A Land Use Planning Reduced Wildfire Risk Handout – from CPAW, Wildfire Planning International, and Headwaters Economics

Land Use Planning Reduces Wildfire Risk

http://planningforwildfire.org/wp-content/uploads/2018/09/CPAW_Firetopia_2016.pdf

Examples of Community Tools



Good land use planning helps reduce wildfire costs, increases public safety, and improves forest health.

COMMUNITY PLANNING ASSISTANCE FOR WILDFIRE

Wildfire Planning International
Wildfire Planning International
Molly Mowery, President
www.wildfireplanning.com
molly@wildfireplanning.com | 303-358-9589

HEADWATERS ECONOMICS
Headwaters Economics
Kimiko Barrett, PhD
http://headwaterseconomics.org
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Helping communities better plan the wildland-urban interface. | www.planningforwildfire.org

Land Use Planning Reduces Wildfire Risk

http://planningforwildfire.org/wp-content/uploads/2018/09/CPAW_Firetopia_2016.pdf

A fire adapted community is prepared for the next wildfire.

The Community Planning Assistance for Wildfire (CPAW) program works with communities to reduce wildfire risks through improved land use planning, including:

- Providing communities with professional consulting services, including land use planners, foresters, and wildfire risk modelers.
- Linking planning policies with other efforts, such as Community Wildfire Protection Plans (CWPP), Multi-Hazard Mitigation Plans, and Firewise Communities.
- Sharing lessons learned between different communities and enabling peer networking opportunities.

Good land use planning helps reduce wildfire costs, increases public safety, and improves forest health.

Participation in CPAW is voluntary and based on a competitive application process.
CPAW is a partnership between Headwaters Economics and Wildfire Planning International.

COMMUNITY PLANNING ASSISTANCE FOR WILDFIRE

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HEADWATERS ECONOMICS
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Helping communities better plan the wildland-urban interface. | www.planningforwildfire.org

MEDFORD OREGON

MEMORANDUM

To:	Mayor and Council
From:	Angela Durant, Principal Planner
Study Session Date:	October 10, 2019
Subject:	City Funding Priorities and Homeless System Action Plan Implementation Plan

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COUNCIL DIRECTION

Staff is seeking Mayor and Council direction on the City of Medford Funding Priorities Recommendation referenced herein and the corresponding Homeless System Action Plan (HSAP) Implementation Plan in Exhibit A. Associated funding sources for consideration include: 1) Housing Opportunity Fund (HOF); 2) Community Development Block Grant (CDBG); 3) General Fund Grant (GFG); and 4) HSAP implementation funding.

PRESENTATION OUTLINE

- Presentation overview and recommendation – Angela Durant and Chief Scott Clauson
- Discussion and Direction – Mayor and City Council

PREVIOUS STUDY SESSIONS AND G-3 MEETINGS ON THE TOPIC

- Council held study sessions to establish 2019-21 Council Goals on February 28, 2019, May 9, 2019 and May 30, 2019.
- On April 25, 2019, Council held a study session to discuss the HSAP with consultants from LeSar Development Consultants.
- Council held G-3 meetings to discuss the HSAP on April 9 and 16, 2019.
- On April 5th, 2018, Council held a study session to discuss the Livability Team.

PREVIOUS COUNCIL APPOINTED ADVISORY COMMISSION MEETINGS ON THE TOPIC

- On September 25, 2019, the Housing Advisory Commission (HAC) and the Community Developments Grants Commission (CDGC) passed a motion to approve the HSAP

Implementation Plan and the Funding Priorities Recommendation for the 2019-21 Biennium, as presented by staff.

- On August 21, 2019, the CDGC held a study session with Medford Police Chief, Scott Clauson and the Continuum of Care Manager, Connie Wilkerson to more effectively narrow the focus on HSAP priority actions.
- July 17, 2019, the CDGC and HAC held a joint study session to identify specific HSAP priority actions for consideration by Council.
- The CDGC provided feedback to staff on the goals and actions recommended in the HSAP during regular meetings held on May 1, 2019, May 15, 2019 and June 5, 2019.
- On May 22, 2019, the HAC held a study session to discuss the HSAP.

BACKGROUND

Over the past several years, the City of Medford has been diligent in exploring and implementing strategies to reduce barriers to the development of affordable housing, address homelessness and improve housing instability. The following key strategies are directly associated with staff's request for Council direction:

- Appoint and roster the CDGC and HAC with experts in the fields of lending, real estate, multifamily housing operation, affordable housing development, tenant organization, budget/finance, healthcare, social services, local business, workforce development, and education. This holistic approach is designed to increase capacity and stimulate greater impact through strategic recommendations to Council on complex issues such as housing and homelessness.

  The CDGC was appointed to advise Council on the strategic investment of City grant resources including the CDBG and GFG programs. Primary commission objectives include helping address the obstacles of the community's underserved populations through the administration of City resources and seeking additional resources through new grant opportunities and partnerships. Implementation of the HSAP and administration of supporting City funding is in alignment with the CDGC's charge.

  The HAC was appointed to implement strategies to remove policy and cost barriers to the development of affordable housing for low- to moderate-income households. One of the highest priorities of the HAC has been to launch and administer the HOF. The goal of the HOF is to ***increase, improve, and preserve supportive and attainable housing to meet the needs of the citizens of Medford***. The HOF provides the community with a local, flexible funding source to incentive development and provide leverage to capture additional resources from funders with aligning goals and objectives.

- Complete the HSAP to accomplish three primary objectives: 1) define the City's role in addressing homelessness and housing instability; 2) identify actionable goals for the City to implement and/or support based on identified system and service gaps; and 3) develop a driving document to assist Council with establishing priorities, partnerships and funding decisions over the next several biennia.

- Hold an annual Council study session in October to establish funding priorities that address the community's real-time priority needs in alignment with Council's goals and strategies, as well as with those of other primary funders in a manner that can help our community capture additional leverage and garnish greater impact. This strategy mirrors the recent work of Oregon Housing and Community Services (OHCS) which is to create a streamlined calendar and transparent alignment of funding opportunities. OHCS accomplishes this in October.

- Budget additional City resources for the implementation of the HSAP and creation of the Medford Livability Team to strategically address homelessness.

STAFF ANALYSIS

In addition to previous meetings held by Council, the HAC and the CDGC, City staff presented the HSAP's recommended goals and actions to the Continuum of Care Board, Regional Public Managers Group, Homeless Task Force and the City Leadership Team. Collective feedback from these leadership groups and other key stakeholders has been the driving influence to the development of the proposed implementation plan and funding priorities; both of which are based on need, timing, funding, and ability to complete the proposed actions in the current biennium. As presented in Exhibit B, **2019-21 Council Goals**, implementation of the HSAP and funding priorities for the current biennium seek to accomplish the following:

- Develop 100 housing units affordable to households with incomes up to 120% of AMI
- Increase the supply of supportive housing
- Address unsheltered homelessness and encampments
- Increase temporary housing programs that lead to permanent housing placements
- Increase collaboration with nonprofits, faith-based organizations, businesses and other government agencies
- Coordinate efforts with the Continuum of Care (COC)
- Expand diversion and prevention strategies through partnerships and funding

Staff recommendations are also in alignment with priorities, goals, strategies and actions taken from other key local, state and federal plans to address housing and homelessness, including the following:

- Medford 2015-19 Consolidated Plan Goals, Objectives and Strategies (Exhibit C)
- Breaking New Ground: Oregon's Statewide Housing Plan Summary (Exhibit D)
- Jackson/Josephine 2019-2022 Community Health Improvement Plan Priorities (Exhibit E)
- The Federal Strategic Plan to Prevent and End Homelessness (Exhibit F)

The HSAP has served as a tool to help develop clarity and focus on specific actions that are appropriate for the City to implement and/or support through funding, partnerships and policy. Strong consensus has landed on the following priorities, which are reflected in the recommended implementation tasks in Exhibit A:

- Support the City's Livability Team with outreach and housing resources for individuals along the Greenway
- Support development of permanent and transitional housing options
- Provide assistance to rapidly rehouse homeless individuals and families
- Coordinate distribution of services
- Increase resources for homelessness diversion and prevention
- Establish City roles to address homelessness and oversee the HSAP
- Establish priorities for City funding programs including the HOF, CDBG, GFG and HSAP implementation fund

FINANCIAL AND/OR RESOURCE CONSIDERATION

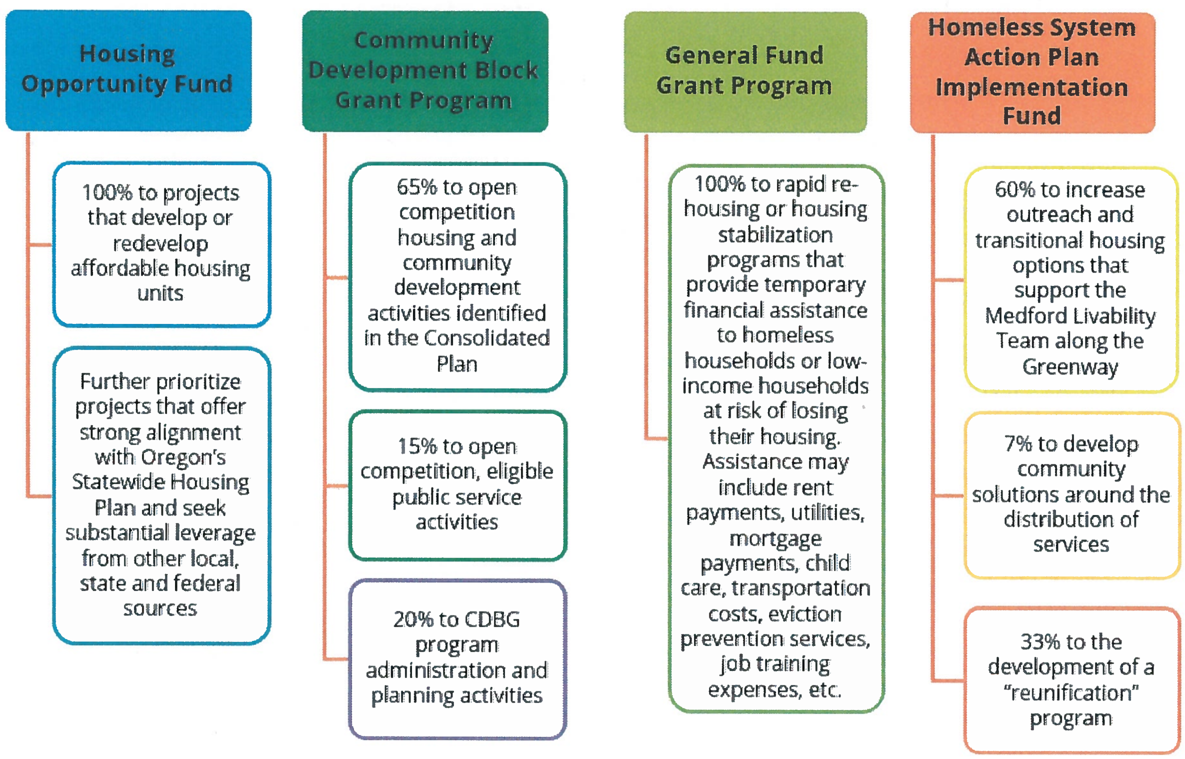
Combined biennial funding consideration is estimated at $2.65 million, with $800 thousand from the HOF; $1.4 million from CDBG; $300 thousand from the GFG; and $150 thousand from HSAP implementation funds. This consideration does not include non-competitive GFG biennial funding.

FUNDING PRIORITIES RECOMMENDATION

Extensive analysis and collection of community feedback inspires a concise funding priorities recommendation that not only provides a roadmap for strategic community investment of City resources, but also establishes a certain level of efficiency that may expand the City's capacity to develop new programs and capture additional resources. Given the regulatory complexities and nondiscretionary funding schedule of the CDBG program; which is over 50% of the City's combined resources, staff is recommending the HOF and GFG be more narrowly focused toward housing development and stabilization activities that demand more flexible, discretionary administration. This strategy may help the City more efficiently reach housing production and homeless prevention goals. Furthermore, staff recommends the City establish specific measurable housing related goals in alignment with Oregon's Statewide Housing Plan.

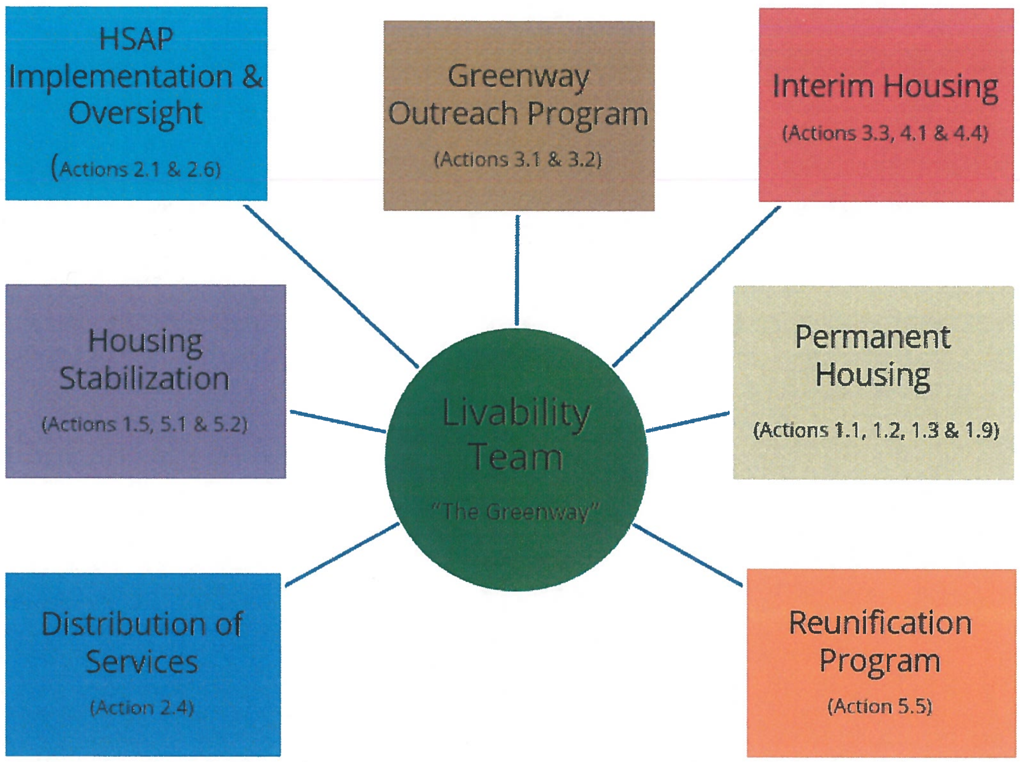
The following chart summarizes recommendations for funding priorities under each program.

City of Medford Funding Priorities Recommendation



The chart to follow illustrates seven categories, including 16 priority actions from the HSAP that are recommended for implementation and/or funding during the first year of the current biennium.

2019-20 HSAP Implementation Plan (Priority Actions)



The highlighted list below further describes the seven recommended categories by providing specific next steps, which are also described in Exhibit A:

<u>Greenway Outreach Pilot Program</u>

- Enhance outreach through the new Medford Livability Team and volunteer partnerships
- Target 10-15 chronically homeless individuals along the Greenway as a pilot study
- Develop a committee similar to the existing Neighborhood Livability Team to track individuals
- Research Department of Justice and other funding opportunities to sustain program funding

<u>Interim Housing</u>

- Provide funding to the new year-round shelter in exchange for 5-8 dedicated beds to support the Livability Team's Greenway Outreach Program

- Lease existing housing unit to provide an interim, co-housing resource for the Livability Team's Greenway Outreach Program
- Secure partners to support the interim housing resource with integrated services including case management, mental health and addiction recovery, jobs training and housing placement
- Seek leverage resources from foundations, hospitals and coordinated care organizations
- Solicit 1-2 churches interested in the safe parking program to analyze program barriers
- Consider funding rehabilitation costs associated with safe parking program requirements
- Review Medford Municipal Code (MMC) 5.557 to consider allowing nonprofits to offer the program

Reunification Program

- Hold collaborative study session with stakeholders to develop the program
- Work with CoC to establish program criteria, best practices, and policies and procedures

Distribution of Services

- Facilitate a convening of service providers including nonprofits, faith-based organizations, individuals and businesses
- Develop solutions for issues associated with the distribution of services
- Develop recommendation regarding the need for a centralized location and potential sites

Housing Stabilization

- Establish program funding priorities under the GFG to increase direct assistance to rapidly rehouse or stabilize housing for households that are homeless or at risk of homelessness
- Establish performance goal that 85% of households served are stabilized in housing for six months or longer, which mirrors OHCS' 2019-23 homelessness goal

HSAP Implementation and Oversight

- Amend MMC 2.441 to expand the advisory capacity of the CDGC to include implementation of the HSAP and other matters associated with homelessness
- Add two members from lived experience to the CDGC to improve performance outcomes

Permanent Housing

Continue efforts to increase development of affordable housing by addressing barriers, implementing economic incentives, identifying supporting resources, and cultivating partnerships

EXHIBITS

- Exhibit A: 2019-21 Homeless System Action Plan Implementation Plan
- Exhibit B: 2019-21 Council Goals
- Exhibit C: City of Medford 2015-19 Consolidated Plan Goals, Objectives and Strategies
- Exhibit D: Breaking New Ground: Oregon's Statewide Housing Plan Summary
- Exhibit E: 2019-2022 Jackson and Josephine Counties Community Health Improvement Plan Priorities
- Exhibit F: The Federal Strategic Plan to Prevent and End Homelessness

Thank you,
Angela Durant
Housing & Community Development Division Principal Planner

Exhibit A
Medford Homeless System Action Plan Implementation Plan

The following table lists the original five goals and 31 actions recommended in the Medford Homeless System Action Plan (HSAP), in order of priority, by LeSar Development Consultants. City Council added the development of a reunification program as a diversion strategy listed under Goal 5, Action 5.5. The table also serves as the HSAP Implementation Plan, which includes staff recommended implementation tasks, responsible groups, proposed resources and begin/end dates. The implementation plan is intended to serve as a roadmap for the City to develop and/or support programs, partnerships and funding priorities. All actions are proposed for consideration or implementation in some capacity during the 2019-21 Biennium. However, 16 of the 32 are identified as priority actions based on need, timing, funding and ability to implement during the targeted timeframe. Collective feedback from community stakeholders, leadership bodies and Council advisory commissions prompted focus on priority actions that seek to accomplish the following:

- Support the City's Livability Team with outreach and housing resources for individuals along the Greenway;
- Support development of permanent and transitional housing options;
- Provide assistance to rapidly rehouse homeless individuals and families;
- Coordinate distribution of services;
- Increase resources for homelessness diversion and prevention;
- Prioritize City funding programs including the Housing Opportunity Fund (HOF), Community Development Block Grant (CDBG), General Fund Grant (GFG) and HSAP implementation funds; and
- Establish City roles to address homelessness and oversee the HSAP.

Goal #1: Increase the Supply of Affordable and Supportive Housing					
Actions	**Role of the City**	**Proposed Implementation Task(s)**	**Responsible Group(s)**	**Proposed Resources**	**Begin Date – End Date**
Action #1.1: Continue implementing ad hoc Housing Advisory Committee recommendations, through the newly appointed permanent Housing Advisory Commission including prioritizing affordable housing project review, creating developer incentives, and updating policies and standards to facilitate increased density and innovative housing models.	Maintain current role within HAC and ensure recommendations from this Action Plan are incorporated into ongoing HAC recommendations.	1) Develop Strategic Housing Plan as part of the consolidated planning process required as a CDBG entitlement jurisdiction. 2) Request Council establish **funding priorities under the HOF and CDBG programs** for the development of affordable housing.	1) HCDD and HAC 2) HCDD, CDGC, HAC and Council	HOF, CDBG, GFG, MURA and community leverage	9/1/17 – 6/30/22

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #1.2: City and County work collaboratively to set annual housing production goals.	Reach out to appropriate County personnel to begin discussions regarding setting goals.	1) Annual production goal of 100 units set by Council. 2) Establish 5-year housing production goal during the CDBG consolidated planning process.	HCDD, HAC, CDGC and MURA	HOF, CDBG and community leverage	7/1/19 – 6/30/22
Action #1.3: City and County work collaboratively to inventory all available publicly-owned land (City, County, State, and Federal) that may be suitable for housing development. Additionally, work with faith-based community and non-profits to identify land they may own for affordable/supportive housing development.	Begin inventorying land and reach out to County personnel to work with them on creating regional inventory list. City and County engage faith-based community and non-profits.	1) Develop Surplus Property List including properties in Downtown and Liberty Park. 2) Work with the COC Housing Pipeline and Faith-based workgroups to identify additional suitable land. 3) Expand surplus property list to include properties, citywide. 4) Research opportunities to create a Community Housing Foundation.	1) City Manager's Office and MURA 2) HCDD and COC 3) City Manager's Office and MURA 4) HCDD and HAC	City, MURA and COC staffing	9/1/19 – 6/30/21
Action #1.4: Engage private landlords in the city to rent to homeless households and develop a city or region-wide landlord engagement program that could provide funding for financial incentives to local landlords, deposits and application fees, and damage/mitigation funds.	Create landlord engagement campaign targeted at landlords to rent to homeless households. Work with partners to create funding pool that would provide financial incentives to landlords, deposits, damage funds, and other housing related expenses for homeless households to access.	Conduct research and present case studies to HAC and CDGC prior to presentation to Council	HCDD	City staffing	7/1/21 – 6/30/22

Actions	Role of the City	Proposed Implementation Task	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #1.5: Increase RRH resources for non-Veteran households, both families and single adults. It is estimated that the region needs to create a MINIMUM of 83 RRH units for single non-Veteran adults and 22 units for non-Veteran families to meet current demand.	City needs to prioritize existing City funds that could be used for the rental assistance portions of RRH. The City should also work with the Housing Authority to understand if there are any rental assistance funds that could be paired with City funds for the use of RRH. The City should then engage in discussions with the County and CCO's to help determine funds to be used to provide the case management support with the rental assistance. The City can work with COC to determine best way to roll out the new RRH program	1) Develop strategic RRH program in partnership with the COC. 2) Request Council establish **funding priorities under the GFG** program. 3) Establish a performance goal that 85% of households served are stabilized in housing for six months or longer, which mirrors Oregon Housing and Community Services' 2019-23 homelessness goal.	HCDD, HAC, and CDGC and Council	CDBG, GFG and community leverage	10/10/19 – 6/30/22
Action #1.6: Increase the supply of new PSH units for Non-Veteran single adults. It is estimated that the region needs to create a **MINIMUM** of 259 PSH units (Includes 245 for non-Veteran single adults and 14 for non-Veteran families to meet current demand).	Prioritize the creation of new PSH. This can include acquiring and rehabbing underutilized or closed hotels or motels, using pre-fabricated or modular units on City-owned land while traditional development is considered, and use City-owned property for PSH development. Work with County, VA, CCOs, and ACCESS to discuss funding of supportive services.	1) Develop Surplus Property List referenced in Action 1.3 and work with community partners to explore opportunities with hotels and/or modular units. 2) Develop Strategic Housing Plan as referenced Action 1.1 which will include strategies to increase production of PSH units.	1) City Manager's Office and MURA 2) HCDD and HAC	HOF, CDBG and community leverage	9/1/19 – 6/30/22

Actions	Role of the City	Proposed Implementation Task	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #1.7: Engage the County, Housing Authority, CCO's, and hospitals to create a PSH pilot targeted to frequent users of healthcare systems.	Convene partners to discuss the creation of a PSH pilot that could be targeted to high-cost homeless individuals. To quickly create a pilot, the most efficient way would be to determine how to create new PSH rental assistance (in form of voucher or other source) and pair with services funds ideally funded by the healthcare sector.	Facilitate a convening including interested culturally specific services providers, behavioral health providers, housing developers, housing funders, Medicaid funders, elected officials, City staff and lived experience.	HCDD and HAC	HOF, CDBG, GFG and MURA	12/18/19 – 6/30/22
Action #1.8: Explore zone changes that would facilitate development of affordable housing, including density bonuses, multi-family zoning, and by-right development	City is responsible for this action.	1) Develop code amendment to address the multi-family residential review process (by-right development) 2) Complete City-initiated zone and GLUP change project	Planning Department, Planning Commission and HAC	City staffing	8/1/19 – 3/31/20
Action #1.9: Implement an ADU program to include SDC waivers. Explore opportunities to create a low-interest ADU loan program for homeowners. Develop permit-ready ADU design options.	City is responsible for this action.	Develop ADU and SDC Reduction programs for implementation during the second round of the HOF	HCDD and HAC	HOF, General Fund and City staffing	10/10/19 – 3/31/20

Goal #2: Increase Leadership, Collaboration and Funding

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #2.1: Identify a single point of contact within the City who is responsible for homelessness and can oversee Action Plan implementation.	City is responsible for this action.	1) Develop a proposal to the CDGC for recommendation to Council to amend Medford Code 2.441: a) increase the membership to include two individuals with lived experience; b) increase the voting members constituting a quorum to six members; and c) add "acting as the advisory body to Council on matters associated with homelessness" and "implementing the Homeless System Action Plan" as statutory responsibilities. 2) Appoint HCDD staff as the single point of contact for the HSAP.	CDGC and HCDD	City staffing	9/25/19 – 12/31/19
Action #2.2: Continue to assess the estimated City and public costs of managing homelessness, including calculating staff time, emergency response, property damage, etc. Use the information to quantify needs and continue to strengthen the business case to invest in housing and services for homeless households.	Work with other sectors including healthcare and criminal justice to identify the costs associated with homelessness.	Complete a Cost Analysis of Homelessness	HCDD, CDGC and COC	CDBG and community leverage	7/1/20 – 12/31/21

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #2.3: Create a cross-sector Funders Collaborative that includes both public- and private- sector funders.	Convene all regional public and private funders to establish a regional funders collaborative to begin discussion of funding needs, priorities, and best way to align and increase funding for impact.	City now participates in the Jefferson Funders Forum	HCDD staff	City staffing	9/12/19 – ongoing
Action #2.4: Support creation and implementation of a City and faith-based collaborative to identify shared goals, coordinate activities, and explore opportunities related to safe parking programs, shared housing opportunities, and affordable housing development. (This can be combined or expanded with COC Faith- Based Workgroup)	Convene all faith-based organizations within the City on an ongoing basis to discuss needs, strategies, and share best practices.	1) Facilitate a convening of all organizations that distribute services to the homeless including nonprofits, faith-based organizations, known individuals and businesses. 2) Request Council establish **funding priorities under the HSAP** to cover associated costs.	1) HCDD, HTF, CDGC and MPD 2) HCDD, CDGC, HAC and Council	HSAP	1/6/20 – 1/30/20
Action #2.5: Support creation and implementation of a City and business sector work group to address issues, develop education materials, and explore partnership opportunities related to workforce development and training.	Convene the Chamber, DMA, and other interested businesses in the City on an ongoing basis to discuss needs, strategies, and share best practices.	Facilitate initial convening to establish local interest	HCDD and CDGC	City staffing	7/15/20 – 12/31/19

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #2.6: Support the creation and implementation of a Lived Experience Advisory Board that would provide input on City policies and programs as well as regional approaches. Determine with the COC, if this is best created at a regional level as part of the COC but could still provide input on City specific activities.	Work with COC and other non-profits to identify potential board members who are current or past participants in homeless services or have been homeless in the city. Act as the group convener and support Board members with incentives for their participation.	1) Develop a proposal to the CDGC for recommendation to Council to amend Medford Code 2.441: a) increase the membership to include two individuals with lived experience; b) increase the voting members constituting a quorum to six members; and c) add "acting as the advisory body to Council on matters associated with homelessness" and "implementing the Homeless System Action Plan" as statutory responsibilities. 2) Make a request to the COC that one of the members with lived experience be appointed to the COC Board.	HCDD	GFG Program	12/4/19 – 1/1/20
Action #2.7: Create an area resource map using Geographic Information Systems (GIS).	Work with COC and other partners to identify and document available resources for homeless households throughout the city.	1) Resource completed. 2) Obtain the enhanced resources list from the COC Manager to provide to the Medford Livability Team for distribution.	1) RVCOG 2) HCDD	RVCOG and City staffing	10/15/19 - ongoing
Action #2.8: Continue to participate and provide leadership within the COC and invest in build-out of infrastructure through the COC.	Work with COC to determine infrastructure needs of the COC and dedicate funds with other regional partners.	City funds COC through noncompetitive GFG program.	City leadership staff and Council	GFG	ongoing

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #2.9: Require applicants demonstrate adherence to best practices and community standards in all City contracts for homeless services.	City is responsible for this action but may need input from COC on community standards.	Add best practices and standards to the City's CDBG public services and capital improvement project guidebooks and update contracts to include federally recommended standards.	CDGC and COC	CDBG, City and COC staffing	8/5/2020 - ongoing
Action #2.10: Develop a performance culture within the City where City funds are only provided to programs that demonstrate positive outcomes. Review current contracts and potentially shift funding to higher performing projects.	City is responsible for this action but may need input from COC on performance measures.	1) Enhance City's quarterly performance reporting platform and regularly attend Jefferson Funders Forum meetings and implement best practices for measuring performance outcomes learned through the JFF. 2) Hold training on evidence-based performance measurement for all City grant recipients.	HCDD and CDGC	City staffing	2/26/20

Goal #3: Address Unsheltered Homelessness and Encampments

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #3.1: Create a Greenway Response Group to support planning activities and increase collaboration between key agencies and outreach partners such as street outreach personnel, MPD, Public Works, Behavioral Health and businesses.	Convene all partners who have a stake in the Greenway.	Establish group similar to the Neighborhood Livability Team and hold regular meetings to target individuals through the Greenway Outreach Pilot program referenced in Action 3.3	MPD Livability Team	City's and other agency's staffing	9/19/19 – 6/30/22

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Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #3.2: Increase resources for non-uniformed street outreach services dedicated to single adults and pair outreach staff with MPD.	Dedicate City funds to increasing street outreach services and work with County and other partners such as CCO's and business groups to identify funding to match.	Target specific partners to develop sustainable volunteer outreach program to accompany the Medford Livability Team along the Greenway and in Parks.	HCDD, MPD, CDGC and HTF	HSAP, CDBG, City staffing and community volunteeris m	9/3/19 – 6/30/22
Action #3.3: Create a pilot to address encampments in the Greenway to assess individuals, provide intensive supports, and offer housing placements.	As part of Greenway Response Ad Hoc Working Group discuss idea of a pilot.	1) Establish the **Greenway Outreach Pilot Program,** which may include dedicated shelter beds, an interim housing facility, integrated mental health and addictions recovery services, jobs training and permanent housing placement services. This program is meant to be a primary resource for the Medford Livability Team to house homeless individuals from the Greenway. Data will be collected through the Greenway Response Ad hoc Working Group referenced in Action 3.1 and reported to 2) Request Council establish **funding priorities under the HSAP** to lease one housing unit with 4-5 rooms to provide an interim, co-housing resource for the Medford Livability Team.	1) MPD, HCDD, CDGC and community partners 2) HCDD, CDGC, HAC and Council	HSAP, shared resources from partners and local grants	10/18/19 – 6/30/22

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #3.4: Update City policies related to encampment abatement to include proactive outreach responses and offer support prior to 24-hour posting and abatement.	City is responsible for this action. Update policies based on input from Ad Hoc Working Group and pilot activities	Assess through the Greenway Outreach Pilot Program to identify and update outreach responses, accordingly.	MPD	City staffing	1/1/20 – 6/30/22
Goal #4: Increase Temporary Housing Programs and Successful Placements					
Actions	**Role of the City**	**Proposed Implementation Task(s)**	**Responsible Group(s)**	**Proposed Resources**	**Begin Date – End Date**
Action #4.1: Support the creation of a year-round, low barrier shelter program for single adults, families, and couples. Keep the winter shelter program during first year of operation and consider if needed beyond that timeframe.	Identify site within the city to be used for shelter program and provide funding to help develop and operate as needed.	1) Year-round shelter completed. 2) Request Council establish a **funding priority under the HSAP** to provide financial assistance to the shelter in exchange for 5-8 dedicated beds to support the Livability Team. 3) Support the search for a location to maintain a temporary winter shelter in addition to the new year-round shelter.	1) ACCESS and Rogue Retreat 2) HCDD, HAC, CDGC and Council 3) HCDD, CDGC, COC, Rogue Retreat, Fire Department and Building Safety Department	HSAP, CDBG, and City, COC and agency staffing	10/15/19 – 6/30/22
Action #4.2: As part of year-round shelter, consider creating a Central Access Point within the city that could be the starting place for all populations to access the homeless services system.	Work with COC to understand if this is needed.	Completed as part of the year-round shelter.	ACCESS, Rogue Retreat and COC	Community partners	Ongoing

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #4.3: Only provide City funds to temporary housing programs that have adopted best practices such as Housing First that includes a low barrier entry criteria and harm reduction, uses HMIS, and uses the CES.	City is responsible for this action.	Hold study session to research best practices and the effective use of multiple models for addressing homelessness.	HCDD, CDGC and COC	City and COC staffing	12/18/19 – 3/18/20
Action #4.4: Work with interested churches to create safe parking programs in their parking lots. Promote partnerships that provide funding to churches to ensure adequate restrooms and basic services at the lots and funds for service engagement. Engage church volunteers to assist with other services at the parking lots.	Engage area churches to develop safe parking programs. Identify funds to provide to area non-profits or churches to operate programs. Engage COC to ensure that parking programs are interacting with CES.	1) Identify 1-2 interested churches to implement a pilot program, potentially using City funding for rehabilitation costs to meet code requirements including access to restrooms and based services. 2) Review code to consider including nonprofits as authorized organizations to offer safe parking under certain circumstances.	1) CDGC and COC 2) Planning Department, City Attorney and Fire Department	HSAP, CDBG, and City and COC staffing	3/1/20 - 6/30/20

Goal #5: Increase Diversion and Prevention Strategies

Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #5.1: Increase resources for homelessness prevention and ensure City funds are targeted to households most likely to become homeless and funds are used efficiently.	Conduct assessment of current contracts where the City is providing funds for homelessness prevention and/or emergency assistance and evaluate target populations and outcomes. Based on assessment, increase funding for activities that are making an impact in preventing households from becoming homeless.	1) Request Council establish a **funding priority under the GFG** program to increase funding to housing stabilization programs that provide temporary financial assistance to low-income households at risk of losing their housing. Assistance may include rent and utilities, mortgage payments, child care, transportation costs, eviction prevention services, job training expenses, etc. 2) Implement the 85% performance standard presented in Action 1.5.	HCDD, CDGC, HAC and Council	GFG and CDBG	10/10/19 – 6/30/22
Action #5.2: Provide increased funding for legal services to support City residents facing eviction.	City is responsible for this action.	Request Council establish a **funding priority under the GFG**, as referenced under Action 5.1. Center for Nonprofit Legal Services is the only local agency offering eviction prevention services to low-income residents.	HCDD, CDGC, HAC and Council	GFG	10/10/19 – 6/30/22
Action #5.3: Increase diversion training and activities and incorporate into CES and temporary housing programs.	Provide funding to COC to create and expand Diversion training to non-profits. Work with partners such as the County to provide match.	Hold study session with CDGC and COC Manager to explore priority need.	HCDD, CDGC and COC Manager	GFG	3/25/20

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Actions	Role of the City	Proposed Implementation Task(s)	Responsible Group(s)	Proposed Resources	Begin Date – End Date
Action #5.4: As part of a diversion strategy, increase shared housing and/or roommate matching strategies to connect homeowners who may have a room to rent or to connect homeless individuals together to live as roommates.	Work with COC to engage in discussions with COC partners to discuss shared housing models.	Hold study session through the HAC and CDGC to explore opportunities and existing code.	HAC, CDGC, Planning Department, COC Manager, and ACCESS Housing Director	City's and organizatio n's staffing	7/15/20
Action #5.5: As directed by Council, increase resources to reunite homeless individuals with their family or support network outside the City of Medford.	Work with the COC and other interested community partners to develop a reunification program that follows best practices and community standards.	1) Launch Request for Expressions of Interest to identify organizations interested in administering the program. 2) Hold study session through CDGC with CoC Manager to develop program criteria and standards.	HCDD, CDGC and COC	HSAP $50K	1) 11/11/19 – 11/25/19 2) 12/4/19

Acronyms and abbreviations

CDBG	Community Development Block Grant
CDGC	Community Development Grants Commission
CCO	Coordinated Care Organization
COC	Continuum of Care
GFG	General Fund Grant
HAC	Housing Advisory Commission
HCDD	Housing and Community Development Division
HOF	Housing Opportunity Fund
HSAP	Homeless System Action Plan
HTF	Homeless Task Force
MPD	Medford Police Department
MURA	Medford Urban Renewal Agency
RVCOG	Rouge Valley Council of Governments

Exhibit B
2020-21 Council Goals

HOUSING STRATEGIES

Housing Strategies: Enhancing livability for all residents by promoting and preserving a range of housing choices in Medford.

- **Increase Opportunities for Downtown Housing:** Implement strategies and recommendations from the Liberty Park Neighborhood Plan and City Center Revitalization Plan. Implementing these strategies will create affordable and workforce housing opportunities as well as diversity housing types. Develop partnerships with private developers in order to produce a targeted number of housing in all categories. Utilize incentives for development through the Construction Excise Tax, Urban Renewal Funds, and other funding sources. Provide guidance to the Housing Advisory and Grants Commission on setting priorities and establishing a targeted goal for number of units produced. Establish a goal for the development of 100 units affordable to households with incomes up to 120% of AMI as detailed in the most recent Downtown Market Study.
    - ***Mayor, Council and MURA Board: Downtown redevelopment. Review and approve changes to development standards, e.g. Adopt new parking policies that encourage downtown residential development.***
    - *Department Lead*: Development Services & Urban Renewal
    - *Biennium Deliverable*: Establish targeted number of units. Award funds and other economic incentives to deliver units. Complete one "Barnum" project (acquire, renovate, construct) with partners. Collaborate with MURA on other residential seismic retrofit projects in downtown.
    - *Funding*: Incentive funding provided through; Construction Excise Tax, Urban Renewal Funds, Community Development Block Grants, General Fund Grants, System Development Deferral program, FEMA seismic mitigation grant, and tax abatements.
    - *Future Deliverables*: Provide update on number of targeted units and funding sources to continue providing housing.

- **Increase Opportunities for Housing:** Convene major employers to assess economic vulnerabilities resulting from housing shortages and explore partnership opportunities to develop housing options within their project areas.
    - ***Mayor and Council: Review and consider staff recommendations regarding deliverables identified below.***
    - *Department Lead*: Development Services & Urban Renewal
    - *Biennium Deliverable*: Identify City surplus property and convert to housing units. Staff to provide options for Council consideration on additional System Development Charge credits for housing and Accessory Dwelling Units (ADUs). Implement regulatory reforms recommended by Housing Advisory Commission/TA Grant Technical Advisory Group. Complete two rounds of Housing Opportunities Fund (HOF) requests for proposals. Explore feasibility and benefits of creating a "Housing and Community Development Foundation" with local employers and the development community in order to sustain a stable work force. Identify infrastructure constraints that discourage residential development in existing/older neighborhoods and develop a strategic plan to address those deficiencies.
    - *Funding*: Incentive funding provided through; Construction Excise Tax, Urban Renewal Funds, Community Development Block Grants, General Fund Grants and System Development Deferral program. Seek to establish funding sources through local improvement districts.

- *Future Deliverables*: Provide update on number of targeted units and funding sources to continue providing housing. Assess feasibility of establishing an employee housing assistance program. Update the City of Medford Housing Element in concurrently with the next Portland State University Projections in 2021.

- **Homeless System Action Plan (HSAP):** Implement goals and actions identified in the HSAP that increase the supply of affordable and supportive housing. Address unsheltered homelessness and encampments along with increasing temporary housing programs that lead to permanent housing and placements. Increase collaboration with non-profits, faith based organizations, business community and other government agencies to implement solutions from HSIP. Implementation of the HSAP will be coordinated with the Continuum of Care.
  - ***Mayor and Council: Adopt plan by October 1, 2019. By November 2019, Council to set priorities for Community Development Block Grants and General Fund Grants. Issue grants based on Council priorities.***
  - *Department Lead*: Housing and Community Development
  - *Biennium Deliverable*: Staff to offer recommended priorities based on need, timing, funding and ability to complete this action within the targeted timeframe. Based on staff recommendations, Council to set priorities for Community Development Block Grants and General Fund Grants. Issue grants based on Council priorities. Report on progress on the HSIP along with CoC.
  - *Funding*: Amount TBD. Funding available through Community Development Block Grants, General Fund Grants and contributions by other agencies.
  - *Future Deliverables*: Provide update on goals and actions contained within the HSIP.

Community & Employee Engagement: Bring community stakeholders together to discuss common vision for what Medford is going to strive to accomplish. Engagement includes involving and informing citizens about the vision, mission and goals for the City. Expand engagement to include employees who will become knowledgeable about all aspects of City services and provide leadership growth opportunities.

- **By July 18, in association with adoption of the 2019-21 Biennial Budget, Council to express support and approve funds to move community engagement forward e.g. OKC MAPS Model**

- **Develop a broad-based vision with community stakeholders:** Development of a vision for what Medford could become in the next 20-40 years. Identify broad goals with community partners and develop potential funding options for implementation.
    - ***Mayor and Council Role: Approve and serve as supportive hosts at public events***
    - *Department Lead*: City Manager's Office
    - *Biennium Deliverable*: Community Vision Master Plan
    - *Funding*: $200,000 – Available from funds identified in 2019-21 biennial budget Issue
    - *Future Deliverables*: Implementation and funding strategies - 21-23 Biennium

- **Community Engagement:** Proactively share information and increase engagement and trust through external communications and community building. This will be accomplished through the implementation of the Strategic Communications and Marketing Plan. Additionally, efforts to identify and broaden stakeholder groups in order achieve a more robust dialog on issues and opportunities.
    - *Department Lead*: City Manager's Office
    - *Biennium Deliverable*: The Communications and Marketing Manager will compile all metrics and create a yearly report. Metrics will be used to guide communication budget and existing and new communication efforts, Operation Care, and Citizens Academy. These efforts will measure and track citizen engagement results, e.g. # of people engaged, online, in person, via emails, surveys, Facebook live events, and other identified methods. Staff will research metrics used by outside organizations that determine livability items that are used by national publications.
    - *Funding*: $200,000 – Available from funds identified in 2019-21 biennial budget
    - *Future Deliverables*: Based on yearly report and evaluation of strategies and tactics listed in the Strategic Communications and Marketing Plan.

- **Government Partnership Engagement:** Seek to expand partnerships with state and local government agencies along with educational organizations in order to align agency collaboration.
    - ***Mayor and Council: Invite and participate in collaboration with, RCC, SOU, Jackson County, RVCOG, 549C and additional agencies.***
    - *Department Lead*: City Manager's Office
    - *Biennium Deliverable*: Establish regular meetings with partners
    - *Funding*: Varies: Costs for meetings are contained within the Mayor/Council budget
    - *Future Deliverables*: Identify ways to collaborate on addressing community and regional challenges

- **Employee Engagement:** Deliver consistent, relevant, and timely communications to our employees. Expand leadership opportunities within.
    - *Department Lead*: All City Departments
    - *Biennium Deliverable*: Establish Leadership Program. Staff response and feedback along with periodic surveys.
    - *Funding*: Varies: Costs are contained within each department's training budgets.
    - *Future Deliverables*: Based on evaluation from employee input.

Public Infrastructure: Proactively plan for and respond to identified infrastructure needs by providing facilities essential for citizens and visitors to live, work and play in a manner that is financially and environmentally sustainable.

- ***Mayor and Council: Council to express support and funding allocation to complete the following essential activities.***

- **Bear Creek Master Plan** – Update the plan to include a vision for all of Bear Creek within City limits. The plan should address lighting, vegetation management, water quality within the creek, park settings, events that promote use by residents and visitors, potential to add security cameras to various locations and a two-sided approach to Bear Creek (meaning both sides of the creek are addressed). The Master Plan should be visionary and include a section on redevelopment of existing businesses along its frontage. One example is whether or not the mall can be repurposed to create more green space along the creek, and/or hotel or event center to attract visitors to the area.
  - *Department Lead*: Parks, Recreation and Facilities
  - *Supporting Departments:* Police, Fire and Development Services
  - *Biennium Deliverable*: Identification of items related to safety, lighting and vegetation management. Present to Council costs and funding sources
  - *Funding*: TBD
  - *Future Deliverables*: Final Master Plan in the 21-23 Biennium

- **Determine feasibility of a potential Aquatics Facility with Event/Recreation Center** - Council directed staff to present facility options, costs for construction and operations and funding options. Information will be presented in the 3rd quarter of 2019.
  - *Department Lead*: Parks, Recreation and Facilities
  - *Supporting Departments:* City Manager's Office and Finance
  - *Biennium Deliverable*: Facility plan along with funding options
  - *Funding*: $730,550 for the facility plan; $1,015,500 construction reserve
  - *Future Deliverables*: Council approved funding options. Possible construction beginning in first year of 21-23 Biennium

- **Citywide space needs assessment/City Hall utilization strategy** - ORW has completed this study that will require analysis and direction by Council.
  - *Department Lead*: Parks, Recreation and Facilities
  - *Supporting Departments:* City Manager's Office and Finance
  - *Biennium Deliverable*: Comprehensive evaluation of current department space needs resulting in a space utilization plan of how City buildings can be used to meet present and future needs. The deliverable may change based on Council feedback from the study session.
  - *Funding:* $14,000
  - *Future Deliverables*: TBD based on study session feedback

- **Public Works' Infrastructure** - As new development comes into the City, it's critical to ensure that the transportation, storm drain and sewer systems have enough capacity to handle future demand. These issues were addressed in newly adopted Transportation System and Sewer Master Plans (the Storm Drain Master Plan is under development).
    - ***Mayor and Council: Council to review and approve recommendation from Transportation Commission on prioritization of 6-year capital improvement list of street projects.***
    - *Department Lead*: Public Works
    - *Supporting Departments:* Development Services
    - *Biennium Deliverable*: Completed projects
    - *Funding*: $1,085,800 for 8 projects that increase sewer capacity. Funding will be developed for street and road improvements through recommendation by Transportation Commission.
    - *Future Deliverables*: Additional projects constructed per Sewer Master Plan, Transportation System Plan and Storm Drain Plan.

- **City Wayfinding Program** – Establish design standards for a city-wide wayfinding program that places an emphasis on identifying entry into Medford along with the downtown area. Prioritize sites and install signage.
    - *Department Lead*: Planning
    - *Supporting Departments:* Public Works
    - *Biennium Deliverable*: Updated wayfinding program that provides signage for entrances into Medford along with the downtown area.
    - *Funding*: $30,000 is contained within the Planning Department 2019-21 Biennial Budget for implementation of this program.
    - *Future Deliverables*: Additional signage will be needed in the 2021-22 Biennium for those areas that have been identified for signage, but were not within the 2019-21 budgeted amount.

- **I-5 Viaduct**. The viaduct has served to divide the City and separates the community. While the Oregon Department of Transportation (ODOT) is responsible for the roadway and has taken the lead on how to address the viaduct, its impact on the City is so great the City needs to aggressively and actively participant in defining the solution. Issues that need to be addressed include easy access to downtown to support both the Economic Development and Downtown Revitalization Council goals as well as address livability around the viaduct. One example could be a food truck/cart pod that would attract people to the area.
    - *Department Lead*: City Manager's Office
    - *Supporting Departments*: Development Services
    - *Biennium Deliverable*: Identify the City's vision for I-5 and the viaduct and prepare a plan that turns the current negatives surrounding the viaduct to positives. The vision should incorporate the area surrounding Biddle, Riverside, Central and the Viaduct.
    - *Funding*: None proposed by the City
    - *Future Deliverables*: TBD in conjunction with ODOT

ECONOMIC DEVELOPMENT

Economic Development: The City will play an active role in maintaining and enhancing Medford's diverse economy with an emphasis on a full spectrum of family wage jobs.

- **Regional Economic Development Strategy (2 points):** Collaborate with SOREDI, private business, government and educational partners to develop a regional economic strategy identifying targeted industries that best align with regional assets and strengths that will become the guiding document for future business development.
    - ***Mayor and Council: Participate in development of the strategy. Completion by SOREDI expected on January 2020. Review implementation strategies specific for Medford. Adopt into the Medford Comprehensive Plan by June 2020.***
    - *Department Lead*: City Manager
    - *Supporting Department*: Planning
    - *Biennium Deliverable*: Regional Economic Strategy with action plan. Staff to identify specific action items related to the City of Medford and present those items for Council consideration for implementation.
    - *Funding*: Funding for study has been accomplished. Funding for implementation has been requested from the 2019 Oregon Legislature.
    - *Future Deliverables*: Measurable outcomes from strategy and action plan that will require action in the 21-23 Biennium

- **Develop a policy framework that integrates economic health, social sustainability and environmental stewardship to inform economic and community development strategies and guide interdepartmental collaboration:** Adopt triple bottom line analysis of planning, development, and infrastructure investment opportunities
    - ***Mayor and Council: Adopt a policy framework by July 2020 applicable to Council, City staff and Boards & Commissions.***
    - *Department Lead:* City Manager
    - *Supporting Departments:* Development Services, MURA, and Parks & Recreation
    - *Biennium Deliverable:* Sustainability policy framework and implementation strategy
    - *Funding:* Departments listed
    - *Future deliverables:* Process amendments to incorporate sustainability framework in practice.

- **Identify and Remove Barriers to Economic Development:** Complete a comprehensive review of the Development Code to identify barriers for development. Review would include creating a database of property within the Urban Growth Boundary which would identify vacant and underutilized opportunities. Review potential opportunities to create additional Urban Renewal Areas.
    - *Department Lead*: Development Services
    - *Supporting Department*: MURA staff
    - *Biennium Deliverable*: Available Employment Development Site Opportunities Map including existing vacant development land and re-developable employment land by 2020
        - Internal review of Land Development Code (e.g. minimum off street parking requirements) and other city regulations to identify regulatory barriers completed by July 2021

   - Identify 2-3 new Urban Renewal Agency districts and complete initial feasibility studies by July 2021
   - Identify known infrastructure-related development constraints and develop strategic plan to address those constraints by July 2021
   - Complete update and refinement of the Downtown 2050 Plan and work with partners to develop marketing strategies for redevelopment projects in downtown
   - Conduct outreach and education with local and non-local development community to promote Opportunity Zone projects
   - Develop CDBG-funded micro-lending and business incubation program, partner with local lending institutions (if possible and beneficial) to leverage additional funding to support small, local startup businesses in targeted industries
   - Assess feasibility of a public maker-space
   - Emphasize the value of place-making in Economic Development strategies
- *Funding*: Funding for review is contained within the 2019-21 biennial budget for the departments listed. Determine appropriate funding source for new UR districts feasibility analysis consistent with statutory limitations on existing TIF.
- *Future Deliverables*:
   - Formally create and begin to administer 2-3 new Urban Renewal Agency districts
   - Update City's Economic Element and incorporate an Economic Development Strategy into that document

DOWNTOWN REDEVELOPMENT

Downtown Redevelopment: The City will seek opportunities to assist with the development and redevelopment opportunities within the downtown core area.

- **Liberty Park Plan:** Implement the strategies from the Liberty Park Plan that will assist with creating housing and redevelopment. Seek opportunities to connect Liberty Park to other areas through public infrastructure improvements. Develop and implement strategies for improvements to Riverside Avenue.
    - ***MURA Board: By October 1, identity and prioritize projects. Direct staff to amend the City Center Revitalization Plan.***
    - *Department Lead*: MURA staff
    - *Supporting Departments*: Development Services and City Manager's Office
    - *Biennium Deliverable*: Completion and adoption of Liberty Park Plan. MURA Board to prioritize projects listed within plan and dedicate funding for implementation.
    - *Funding*: $15-$18 million from MURA with possible funding coming from Public Works for infrastructure.
    - *Future Deliverables*: Staff anticipates that the implementation of the plan will require two biennium's. Projects identified by the Liberty Park Plan.

- **Reimagine Parking District:** Develop an updated strategy to provide both public and private parking opportunities. Review opportunities to develop more robust and responsive parking options, including an assessment of potential expansion of the Parking District to address both business, student, and residential needs.
    - *Department Lead*: City Manager's Office
    - *Supporting Departments*: Planning Department and MURA Staff
    - *Biennium Deliverable*: Parking District Capacity Plan
    - *Funding*: Undefined, but contained within the Parking Fund.
    - *Future Deliverables*: Actions defined within the Capacity Plan; improved signage, improved metering, location based standards, expanded hours of use of city owned lots.

- **Seismic Retrofit Program:** Continue working with property owners within the Urban Renewal District in providing financial assistance as a match for seismic retrofitting of buildings that will provide housing or economic improvements.
    - *Department Lead*: Urban Renewal
    - *Supporting Departments*: Development Services
    - *Biennium Deliverable*: Provide matching funds for either engineering studies or actual improvements to six buildings during the biennium.
    - *Funding*: $2,000,000 from Urban Renewal along with grants from the State and Federal Sources.
    - *Future Deliverables*: Evaluation of the program will determine impacts and consideration for future renewal of this program.

- **Public/Private Partnerships:** Create Public/Private Partnerships for the development of City and privately owned downtown properties for housing and/or retail. Create a streamlined development process to assist private property owners and developers. Update already established City plans that will help develop clean, safe and inviting spaces. Leverage existing, near-term and long-term opportunities to focus on economic development and Bear Creek Greenway as a recreational amenity. Update land-use and design standards for MURA and Downtown areas that establishes a compatible use to achieve Council goals. Seek to replicate where appropriate throughout Medford.
    - *Department Lead*: Urban Renewal
    - *Supporting Departments*: City Manager's Office and Development Services
    - *Biennium Deliverable*: Development Services staff to create a streamlined review process for projects within the downtown area. Review and update the Medford 2050 to assist with the direction on development. Review and implement appropriate items within the Bear Creek Master Plan. Identify all City owned properties to market for possible development.
    - *Funding*: City to possibly provide property as matching funds for development project.
    - *Future Deliverables*: Evaluation of the program will determine impacts and consideration for future renewal of this program.

Health and Safety: Proactively address the health and safety needs of the community by providing a high quality of service and collaboration with community partners to implement initiatives aimed at improving challenges related to a growing city.

- **Neighborhood Livability Partnership:** Continue with the support of this program which partners with other government agencies and non-profits to address residential properties that are out of compliance.
  - *Department Lead*: Police
  - *Support Departments*: Legal, Community Development, Jackson County, and local non-profits.
  - *Biennium Deliverable*: Substantial improvements to identified properties, which assists with livability issues within their neighborhoods. Staff estimates addressing 12 of these properties per biennium.
  - *Funding*: Program funding is currently contained within various departments' budgets. Abatement costs are recovered.
  - *Future Deliverables*: Reduction on number of problem properties and increased safety within those neighborhoods.

- **Address Livability Issues:** Implementation of the Livability Team that will focus on issues around the Bear Creek Greenway, Downtown and nuances properties. Continue to partner with Jackson County, Oregon Department of Transportation and non-profits on Greenway Health and Safety Operations.
  - *Department Lead*: Police
  - *Supporting Departments*: Fire, and Parks & Recreation
  - *Biennium Deliverable*: Increase patrols in the downtown and greenway. Link at least 40 individuals to available services. Removal of 10-acres non-native vegetation which will reduce fire hazards and provide safety along the greenway.
  - *Funding*: $150,000 for the biennium has been budgeted by the various departments for other action items. Additional funds are needed to address the removal of non-native vegetation.
  - *Future Deliverables*: Five percent reduction in the amount of illegal camping as a result of the efforts, nuance properties are abated and an increase in community use of Bear Creek Greenway Park areas.

- **Homeless System Action Plan (HSAP):** Implement goals and actions identified in the HSAP that address health and safety issues. Addressing unsheltered homelessness and encampments along with expanding diversion and prevention strategies through establishing partnerships and funding.
  - ***Mayor and Council: Adopt plan by October 1, 2019. By November 2019, Council to set priorities for Community Development Block Grants and General Fund Grants. Issue grants based on Council priorities.***
  - *Department Lead*: Housing and Community Development
  - *Support Departments*: City Manager's Office, Police, Fire, CoC and partners.

  - *Biennium Deliverable*: Staff to recommend priorities based on health and safety needs. Report on progress on the HSIP along with CoC.
  - *Funding*: Amount TBD. Funding available through Community Development Block Grants, General Fund Grants and contributions by other agencies.
  - *Future Deliverables*: Provide update on goals and actions contained within the HSIP.

- **Public Safety Level of Service:** Update strategic and operational plans for both Fire & Rescue and Police Department. Plans are to identify recommendations on levels of service and expectations by Mayor and Council.
  - ***Mayor and Council: Adopt Level of Service along with Strategic Plans for both Fire & Rescue and Police. Identify resources if additional staffing is needed for future biennium.***
  - *Department Lead*: Fire & Rescue, Police Department
  - *Support Departments*: City Manager's Office and Finance
  - *Biennium Deliverable*: Medford Fire & Rescue Strategic Plan: Level of Service, Alternative Responses, Services Boundaries and Facilities Plan. Medford Police Department Strategic Plan: Level of Service
  - *Funding*: $150,000 for Fire & Rescue plan have been provided through the 2019-21 Biennial Budget and is contained within the City Manager's Budget. The Police Department plan has funding within the 2019-21 budget.
  - *Future Deliverables*: Fire & Rescue – Level of Service, service boundaries, and alternative responses to medical calls. Police – Level of Service.

- **Emergency Management:** Complete an update to the City of Medford Emergency Operations Plan. Complete necessary training for elected officials, staff and volunteers. Plan needs to include access to east and west areas of Medford for Police, Fire, Public Works and other organizations as necessary, address first and second response teams, identify additional public works infrastructure that could be needed (e.g., eastside service center for Public Works that includes a fueling station) and include a business resumption plan for City offices and staff.
  - ***Mayor and Council: Adopt an update to the City of Medford Emergency Operations Plan. Complete all necessary National Incident Management System training.***
  - *Department Lead*: Emergency Management Coordinator and Public Works
  - *Support Departments*: All City Department's
  - *Biennium Deliverable*: Updated Emergency Operations Plan. Training for all elected officials and identified City Staff. Recommendations and implementation of an East Medford Service Center.
  - *Funding*: Is contained within the 2019-21 Biennial Budget for Emergency Management. $3,000,000 to design and construct Phase 1 of an eastside Public Works facility that may include constructing site access and fencing, installation of utilities, construction of a second fueling facility and fuel storage.
  - *Future Deliverables*: Fire & Rescue – Maintenance of City of Medford Emergency Operations Plan. Updated contacts to be updated/transitioned into digital system, Everbridge. Table top exercises to be performed involving all-hazards within the City's plan. Public Works – completion on future phases of East Medford Service Center

Exhibit C
City of Medford 2015-19 Consolidated Plan Goals, Objectives and Strategies

The Consolidated Plan outlines a set of five-year goals, objectives and strategies that the City aims to accomplish through annual Community Development Block Grant (CDBG) federal entitlement funds, the Housing Opportunity Fund (HOF) through construction excise tax revenue, and leverage from the City's community partners. Partnership and collaboration with agencies from the nonprofit and private sector are essential to achieving outcomes through implementation of targeted projects and programs. The following goals, objectives and strategies serve as a foundation for annual funding priorities and allocations to accomplish outcomes also presented below:

<table>
<tr><td>Goal 1</td><td>Improve the Condition and Availability of Affordable Housing</td></tr>
<tr><td>Objectives & Strategies</td><td><u>Objective 1</u>: Improve and maintain living conditions, safety and long-term affordability of rental and/or homeowner housing occupied by low/moderate-income and special needs households.

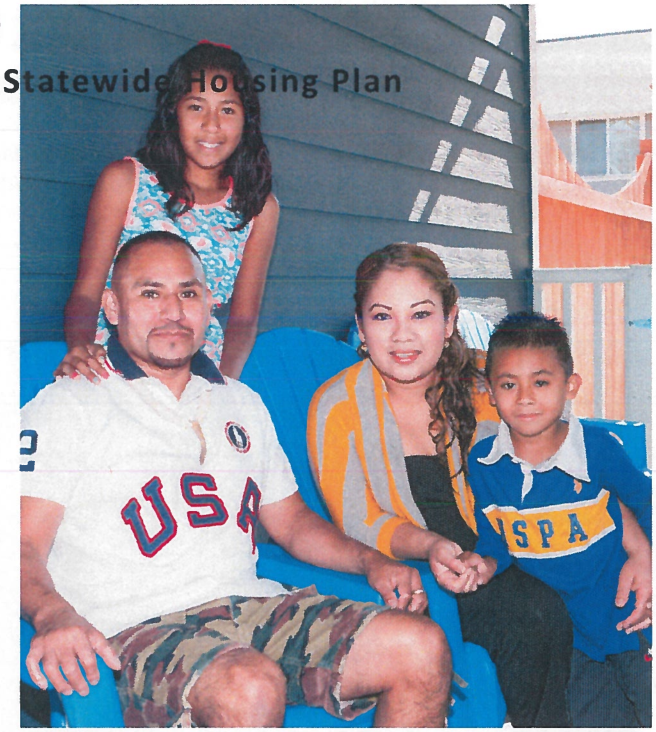
Strategies:
Provide no-interest loans to low/moderate-income homeowners for the correction of recognized hazards to health and safety, such as leaking roofs, failed heating systems, unsafe wiring, failed plumbing and other necessary eligible repairs.
Support programs that provide low/moderate-income and special needs homeowners and/or renters with minor and emergency repairs, and rehabilitation and weatherization assistance.
<u>Objective 2</u>: Create more opportunities for low/moderate-income and special needs residents to secure affordable and livable rental and/or homeowner housing.

Strategies:
Provide financial assistance to help potential low/moderate-income homeowners with down payment and closing costs.
Support programs that provide financial assistance to low/moderate-income residents with rental deposits, rent and utility payments and foreclosure prevention services.
Support the creation of higher density, mixed-income and mixed-use housing in the redevelopment of the downtown area.
Provide financial assistance to acquire land and/or improve infrastructure in support of new affordable housing.
Support housing programs that help homeless persons transition from homelessness to permanent housing.</td></tr>
</table>

	• Reduce barriers to affordable housing by developing a plan to address the Regulatory Barriers Report for Medford, which will include plans to reduce these barriers.
Goal 2	**Improve the Ability of Low/Moderate-Income and Special Needs Populations to Become Self-Sustaining**
Objectives & Strategies	<u>Objective 1</u>: Improve the opportunities of low/moderate-income residents and special needs populations to become self-sustaining through the availability and accessibility of essential support services offered directly through public service agencies. ***Strategies:*** • Support public services agencies that assist low/moderate-income and special needs populations with safety net services to overcome barriers including mental illness, substance abuse, domestic violence, child abuse, physical and mental disabilities and homelessness. • Support programs that provide fair housing services and education to low/moderate-income and special needs populations. • Support programs that assist low/moderate-income and special needs residents to become self-sustaining through job skills training and workforce readiness programs, transportation services and the availability and affordability of day care and after school care. • Support programs that provide loans and technical assistance to small businesses and promote development of mechanisms that will encourage micro-enterprise such as the creation of small business incubators.
Goal 3	**Improve Living Conditions in by Addressing Community Development Projects that Improve Public Infrastructure, Public Facilities and Neighborhood Revitalization**
Objectives & Strategies	<u>Objective 3</u>: Improve community infrastructure and facilities, reduce blighting influences, and preserve and build community through neighborhood revitalization in low/moderate-income neighborhoods. ***Strategies:*** • Provide assistance to repair and improve public infrastructure including street improvements, sidewalks, water and sewer improvements, curbs, gutters, lighting and street trees in low/moderate-income neighborhoods. • Provide assistance to develop neighborhood facilities such as youth centers, senior centers, parks and recreation facilities, open space and community centers. • Support the removal of dilapidated structures and other blighting influences in low/moderate-income areas and on a spot blight basis. • Actively enforce City codes to improve the habitability and safety of housing and eliminate blighting influences in neighborhoods.

The table below identifies the City's five-year outcome indicators adopted through the Consolidated Plan.

Goal 1	Objective 1	Homeowner Housing Rehabilitated	76 Units
	Objective 2	Tenant-based Rental Assistance/Rapid Re-housing	35 Households, annually
Goal 2	Objective 1	Homeless Person/Overnight Shelter	1,875 Persons
		Public Service Activities other than LMI Housing Benefit	7,166 Persons
Goal 3	Objective 1	Public Facility or Infrastructure Activities other than LMI Housing Benefit: 6,030 persons	6,030 Persons
		Public Facility or Infrastructure Activities for LMI Housing Benefit	50 Households
		Buildings Demolished/Blight Removal/Code Enforcement Resolutions	27 Properties



Breaking New Ground

OREGON'S STATEWIDE HOUSING PLAN

SUMMARY

2019-2023

Across Oregon, housing has emerged as a paramount concern.

The lack of available housing, high rents and high home prices are driving rapid increases in housing instability and homelessness. The data is clear: too many Oregonians are without a safe, stable and affordable place to call home.

As we embarked on this Statewide Housing Plan in 2017, we traveled throughout Oregon on a listening tour, which brought us to communities large and small — coastal villages, Central Oregon boomtowns, Eastern Oregon wheat country, and growing Portland area suburbs. In each community, the housing crisis loomed large. You told us the heartbreaking stories of your friends, neighbors and family members who are struggling to find a pathway out of poverty; you described the homeless youth in your city that line up around the block hoping for shelter each night; you shared the fear of speaking out about mold and dirty water in your homes; and you talked about the business in the next town that had to cut jobs because there is nowhere for employees to live. We heard about the impacts this housing instability is having on our school children, the medically fragile, elders, communities of color and the workforce.

Across the state, we also heard inspirational stories that demonstrate our communities' resolve and desire to bring about change. We have unprecedented engagement and leadership on housing issues from our elected officials in Salem and at the local level. Oregon Housing and Community Services is ready to match that resolve and engagement. At the date of this letter, we have a record number of homes — over 8,000 — in our affordable housing development pipeline. This is nearly three times our historic production. We are serving more people through our homeless programs than ever before, and we are in the midst of another banner year for first time homebuyers. Yet more is needed. The people we serve will stand front and center as we drive to solutions through national best practices, increased impact, partnership and innovation.

This Statewide Housing Plan is our road map as we embark upon a series of bold initiatives to realize this vision over the next five years. I encourage you to join us in this endeavor to lay the foundation for a new era of hope and opportunity for our communities. For one individual, for one family at a time, we can end homelessness. We can end housing instability. We can create a system that advances equity and eliminates disparities for people of color. And we can create an Oregon where we all have the opportunity to pursue prosperity and live free from poverty.

Sincerely,
Margaret Salazar, *Director*

Together, we can make Oregon a place where every child has a safe and stable place to call home.

Plan Purpose

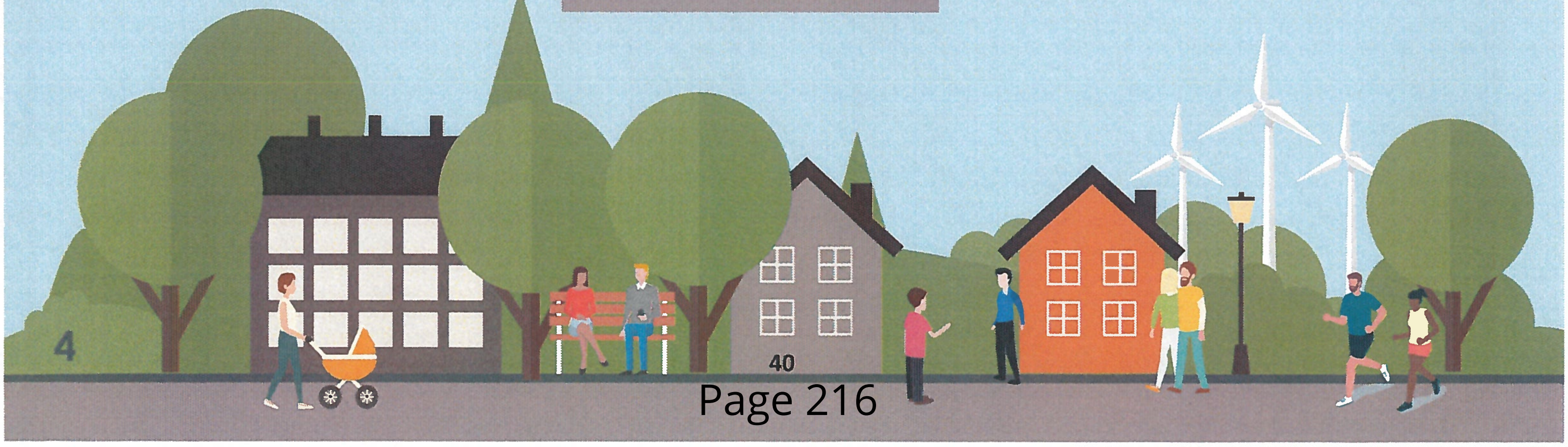
The Statewide Housing Plan articulates how Oregon Housing and Community Services (OHCS) will pave the way for more Oregonians to have access to the stable housing opportunities necessary for self-sufficiency. To do this, the Plan...

- Draws on quantitative and qualitative data to illuminate areas of need across the state and within specific communities;
- Communicates **six priorities** to build support and inspire coordinated action;
- Describes how OHCS will lead, fund, and support our partners on priority issues over the next five years; and
- Provides a framework and direction for OHCS to prepare annual work plans, set goals, monitor progress and implement our priorities.

The Plan marks a new way of doing business for OHCS. It lays the foundation for OHCS to be a data- and research-driven organization, and proposes a new way of collaborating and focusing resources and energy to address the most pressing housing issues facing Oregon today.

Guiding Principles

The **guiding principles** set direction for OHCS over the five-year plan horizon and beyond, building on our mission statement, vision and core values. They are crosscutting philosophies that inform how we will approach our work and guide our decisions over the next five-plus years across the department's many programs.



PRIORITY

Equity and Racial Justice

Advance equity and racial justice by identifying and addressing institutional and systemic barriers that have created and perpetuated patterns of disparity in housing and economic prosperity.

GOAL A: Communities of color experience increased access to OHCS resources.

GOAL B: Create a shared understanding of racial equity.

*** Numerical target to be published by December 2019**

People of color have long faced discrimination and inequity in housing, home loans and government services. African Americans, Native Americans, Latinos and others face persistent poverty and wage gaps that force families to spend a greater share of their incomes on rent, leading to housing insecurity and a higher risk of homelessness. In addition, ongoing discrimination in the housing market combined with systemic barriers to economic mobility, wealth creation and opportunities impede progress toward parity. We are committed to an intentional, data-driven approach in collaboration with our partners to reduce disparities in housing and social service provision and to achieve greater parity in housing stability, self-sufficiency and homeownership for communities of color.

PRIORITY

Homelessness

Build a coordinated and concerted statewide effort to prevent and end homelessness, with a focus on ending unsheltered homelessness of Oregon's children and veterans.

GOAL: 85% of households served are stabilized in housing for six months or longer.

All available data suggests that homelessness has increased during the current housing crisis, likely driven by increasing rents, which compound personal and societal causes of homelessness. Homelessness and housing instability make it harder to find and keep a job, treat or manage medical conditions, and learn in school. Ending homelessness means that every community has a comprehensive system in place to prevent homelessness, and where it can't be prevented, ensure it is a brief, one-time experience. There is substantial momentum around ending homelessness, particularly for veterans and children. OHCS will focus services and resources to drive improvement in housing stability and collaborate with partners to end veterans' homelessness in Oregon and build a system in which every child has a safe and stable place to call home.

PRIORITY

Permanent Supportive Housing

Invest in permanent supportive housing, a proven strategy to reduce chronic homelessness and reduce barriers to housing stability.

GOAL: Fund the creation of 1,000 permanently supportive homes.

Permanent supportive housing is a proven model for successfully housing economically vulnerable people who may not otherwise be able to maintain stable housing. Permanent supportive housing combines housing affordable at extremely low incomes with wraparound supportive services. A wide body of evidence supports the use of permanent supportive housing to provide better outcomes for people and reduce costs for health care, criminal justice, emergency services and other public systems. OHCS has heard resounding support for the permanent supportive housing model from local governments and partners. OHCS will increase our commitment to permanent supportive housing by working with partners to align resources for, and eliminate barriers to, producing permanent supportive housing.

PRIORITY

Affordable Rental Housing

Work to close the affordable rental housing gap and reduce housing cost burden for low-income Oregonians.

GOAL: OHCS will triple the existing pipeline of affordable rental housing up to 25,000 homes.

Many studies have shown that access to affordable housing has broad, positive impacts. Affordable housing increases financial stability and allows families to prioritize spending on what matters most, including food, transportation, healthcare and saving for college or retirement. In recent years, OHCS and its affordable housing development partners responded to an ongoing housing crisis with record production of new units. Still, rents and housing prices continue to rise relative to incomes, increasing levels of housing cost burden, while low vacancy rates make it difficult to find housing. OHCS will work with our partners to expand and expedite delivery of affordable rental housing, reduce housing cost burden for low-income renters, and preserve existing affordable housing units.

PRIORITY
Homeownership

Provide more low- and moderate-income Oregonians with the tools to successfully achieve and maintain homeownership, particularly in communities of color.

GOAL A: Assist 6,500 households in becoming successful homeowners.

GOAL B: Double the number of homeowners of color in OHCS homeownership programs.

Affordable homeownership is a critical component of any forward-thinking strategy that seeks to address both housing and prosperity. In markets with rising home prices, fixed home payments insulate homeowners from displacement pressures. Homeownership provides an avenue to build wealth and home equity that can support college education, business start-up, or other financial needs. Across the income spectrum, communities of color have lower homeownership rates than whites due to historical and ongoing discriminatory lending and disparate access to home financing. OHCS will expand the reach of existing homeownership programs for low- and moderate-income households and explore innovative new programs to address unmet needs in the marketplace. We will also increase the number of homebuyers of color in our homeownership programs through engagement with culturally responsive organizations and intentional program design.

PRIORITY
Rural Communities

Change the way OHCS does business in small towns and rural communities to be responsive to the unique housing and service needs and unlock the opportunities for housing development.

GOAL: Increase OHCS funded housing development in rural areas by 75%.

Small towns and rural communities face distinct housing and service provision challenges. While housing costs may be lower, incomes are lower as well, and transportation costs can be significantly higher. There has been little new housing, especially multifamily housing, built in rural areas in the last decade. Issues include lack of suitable and available land, high labor costs to bring contractors to rural areas, rents and home prices too low to cover the cost of new construction, and lack of financing for smaller-scale projects. OHCS will collaborate with small towns and rural communities to increase housing development; tailor services to rural areas' unique needs; and build stronger partnerships among housing and service providers, private industry, employers, local governments, philanthropy and other stakeholders to improve capacity and leverage resources.

Working together to serve individuals, families and communities throughout Oregon

The full Statewide Housing Plan, appendices, and baseline data for each priority goal are available on the OHCS website at:

https://www.oregon.gov/ohcs/pages/oshp.aspx

Published February 2019

Equal Opportunity Housing and Equal Opportunity Employment
Oregon Housing and Community Services is committed to providing meaningful access.
For accommodations, modifications, translation, interpretation or other services,
please contact the OHCS office at
PH 503-986-2000, TTY 503-986- 2100,
or email at **housinginfo@oregon.gov.**

ALL IN **FOR HEALTH** | **JACKSON** AND **JOSEPHINE COUNTIES**

A healthy community **IS EVERYONE'S BUSINESS**

Jackson and Josephine Counties
2019-2022 Community Health Improvement Plan Priorities

Overview

A person's health is shaped by the overall health of the area they live in. Things that affect lives, jobs, relationships and available resources can also change a person's health.

What is the *All in for Health* Community Health Improvement Plan (CHIP)?

The *All in for Health* CHIP is a set of priorities aimed at improving local health issues in Jackson and Josephine counties. It was developed from a study called the Community Health Assessment (CHA). The study results showed health needs and strengths of our area based on things like jobs, housing, and education. Information was included from over 200 existing local, regional, state, and national sources. Over 1,100 people took a survey or met in person. People were asked their views on the area's strengths, challenges, and health concerns.

Six major themes rose to the top:

- Substance use
- Education and workforce growth
- Mental health and well-being
- Poverty and employment
- Parenting and life skills
- Affordable housing

From the CHA study, the *All in for Health* CHIP for 2019-2022 was made. **The plan is to work on these three (3) priorities:**

- Behavioral health (mental health and substance use)
- Parenting support and life skills
- Affordable housing

What happens next?

The plan will require teamwork among health care providers, local governments, educators, non-profits, and the people who live in the area. It builds on current programs and helps bring together local resources.

How can I help?

Spread the word about the *All in for Health* CHIP! To learn more and get involved, contact Angela Warren, at *angela@jeffersonregionalhealthalliance.org* or **(541) 292-6466**. The full CHA and CHIP can be seen at *JeffersonRegionalHealthAlliance.org*.

Jackson and Josephine Counties Collaborative

2019–2022 Community Health Improvement Plan (CHIP) priority themes and goals

The priority themes and goals listed here were developed with the help of more than 100 people from 60 local agencies in Jackson and Josephine counties. Local partners are working together to put in place action plans to help meet the goals.

Affordable housing

- Increase the number of people paying 30% or less of what they earn for housing.
- Increase the number of people living in homes that are safe, accessible, and are easily served by community services.

Mental health and well-being

- Lessen the effects of trauma.
- Help young people and older adults feel less alone.
- Provide the community with ways to accept and help people who need behavioral health services.
- Prevent use and misuse of substances.
- Promote ways to reduce the harm that happens with mental health and substance use issues.
- Improve access and coordination of care for people needing mental health and addiction services.

Parenting support and life skills

- Help families feel connected, cared for and strengthened.
- Help families have access to safe, affordable and quality child care.
- Increase access to food, including healthy food.
- Assure community-based organizations work together to deliver coordinated services.

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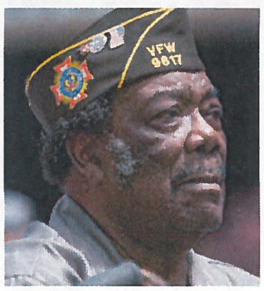
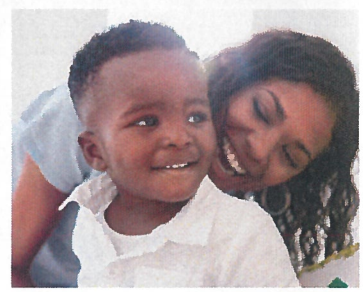
Exhibit F
The Federal Strategic Plan to Prevent and End Homelessness





Home, Together:

THE FEDERAL STRATEGIC PLAN TO PREVENT AND END HOMELESSNESS

UNITED STATES INTERAGENCY COUNCIL ON HOMELESSNESS

United States Interagency Council on Homelessness

Department of Agriculture

Department of Commerce

Department of Defense

Department of Education

Department of Energy

Department of Health and Human Services

Department of Homeland Security

Department of Housing and Urban Development

Department of the Interior

Department of Justice

Department of Labor

Department of Transportation

Department of Veterans Affairs

Corporation for National and Community Service

General Services Administration

Office of Management and Budget

Social Security Administration

US Postal Service

White House Office of Faith-Based and Community Initiatives

USICH would like to thank the hundreds of people from across the country, including staff from local, state, and national agencies and organizations, community volunteers, advocates, people with past and current experiences of homelessness, and many others, who provided their time and expertise to ensure that this Plan reflects a diversity of perspectives.

Home. Because we know that the only true end to homelessness is a safe and stable place to call home.

Home enables our families, friends, and neighbors—indeed, everyone in our nation—to have a platform from which they can pursue economic opportunity. Having a home provides people with better chances for succeeding in school and advancing their careers. It also allows them to take care of their health, build strong families, and give back to their communities.

But far too many people experience homelessness in our country, limiting their ability to pursue these opportunities.

Together. Because the causes of homelessness are complex, and the solutions are going to take all of us working together, doing our parts, strengthening our communities.

Thriving communities need enough housing that is affordable and equitably available to people across a full range of incomes—from young adults just starting out to seniors who want to spend their remaining years feeling secure. Quality educational and career opportunities, child care, health care, substance abuse and mental health services, and aging services can help individuals and families build strong social networks, pursue economic mobility, and strengthen their overall well-being. These services, and other federal, state, and local programs, must be well-coordinated among themselves, and with the business, philanthropic, and faith communities that can supplement and enhance them.

Together, We Are Making Progress

The problem of homelessness can seem daunting—it is estimated that on any given night more than 550,000 people are experiencing homelessness in America.[1] The good news is that states and communities, with the support of the federal government and the private sector, are making progress, using best practices and building the coordinated responses that are necessary to reduce and ultimately end homelessness in America.

Driven by federal, state, and local actions, and by public and private partnerships, point-in-time data shows an estimated 13% fewer people were experiencing homelessness in 2017 compared to 2010, and there were 17% fewer people who were unsheltered, sleeping on our sidewalks, in our parks, and in other unsafe environments.[2]

For some targeted groups, communities have made even greater progress. For example, since 2010, there are 46% fewer Veterans and 27% fewer families with children experiencing homelessness. And we've reduced chronic homelessness—homelessness among people with disabilities who have been without a home for long or repeated periods of time—by 18%.[3]

In addition, since the release of federal criteria and benchmarks in 2015 to measure progress for ending homelessness among Veterans, more than 60 communities across more than 30 different states have effectively ended Veteran homelessness.[4] And three communities have achieved the federal criteria and benchmarks for ending chronic homelessness.

These achievements show that ending homelessness is possible. And we know that it's possible in all kinds of places—big cities, suburbs, small towns, and across entire states.

Areas of Increased Focus in This Plan

- Increasing Affordable Housing Opportunities
- Strengthening Prevention and Diversion Practices
- Creating Solutions for Unsheltered Homelessness
- Tailoring Strategies for Rural Communities
- Helping People Who Exit Homelessness to Find Employment Success
- Learning from the Expertise of People with Lived Experience

Working Together is What Works

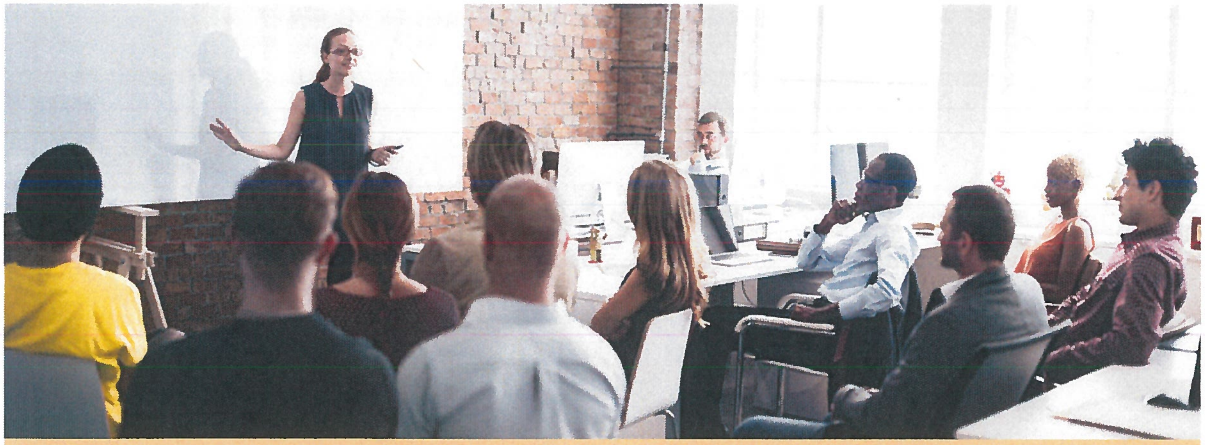
We are making this progress because communities are focused more than ever on the ultimate solution to homelessness: Home. And they are doing this work by breaking down silos and working together in profoundly new ways. To help people find the stability of home, communities are embracing Housing First practices, through which people experiencing homelessness are connected to permanent housing swiftly and with few to no treatment preconditions, behavioral contingencies, or other barriers. Communities are also developing coordinated homelessness service systems so that people who need help are identified quickly, their needs and strengths are assessed, and they can be matched to the appropriate local housing and services opportunities and social supports. Through housing interventions like supportive housing and rapid re-housing, individuals and families are connected to the tailored array of community services that can help them stay and succeed in their home and pursue economic advancement.

Our Path Home

While our progress is promising, we also know that we have much more work to do, and many more challenges that we must face together. Beyond the critical work to make sure there is enough housing for everyone, we must also focus more attention on preventing people from falling into homelessness in the first place and on diverting people from entering emergency shelter if they have other stable options available.

We also have an urgent need for strategies to address the immediate crisis of unsheltered homelessness—especially in communities with high-cost housing markets—and homelessness in rural communities, where housing and services are scarce. We must also address the racial inequities and other disparities in the risks for, and experiences of, homelessness. And we must be clear that exiting homelessness is not the end point for people, it is a starting place from which they can pursue employment, education, community involvement, and other goals.

These are difficult challenges, but momentum is on our side. We know where we are going and we know how we are going to get there: **Home, Together**.



OUR SHARED NATIONAL GOALS

Through the hard work of communities around the country, we now have proof of something that we didn't before—that ending homelessness is achievable. *Home, Together* builds upon what we have learned from states and communities over time, and lays out the strategies we know we must advance at the federal level in order to support and accelerate state and local progress.

Home, Together has one fundamental goal, a goal shared across federal, state, and local partners: to end homelessness in America.

But the people who experience homelessness are diverse—in their experiences, in their challenges, in their household compositions, in their ages, in many other ways—and we must tailor and target our strategies and actions to reflect that diversity.

Therefore, the Plan sets important population-specific goals as well:

- **To end homelessness among Veterans**
- **To end chronic homelessness among people with disabilities**
- **To end homelessness among families with children**
- **To end homelessness among unaccompanied youth**
- **To end homelessness among all other individuals**

Achieving these shared goals is not possible through federal action alone—it requires strategic focus, effort, and investments from both the public and the private sectors and across all levels of government.

Achieving these goals as a nation means achieving these goals in all our communities, communities that are also diverse—in their demographics, in their needs, in their geographic characteristics, in their progress to date, in their resources, in their infrastructure, in their housing markets, and in many other ways. Some communities have already succeeded at achieving some of these sub-goals, others are on the cusp of major successes, and many are striving hard to make progress but face very significant challenges.

Therefore, the Plan does not set uniform timeframes. Rather, federal partners will continue to work with communities, and provide tools and information, that will enable them to set their own ambitious goals, tailored to their local conditions, and grounded in their local data.

With a few exceptions, the Objectives and Strategies outlined in this Plan are not population-specific. In the implementation of the Plan, USICH will work with its federal partners, through established interagency working group structures, to plan, implement, and assess the impact of specific activities to drive progress toward the population-specific sub-goals. Those activities will also be attentive to the specific needs of other subpopulations of people, such as older adults, people with disabilities, or people with substance use disorders, including opioid use disorders, who are represented across the population goals identified above.

Defining Success

Achieving these goals is grounded in a shared vision of what it means to end homelessness: that every community must have a systemic response in place that ensures homelessness is prevented whenever possible, or if it can't be prevented, it is a rare, brief, and one-time experience. That means that every community must have the capacity to:

- Quickly identify and engage people at risk of and experiencing homelessness.
- Intervene to prevent people from losing their housing and divert people from entering the homelessness services system.
- Provide people with immediate access to shelter and crisis services without barriers to entry if homelessness does occur.
- Quickly connect people experiencing homelessness to housing assistance and services tailored to their unique needs and strengths to help them achieve and maintain stable housing.

To help communities to assess their progress toward achieving this vision, USICH and our federal partners have developed qualitative criteria and quantitative benchmarks that provide states and communities a clear road map for assessing how well their local systems are designed and implemented, for measuring the effectiveness of those systems, and for determining if they have achieved the goals.

About the U.S. Interagency Council on Homelessness

The U.S. Interagency Council on Homelessness (USICH) leads national efforts to prevent and end homelessness in America. We drive action among the 19 federal member agencies that comprise our Council and foster the efficient use of resources in support of best practices at every level of government and with the private sector.

USICH is statutorily charged with developing and regularly updating a national strategic plan to prevent and end homelessness. *Home, Together* is the strategic plan adopted by our Council for Fiscal Years 2018-2022.

USICH will work with its federal partners and the interagency working groups we manage to implement this Plan. USICH will lead and support federal activities aligned with the Plan's Objectives and Strategies, partner with states and communities to implement the most effective practices, and assess the Plan's impact to further strengthen our actions and outcomes.

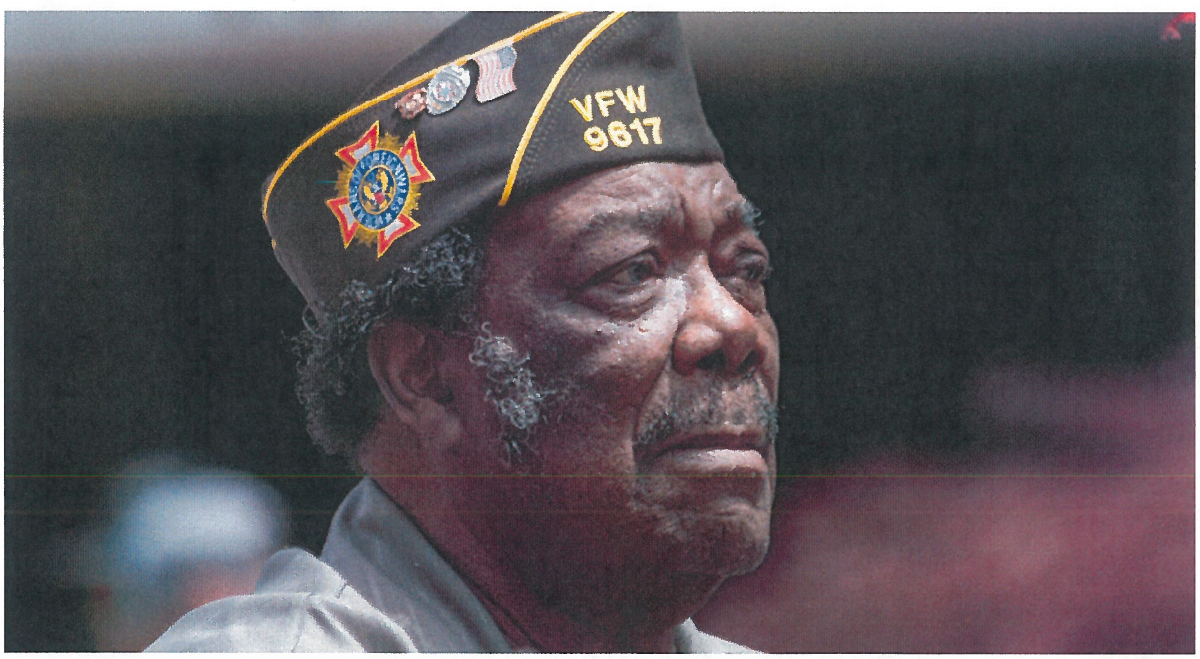
Measuring Our Progress

To drive and track progress against the federal Strategies outlined in *Home, Together,* USICH and its federal partners will develop and utilize an annual performance management plan with specific target actions, milestones, and deadlines. USICH will also use multiple performance measures to assess the overall impact of the implementation of *Home, Together.*

USICH will focus on changes in the following key measures:

- The number of people experiencing sheltered and unsheltered homelessness at a point in time in the annual Point-in-Time count, including Veterans, people experiencing chronic homelessness, families with children, unaccompanied youth, and all individuals.
- The number of states reporting increases versus decreases in the number of people experiencing sheltered and unsheltered homelessness within annual Point-in-Time counts.
- The number of Continuums of Care reporting increases versus decreases in the number of people experiencing sheltered and unsheltered homelessness within annual Point-in-Time counts.
- The number of people, including Veterans, people experiencing chronic homelessness, families with children, unaccompanied youth, and all individuals, spending time in emergency shelter and transitional housing annually.
- The number of children and youth, including both students in families and unaccompanied students, identified as experiencing homelessness at some point during the school year.
- The number of communities, states, and Continuums of Care that have achieved each population-specific goal.

These assessments will be used to inform future revisions to the Plan and its Objectives and Strategies, and USICH will provide an annual report on its effort to the President and to Congress.



THE PLAN: FISCAL YEARS 2018-2022

To end homelessness, every community needs to be able to implement a systemic response that ensures homelessness is prevented whenever possible or, if it can't be prevented, it is a rare, brief, and one-time experience. And that systemic response must endure for the long term. The development of such capacity cannot be achieved by any one level of government, or by any one sector alone, and requires the investment of time, effort, and financial resources by federal, state, and local public and private partners, working together in close collaboration.

The Plan focuses on identifying and describing essential federal strategies that will help states, communities, and public and private partners build effective, lasting systems that will drive toward the goals now, and be able to respond quickly and efficiently when housing instability and homelessness occur in the future.

The plan also seeks to serve as a road map for non-federal agencies and partners, providing a detailed framework through which they can identify and implement their own strategic activities and align their efforts with federal agencies and other partners.

Home, Together's Eight Objectives

Home, Together is focused on federal strategies that will support states and communities to make homelessness a rare, brief, and one-time experience—and that will sustain that success once achieved. That focus is reflected in its structure.

1. Ensure Homelessness is a Rare Experience

Objective 1.1: Collaboratively Build Lasting Systems that End Homelessness

Objective 1.2: Increase Capacity and Strengthen Practices to Prevent Housing Crises and Homelessness

2. Ensure Homelessness is a Brief Experience

Objective 2.1: Identify and Engage All People Experiencing Homelessness as Quickly as Possible

Objective 2.2: Provide Immediate Access to Low-Barrier Emergency Shelter or other Temporary Accommodations to All Who Need it

Objective 2.3: Implement Coordinated Entry to Standardize Assessment and Prioritization Processes and Streamline Connections to Housing and Services

Objective 2.4: Assist People to Move Swiftly into Permanent Housing with Appropriate and Person-Centered Services

3. Ensure Homelessness is a One-Time Experience

Objective 3.1: Prevent Returns to Homelessness through Connections to Adequate Services and Opportunities

4. Sustain an End to Homelessness

Objective 4.1: Sustain Practices and Systems at a Scale Necessary to Respond to Future Needs

1) ENSURE HOMELESSNESS IS A RARE EXPERIENCE

The Objectives and Strategies in this section focus on actions that will help to make sure that individuals and families experience homelessness much less often. This includes strategies for building strong local systems, expanding partnerships with mainstream programs that are not specifically targeted to people experiencing homelessness, putting a greater emphasis on diversion strategies, and strengthening our ability to prevent housing crises and homelessness. Implementation of these strategies will be grounded in data and analysis and will support communities to address the needs of populations that are disproportionately impacted by homelessness in each community.

Objective 1.1: Collaboratively Build Lasting Systems that End Homelessness

To achieve the goal of ending homelessness and to ensure that homelessness is a rare experience, leaders from all levels of government and the private, non-profit, and faith sectors can come together to:

Build momentum behind a common vision. The national definition of an end to homelessness, and the criteria and benchmarks for achieving the goals, provide the roadmap to success for communities across the country. This common vision allows us to coordinate and align activities, policies, and priorities through regional, state, and local interagency working groups, councils, and other processes, in a way that drives progress.

Understand and enumerate the size and scope of the problem. Collecting, analyzing, and reporting high-quality, timely data on homelessness is essential for understanding who experiences homelessness in the community at disproportionate rates and why. It also helps us target and scale interventions, track results, plan strategically, and allocate resources at the state and local level. By having comprehensive data at the center of collaborative decision-making processes, communities can stretch the resources they have further, understand where new resources are needed, target prevention efforts, and get better results.

Reduce fragmentation. Bringing together areas of government that have typically operated in silos reduces duplicative or contradictory activities and ensures the most effective use of public resources. For example, programs funded by the Departments of Housing and Urban Development (HUD) and Veterans Affairs (VA) have increased coordination to provide better care and quicker access to permanent housing for Veterans experiencing homelessness.[5]

Drive implementation of cost-effective solutions. Using data, evaluation, performance measurement, and research to guide investments can lead to greater utilization of evidence-based and evidence-informed practices that efficiently solve homelessness and make better use of limited resources. For example, evidence-based Housing First approaches have helped serve more people with better results.

To support communities' progress, USICH and its member agencies will focus on the following Strategies:

a. **Equip states and communities to set their own bold and ambitious goals for ending homelessness and to prioritize and appropriately scale state, local, public, and private investments.** Federal agencies will provide technical assistance and modeling tools that can be implemented locally to project current and future needs and the types and scale of housing and services interventions that will be needed to achieve their goals and sustain those successes.

b. **Strengthen the collection, reporting, and utilization of essential data sources,** including Point-in-Time count data, Homeless Management Information System (HMIS) data, State and Local Education Agency Education for Homeless Children and Youth data,[6] Worst Case Housing Needs data,[7] and other relevant data, to better understand and enumerate the size and scope of the challenges that must be addressed. This work also includes increasing community capacity to match administrative data sets, such as health care and corrections, to improve interventions, tailor strategies, and improve outcomes for populations that are disproportionately represented among people experiencing homelessness.

c. **Engage people with lived experience** through advisory committees and policy and planning processes at the federal level, and encourage such engagement at the local and state levels to ensure meaningful opportunities for providing expert advice and input.

d. **Further engage and support state and local elected officials, and educate partners and the public,** regarding the: scope, causes, and costs of homelessness; necessary solutions; evidence-based practices and strategies; and risk factors of homelessness locally, including the disproportionate and persistent impact of homelessness on some populations.

e. **Provide guidance about the roles that a wide range of federal programs and resources can play to support best practices and increase their impact within efficient systems** to prevent and end homelessness—including both the programs that are targeted to addressing homelessness and those that are not.

> ***"Homelessness prevention is not the responsibility of the homelessness crisis response system alone."***

Objective 1.2: Increase Capacity and Strengthen Practices to Prevent Housing Crises and Homelessness

Homelessness prevention is not the responsibility of the homelessness crisis response system alone. Rather, it requires a multi-sector approach and an active focus on housing needs, housing stability, and risks of homelessness across many different public systems. To strengthen our understanding of and approach to implementing effective prevention, communities will be supported in developing partnerships that build a multi-pronged approach to preventing homelessness, focused on actions that:

Reduce the prevalence of risk of housing crises. A complex set of external factors contribute to the risk of housing crises within a community and among different sub-populations. To make inroads in reducing the risk of housing crises, communitywide action is needed to address the wide range of policies contributing to the availability of, and access to, an adequate supply of safe and affordable housing; health and behavioral health resources; education and meaningful and gainful employment; opportunities for economic mobility; affordable child care; and legal assistance.

Reduce the risk of homelessness while households are engaged with or are transitioning from systems. Research and data demonstrate that individuals or families are often engaged with multiple public systems, such as health and behavioral health care, child welfare, and the juvenile and criminal justice systems, prior to their experiences of homelessness.[8] Effective prevention approaches must include enhanced cross-system collaboration, such as increased awareness and attentiveness to housing stability, and effective transition and/or discharge planning that link people to other resources, including employment and other economic mobility supports, to reduce the risk of homelessness upon discharge or following the end of service provision. Communities can also consider policies that increase access to home-visiting programs, family support networks, school-based supports, and other community-based programs that focus on strong families and positive youth development. Family preservation and reunification can also be explored, whenever safe and appropriate, in order to address the disproportionate impact of homelessness on single mothers and youth of color.

Target assistance to prevent housing crises that do occur from escalating further and resulting in homelessness. Targeted assistance may include a combination of financial assistance, mediation and diversion, housing location, legal assistance, employment services, or other supports—many of which can be provided by public, non-profit, faith-based, and philanthropic programs within the community. Strong identification efforts through the implementation of housing status assessments are important tools for programs to effectively identify the most at-risk households, to connect them to the supportive services and/or resources that will best respond to their housing crisis, and to prevent homelessness from occurring.

To support communities' progress, USICH and its member agencies will focus on the following Strategies:

a. **Promote development of an expanded supply of safe and affordable rental homes** through federal, state, and local efforts and investments. This includes assisting communities that are working to adopt policies to expand overall housing supply and to project the scale of affordable housing units—including units that are affordable to people exiting homelessness and units that are accessible to persons with disabilities—needed to meet local demand on an ongoing basis.

b. **Improve access to federally funded housing assistance by eliminating administrative barriers and encouraging targeting and prioritization of affordable housing** to people experiencing homelessness in a community and/or to populations that are especially vulnerable to homelessness.

c. **Increase community capacity and state-level coordination to effectively identify, target, and connect at-risk individuals and families to local resources and opportunities that contribute to and strengthen housing stability,** including job training and apprenticeship programs that create access to career pathways, primary and behavioral health services, early childhood programs, and elementary, secondary, and post-secondary education. For children and youth at risk of homelessness, this work includes strengthening connections to school- and community-based resources that encourage education retention, high school completion, and services that address needs related to these goals, including transportation and additional education services.

d. **Strengthen the evidence base for effective homelessness prevention programming and interventions,** including through rigorous evaluation strategies where possible, disseminate results widely, and use that evidence to encourage resources that are not specifically targeted to ending homelessness to prioritize individuals and families imminently at risk of experiencing homelessness.

e. **Improve efforts to prevent people from entering homelessness as they transition from other systems, such as justice settings, health care facilities, and foster care,** by supporting the development of stronger transition planning, discharge practices, and re-entry processes to improve outcomes, and by prioritizing connections to housing options, family-focused interventions, education resources, health and behavioral health supports, employment and income supports, health care coverage, and legal services.

f. **Strengthen diversion strategies and practices** through guidance and technical assistance with a focus on using identified strengths and existing connections and on assisting people to access safe alternatives to emergency shelter.

g. **Identify and promote implementation of eviction prevention strategies,** including access to: civil legal aid and legal assistance to address obstacles to employment and housing; eviction and foreclosure prevention; and short-term and flexible financial assistance for households experiencing financial crises.

h. **Utilize opportunities in child welfare policy to expand resources for community-based preventive services to support stable housing outcomes** for children and families involved with, or at risk of involvement with, the child welfare system.

i. **Encourage programs that are not specifically dedicated to ending homelessness to fund interventions that promote and support housing stability or to prioritize or serve individuals and families experiencing homelessness.** Federal partners will further encourage partnerships with sources of public resources that can fund housing and related interventions, or that can prioritize or serve those experiencing homelessness, such as public housing, Temporary Assistance for Needy Families (TANF) and child welfare agencies, Head Start programs, and Child Care and Development Fund providers, to strengthen the communitywide approach that ensures that homelessness is a brief experience in any community.

2) ENSURE HOMELESSNESS IS A **BRIEF** EXPERIENCE

The Objectives and Strategies in this section focus on actions that will help make sure people experiencing homelessness are quickly linked to permanent housing opportunities with the right level of services to support their stability and success. Strategies focus especially on coordinated and comprehensive outreach, low-barrier emergency shelter, strong coordinated entry processes, and swift connections to different forms of permanent housing. Housing First practices underpin every element of this response.

Objective 2.1: Identify and Engage All People Experiencing Homelessness as Quickly as Possible

It is important to quickly identify and engage individuals and families when they do fall into homelessness—including sheltered and unsheltered homelessness in locations such as cars, parks, abandoned buildings, encampments, or on the street—to ensure that experience is brief. Communities can use coordinated, housing-focused outreach to people who are unsheltered, in-reach to people in institutional settings, data from multiple systems, and other methods, to identify and engage individuals and families experiencing homelessness, in conjunction with coordinated entry processes and other systems.

> ***"It is important to quickly identify and engage individuals and families when they do fall into homelessness—including sheltered and unsheltered homelessness—to ensure that experience is brief."***

While recognizing that people may move among a variety of settings, communities need the capacity to:

- **Identify every individual and family** that is unsheltered, in shelter, or in transitional housing settings or other residential programs, and to implement robust efforts to identify at-risk households;

- **Coordinate a comprehensive set of strategies** that collect information and data from hospitals, jails, schools, the child welfare system, hotlines and 2-1-1, and other community-based programs; and
- **Use HMIS and other data sources to build and maintain active lists of people experiencing homelessness** and to track the homelessness status, engagements, and permanent housing placement for each individual or family.

Many individuals experiencing homelessness are disengaged from—and may be distrustful of—public and private programs, agencies, and systems, and they may be reluctant to seek assistance. Helping individuals to overcome these barriers often requires significant outreach time and effort, and can take months or even years of proactive and creative engagement to build trust. In order to comprehensively identify and engage all people experiencing homelessness, partnerships across multiple systems and sectors are critically important, particularly among homelessness service systems and health and behavioral health care providers, schools, early childhood care providers and other educators—including higher education institutions—child welfare agencies, TANF agencies, law enforcement, criminal justice system stakeholders, workforce systems, faith-based organizations, and other community-based partners.

To support communities' progress, USICH and its member agencies will focus on the following Strategies:

a. **Support increased capacity of communities to ensure that identification, outreach, and engagement efforts are comprehensive and coordinated** across sectors and agencies, are focused on creating connections to permanent housing with appropriate services, are maximizing utility of shared data sets, and are effectively identifying and engaging people with diverse experiences, needs, and challenges.

b. **Provide targeted guidance and technical assistance to communities with high rates of unsheltered homelessness and high-cost, low-vacancy housing markets** to support innovation, develop stronger practices, and build the evidence base for the most effective practices and strategies for reaching, engaging, and linking people experiencing unsheltered homelessness to options for shelter and to permanent housing opportunities.

c. **Promote targeted outreach, in-reach, and data collection strategies to strengthen state and local efforts to identify people experiencing chronic homelessness and frequent users of shelter and other systems,** including emergency health services and the criminal justice system, and connect them to the housing and support they need.

d. **Strengthen capacity in rural and suburban areas to maximize outreach efforts** tailored to the unique challenges posed by geography and population distribution. Federal partners will develop guidance and tools to support such communities to build partnerships and efficient systems to identify and engage individuals and families experiencing homelessness.

e. **Support communities to develop partnerships with law enforcement that reduce the criminalization of homelessness.** Federal partners will develop further guidance on best practices in addressing unsheltered homelessness and encampments and strategies that reduce the criminalization of homelessness.

f. **Help communities to develop the skills of staff to implement essential best practices,** such as trauma-informed care, motivational interviewing, and critical-time intervention, as well as other skills, such as open communication, cultural responsiveness, mental health first aid, staff care, and recognizing patterns of interaction.

> ***"Crisis services are the critical front line of communities' responses to homelessness, helping people meet basic survival needs while also helping them swiftly secure permanent housing opportunities."***

Objective 2.2: Provide Immediate Access to Low-Barrier Emergency Shelter or Other Temporary Accommodations to All Who Need it

Emergency shelter, other temporary accommodations, and other crisis services are the critical front line of communities' responses to homelessness, helping people meet basic survival needs for shelter, food, clothing, and personal hygiene, while also helping them resolve crises and swiftly secure permanent housing opportunities.

Provide access to low-barrier emergency shelter. An effective crisis response system helps individuals and families experiencing homelessness avoid the need to enter emergency shelter whenever possible. It is also able to immediately provide high-quality, housing-focused shelter or other temporary accommodations for those living in unsafe situations, including those fleeing domestic violence and human trafficking and those living in unsheltered locations. Communities should have effective models of emergency shelter and other temporary accommodations available that:

- Meet the needs of all members of a household and self-defined family and kinship groups, including infants and young children;
- Do not turn people away or make access contingent on sobriety, minimum income requirements, or lack of a criminal history;
- Do not require family members and partners to separate from one another in order to access shelter;
- Ensure that policies and procedures promote dignity and respect for every person seeking or needing shelter; and
- Provide a safe, decent, welcoming, and appropriate temporary living environment, where daily needs can be met while pathways back to safe living arrangements or directly into housing programs are being pursued.

Provide access to service-enriched, longer-term temporary accommodations when needed and appropriate. Longer-term temporary accommodations with a high level of supportive services, such as transitional housing programs, are typically costlier, but may fill a need for households with more intensive service needs.[9] These households might include youth and young adults who would benefit from a longer-term, more supportive living environment, survivors of domestic violence or other forms of severe trauma who feel unsafe living on their own in the community, or some people in recovery from substance use disorders who are seeking a communal, recovery-focused environment. Communities need the capacity to provide a meaningful array of housing options to promote choice and to assess both how these interventions are targeted and their outcomes in connecting people to permanent housing.

To support communities' progress, USICH and its member agencies will focus on the following Strategies:

a. **Partner with communities to identify and define appropriate standards for the provision of emergency shelter and other temporary accommodations,** addressing physical environments, service strategies, operational protocols, and performance expectations.

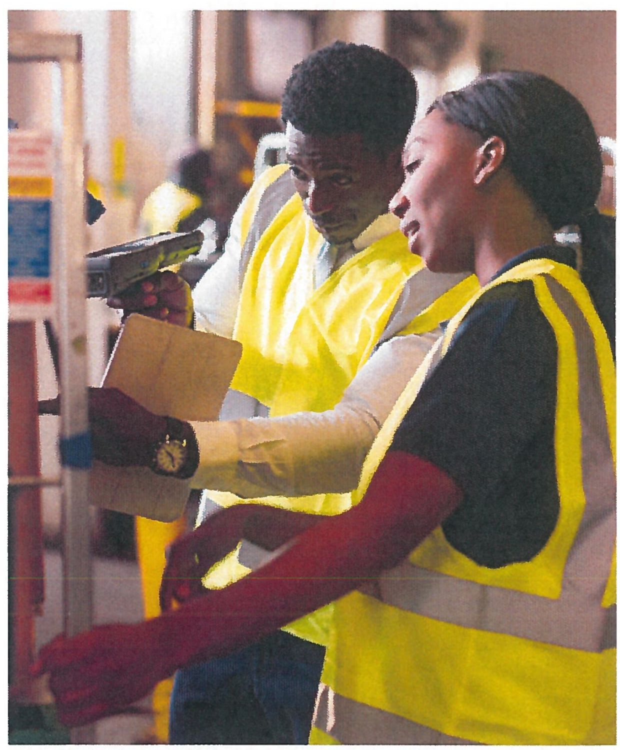
b. **Enhance the capacity of emergency shelter providers to implement low-barrier approaches,** to provide fair and equitable access, to address the needs of households of all compositions, and to implement Housing First approaches and provide adequate services within communities to strengthen exits to permanent housing.

c. **Improve access to emergency assistance, housing, and supports for historically underserved and overrepresented groups,** such as youth who have been involved in the juvenile justice and/or child welfare systems; people who have been sexually exploited or labor-trafficked; people who identify as LGBTQ; people who are gender-non-conforming; people living with HIV/AIDS; youth that are pregnant or parenting; people with mental health needs; and racial and ethnic minorities.

d. **Increase the availability of medical respite programs** in communities to allow hospitals to discharge people experiencing homelessness with complex health needs to medical respite programs that can help stabilize their medical conditions and assist them to access or return to safe and stable housing.

e. **Align services to ensure that people with behavioral health care needs have adequate and appropriate access to emergency shelter or other temporary accommodations** that can address their service and housing needs.

f. **Continue to assess and retool transitional housing programs to best address local needs.** Federal partners will support communities to reduce barriers to entry and consider conversion or reallocation of resources where appropriate to cost-effective alternatives, such as permanent supportive housing, rapid re-housing, crisis or interim housing, or transition-in-place models, and to maximize the effectiveness of transitional housing programs where appropriate.



Objective 2.3: Implement Coordinated Entry to Standardize Assessment and Prioritization Processes and Streamline Connections to Housing and Services

Coordinated entry processes make it possible for people experiencing or at risk of experiencing homelessness to have their strengths and needs quickly assessed, and to be swiftly connected to appropriate, tailored housing and services within the community or designated region.

Standardized assessment tools, prioritization policies, and practices used within local coordinated entry processes should take into account the unique needs of different populations, including parents, infants and young children, youth, people with disabilities, people living with HIV/AIDS, survivors of domestic violence, and populations that are disproportionately represented among people experiencing homelessness. These processes make it possible for households to gain access to the best options available to address their needs—incorporating participants' choice—rather than being evaluated for a single program within a community. The most intensive interventions should be prioritized for those with the highest needs, as identified by the community. To implement effective coordinated entry systems, communities need the capacity to train staff consistently, to implement trauma-informed approaches, and to protect the confidentiality and safety concerns of people experiencing homelessness, including people living with HIV/AIDS and individuals or families fleeing domestic violence.

Coordinated entry systems also create the opportunity to bring non-traditional partners and resources to the table as part of a broad and collaborative community effort that engages other public programs and community- and faith-based organizations in preventing and ending homelessness. While these programs are often not targeted to individuals and families experiencing homelessness, they may have resources that are critical for ensuring that any experience of homelessness in a community is brief and for meeting the longer-term service needs of people experiencing homelessness.

To support communities' progress, USICH and its member agencies will focus on the following Strategies:

a. **Support the implementation of strong coordinated entry processes that provide effective, low-barrier, comprehensive, and coordinated access to housing and services programs.** Federal partners will assist communities in improving access to programs, standardized assessment, prioritization, and referral processes between systems. This work will include developing guidance and technical assistance to navigate emerging challenges. Federal partners will also provide technical assistance and tools to support community partners to address data-sharing concerns, particularly in navigating confidentiality and safety concerns for survivors of domestic violence, individuals living with HIV/AIDS, and minors, including children identified by schools as experiencing homelessness.

b. **Encourage a wide range of programs to develop or strengthen partnerships with coordinated entry processes and to implement effective practices for referrals between systems.** Federal partners will encourage schools, early childhood programs, child welfare agencies, health and behavioral health care providers, HIV/AIDS housing and service organizations, affordable housing programs, benefits programs such as Supplemental Security Income and Social Security Disability Insurance (SSI/SSDI), and other programs to implement processes to identify individuals and families who are experiencing homelessness to connect them to local coordinated entry systems and to connect people identified by the coordinated entry systems to other necessary programs.

c. **Strengthen the focus on income and employment within coordinated entry systems to effectively target and connect individuals and families to opportunities** and services needed to attain and sustain income and employment, including job training and apprenticeship programs that create access to career pathways, primary and behavioral health services, early childhood education and child care programs, and resources for young children and youth available through schools and post-secondary institutions.

d. **Develop and strengthen best practices in population-specific coordinated entry strategies and processes** to ensure that practices effectively engage people with varied experiences of homelessness, diverse service needs, and differing eligibility for programs and services.

e. **Support rural and suburban areas to implement effective, regionally specific coordinated entry processes.** Recognizing the unique challenges posed by geography and population distribution in these areas, federal partners will offer technical assistance and tools to support communities in strengthening their coordinated entry processes and ensuring that they are fully accessible.

> ***"Communities across the country have been embracing Housing First approaches across their systems, removing as many obstacles and unnecessary requirements as possible in order to expedite people's access to stable housing."***

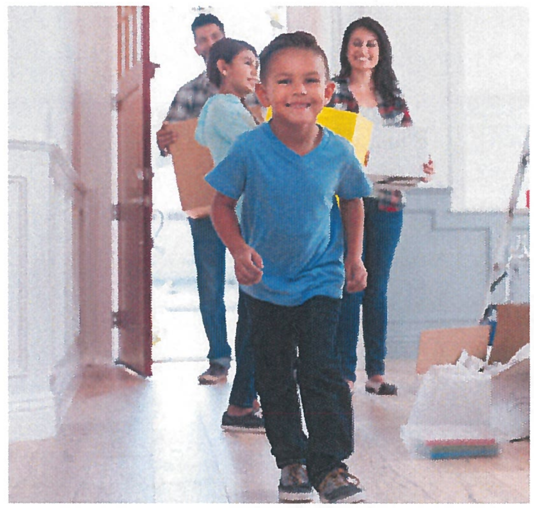
Objective 2.4: Assist People to Move Swiftly into Permanent Housing with Appropriate and Person-Centered Services

To end homelessness as quickly and efficiently as possible, communities must focus on streamlining connections to permanent housing and providing people with the appropriate level of services to support their long-term housing stability. Communities across the country have been embracing Housing First approaches across their systems, removing as many obstacles and unnecessary requirements as possible in order to expedite people's access to stable housing. Effective Housing First approaches, developed in response to strong evidence, include: expanding access to new and existing affordable housing for people experiencing homelessness; providing rapid re-housing to families and individuals; and providing supportive housing to people with the most intense needs.

Expand access to new and existing affordable housing for people experiencing homelessness. To provide adequate housing opportunities, and for Housing First approaches to be taken to scale, it will be necessary to expand access to housing affordable to people who are at risk of or are experiencing homelessness. Strategies to expand the supply can be implemented by all levels of government and across the public and private sectors, and can also include:

- Examining and removing local policy barriers that limit housing development in the private market and have adverse impacts on housing affordability;
- Prioritizing people experiencing homelessness for affordable housing resources; and
- Expanding affordable housing opportunities through actions across all levels of government.

Connect people to rapid re-housing. Effective implementation of rapid re-housing requires providing each of the essential components of this intervention—housing identification, rent and move-in assistance, and case management. Rapid re-housing assistance should be offered without preconditions to entry—like income, absence of criminal record, or sobriety requirements—and the resources and services provided should be tailored to the unique needs of the household. Preliminary evidence shows that rapid re-housing, when combined with connections to appropriate resources, such as employment supports and other income, can successfully end homelessness for many families and individuals who do not need intensive and ongoing supports.[10] For these households, rapid re-housing may also be a less expensive housing intervention when compared to other interventions, such as transitional housing.[11] Further evidence regarding the most effective rapid re-housing practices for different populations, and within different types of housing markets, needs to continue to be developed.



Connect people with the most intense needs to permanent supportive housing. Supportive housing combines non-time-limited affordable housing assistance with wraparound supportive services for individuals and families with the longest histories of homelessness and disabilities. When operated with Housing First practices, there are few or no preconditions for entry, such as sobriety, absence of a criminal record, or medication adherence. While participation in services is encouraged, it is not a condition of housing. There is no single model for supportive housing design—it may involve the renovation or construction of new housing, set-asides of apartments within privately owned buildings, or the leasing of individual apartments dispersed throughout an area.

When implemented effectively, permanent supportive housing can result in fewer expenses for shelters, jails, ambulances, and emergency departments.[12] Households in supportive housing programs receive support to get connected to SSI/SSDI benefits when eligible, health and behavioral health care, social supports, employment and supported employment opportunities and workforce programs, and other supportive services that promote health and long-term housing stability.

Link people experiencing unsheltered homelessness to housing and services solutions. Communities need to consider strategies to address the immediate safety and health concerns of people who are unsheltered, but they must also work to develop more low-barrier pathways into permanent housing. To drive greater progress, communities will need support to strengthen their capacity to identify and engage people who are unsheltered and to assist them to access permanent housing solutions, including strengthening the outcomes achieved for people who enter emergency shelter.

To support communities' progress, USICH and its member agencies will focus on the following Strategies:

a. **Support communities to expand the supply and increase access to rental housing subsidies and other affordable housing options** for individuals and families experiencing or most at risk of homelessness. These efforts will include:

- Encouraging collaboration between public housing agencies, multi-family housing owners, and homelessness services systems, and promoting guidance on how public housing agencies and multi-family housing owners can adopt admissions preferences and successfully house people exiting homelessness; and

- Supporting states and communities to better target and align rental assistance and capital financing sources to support new construction and rehabilitation of affordable housing units that can be effectively accessed by people exiting homelessness.

b. **Increase the capacity of communities to implement Housing First and harm reduction practices** in programs across their systems, to further explore and refine alternative housing interventions, such as shared housing, and to evaluate effectiveness.

c. **Encourage increased use of health, behavioral health, TANF, workforce, early childhood education, K-12 and higher education supports, and child welfare programs** to provide supportive services in conjunction with housing programs and interventions in order to expand capacity to create stable housing outcomes.

d. **Provide guidance and technical assistance to assist communities to implement and improve outcomes for rapid re-housing for families, youth, and individual adults,** drawing upon knowledge gained from implementation of VA's Supportive Services for Veteran Families program, HUD-funded programs, and program evaluations and research studies on effective models.

e. **Increase access to permanent housing models for people with substance use disorders, including opioid use disorders,** by aligning housing and services and scaling evidence-based approaches, like medication assisted treatment.

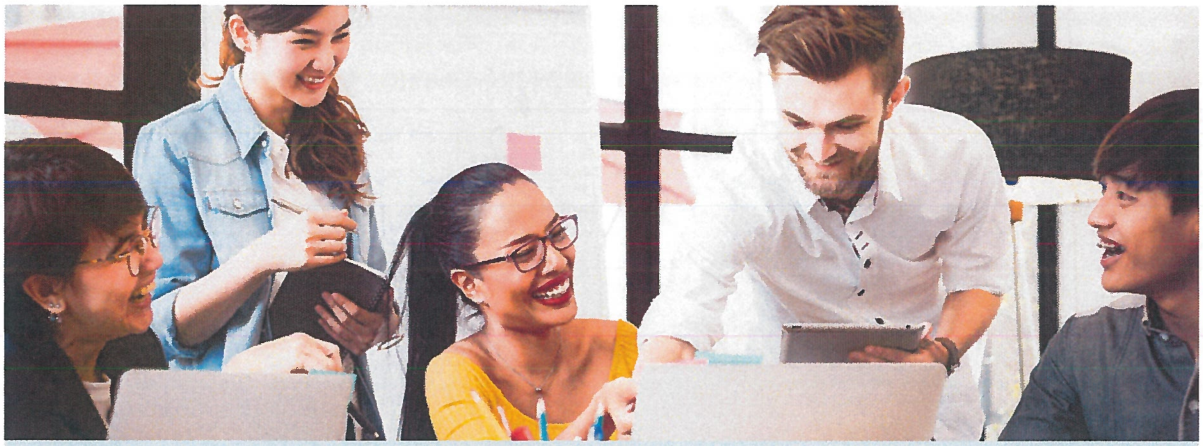
f. **Support communities to implement expanded "move-on" strategies to assist people who have achieved stability in permanent supportive housing**—and who no longer need and desire to live there—to move into other housing options they can afford and create access to those permanent supportive housing units for other prioritized households currently experiencing homelessness.

g. **Help communities set specific, ambitious short-term goals to swiftly connect people experiencing homelessness** to housing and services appropriate to their needs, and support their efforts in achieving and tracking performance against those goals.

h. **Continue to improve targeting of permanent supportive housing for people with disabilities experiencing chronic homelessness** and for other individuals and families that are particularly vulnerable in order to improve cost savings and outcomes.

i. **Improve access to federally funded housing assistance by eliminating administrative barriers and encouraging prioritization** of people experiencing or most at risk of homelessness, including implementing the housing anti-discrimination and eviction protection provisions covered in the Violence Against Women Act. Federal partners will review federal program policies, procedures, and regulations to identify administrative or regulatory mechanisms that could be used to remove barriers and improve access to stable health care, housing, and housing supports.

j. **Encourage partnerships between housing providers and health and behavioral health care providers, such as health centers,** to co-locate, coordinate, or integrate health, behavioral health, safety, and wellness services with housing and create better resources for providers to connect patients to housing resources.



3) ENSURE HOMELESSNESS IS A ONE-TIME EXPERIENCE

The Objective and Strategies in this section focus on ensuring that people exit to permanent housing stably and successfully, using that housing as a platform for accessing essential services and connecting to the opportunities they need to pursue their goals and dreams for themselves and their families. Strategies emphasize strengthening the quality of housing and services interventions and providing connections to other services and opportunities, such as education and employment, that can help people find lasting success.

Objective 3.1: Prevent Returns to Homelessness through Connections to Adequate Services and Opportunities

To ensure that individuals and families don't fall back into homelessness, it will be necessary to strengthen partnerships with, and connections to, a larger array of federal, state, local, and private programs that serve low-income households, including programs that: advance education and employment opportunities and support upward economic mobility; provide connections to health and behavioral health care services; and link people to a range of other programs and systems that support strong and thriving communities, such as quality child care, schools, family support networks, and other resources.

To support communities' progress, USICH and its member agencies will focus on the following Strategies:

a. **Strengthen effective implementation of the core components of rapid re-housing—housing identification, rent and move-in assistance, case management**—by helping communities to assess outcomes being achieved and tailor their financial subsidy and services practices in order to reduce returns to homelessness among individuals and families, including households residing in high-cost, low-vacancy markets.

b. **Support communities to increase on-the-job training and apprenticeship opportunities, supported employment, and other strategies that offer access to employment and career pathways** for people with histories of homelessness and other significant barriers to employment, including people with disabilities.

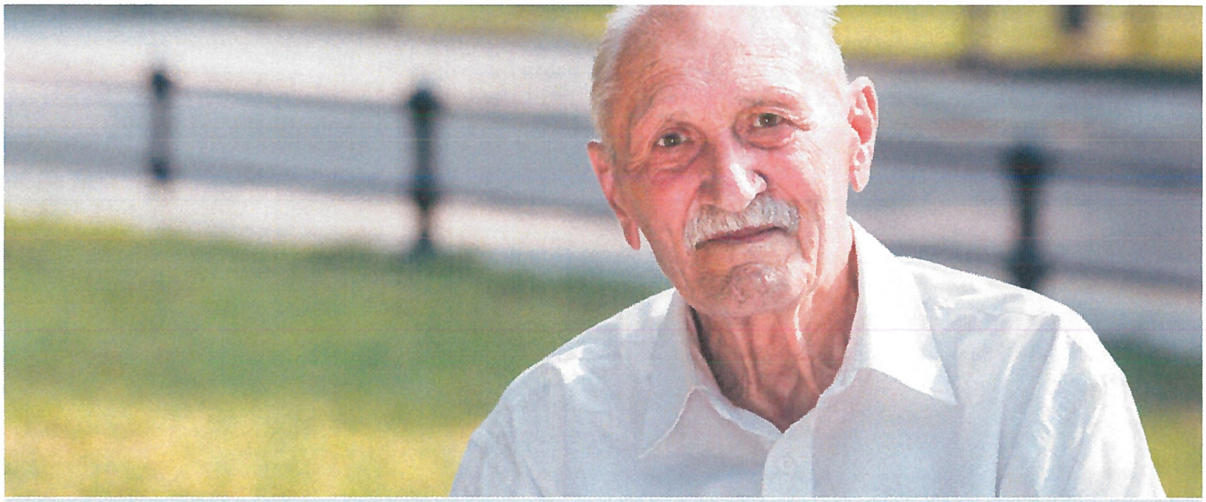
c. **Review federal program policies, procedures, regulations, and administrative barriers to improve access to employment opportunities and income supports.** Identify and promote ways in which the Workforce Innovation and Opportunity Act, the Supplemental Nutrition Assistance Program Employment and Training, the Special Supplemental Nutrition Program for Women, Infants and Children (WIC), early care and education, SSI/SSDI, and TANF programs can help people who are experiencing or most at risk of homelessness—including people with multiple barriers to employment—access and maintain jobs.

d. **Encourage state and local efforts to implement a flexible array of behavioral health services that impact housing stability,** including quality case management and care coordination, peer supports and navigation services, intensive in-home services, mobile crisis and stabilization services, and other home- and community-based services.

e. **Support communities to increase access to and retention within high-quality education programs,** including quality child care and early childhood education through elementary, secondary, and post-secondary education.

f. **Share examples and best practices that support communities to maintain capacity to provide resources that will promote the long-term stability of people who have entered permanent housing,** including employment supports, case management and peer support, emergency financial assistance, transportation, legal services, early care and education, connection to programs, and other necessary services and supports.

g. **Strengthen coordination between early childhood, education, housing, employment, and homelessness services providers as part of a whole-family approach** to improve both child and family outcomes through meaningful connections to community-based programs and resources that target and prioritize the assessed needs of the entire household, including infants and young children, for sustained housing stability and economic mobility.



4) SUSTAIN AN END TO HOMELESSNESS

The Objective and Strategies in this section focus on supporting communities that have made homelessness a rare, brief, and one-time experience—either for a specific population or for all populations—as they respond to housing instability and homelessness quickly and efficiently into the future. Strategies emphasize the importance of tracking and measuring key data points routinely, projecting and responding to future needs, and implementing continuous quality improvement efforts.

Objective 4.1: Sustain Practices and Systems at a Scale Necessary to Respond to Future Needs

Communities across the country are demonstrating that ending homelessness is not just a worthy ambition, but a measurable, achievable goal. In order to sustain those successes, communities will need to monitor outcomes and returns to homelessness, to ensure that adequate investments into the crisis response system and into permanent housing interventions are sustained to address future needs, and to continue to refine projections to address changing needs and ensure the maximum impact of investments over time.

To support communities' progress, USICH and its member agencies will focus on the following Strategies:

a. **Support communities to track and measure their progress** on a routine basis by looking at key metrics, such as inflow, permanent housing rates, average length of time homeless, and housing retention rates. Federal partners will provide technical assistance and tools to help communities develop and refine by-name or master lists of people experiencing homelessness to track and report essential data and to inform projections.

b. **Identify and promote the strategies of communities that have effectively ended homelessness among one or more populations and are successfully sustaining those achievements** to enable other communities to learn from, replicate, and adapt those practices to their own local contexts.

c. **Support communities to implement continuous quality improvements to housing and services interventions** in order to sustain their successes and to be able to respond to changes in needs and conditions into the future.

HOME, TOGETHER

Through federal, state, and local actions, and through public and private partnerships, we've seen substantial progress toward ending homelessness and have identified many best and promising practices. Yet, there is still much more work to be done to ensure that all Americans have a safe and stable home, in a strong, nurturing community, where they can pursue their goals and succeed. USICH and its member agencies are committed to the implementation of this Plan in order to help drive continued progress—confident that, together, we can end homelessness.

Endnotes

[1]Henry, Meghan et al., "The 2017 Annual Homelessness Assessment Report (AHAR) to Congress, Part 1: Point-in-Time Estimates of Homelessness." (U.S. Department of Housing and Urban Development, December 2017): https://www.hudexchange.info/resources/documents/2017-AHAR-Part-1.pdf.

[2]Henry et al., *2017 AHAR Part 1*. (HUD, 2017).

[3]Henry et al., *2017 AHAR Part 1*. (HUD, 2017).

[4]U.S. Interagency Council on Homelessness, "Mayors' Challenge to End Veteran Homelessness," (June 2018): https://www.usich.gov/solutions/collaborative-leadership/mayors-challenge.

[5]U.S. Department of Veterans Affairs, "Memorandum: VA Medical Center Participation in Continuums of Care Coordinated Entry System", (October 1, 2017): https://www.hudexchange.info/resources/documents/VA-Participation-in-Coordinated-Entry-Guidance.pdf.

[6]National Center for Homeless Education. "Federal Data Summary School Years 2013-14 to 2015-16: Education for Homeless Children and Youth", (December 2017): https://nche.ed.gov/downloads/data-comp-1314-1516.pdf.

[7]Watson, Nicole et al., "Worst Case Housing Needs 2017 Report to Congress", (U.S. Department of Housing and Urban Development, August 2017): https://www.huduser.gov/portal/publications/Worst-Case-Housing-Needs.html.

[8]Burt, Martha R. et al., "Are Homeless Families Connected to the Social Safety Net? Homeless Families Research Brief, OPRE Report": https://aspe.hhs.gov/system/files/pdf/198426/HomelessSafetyNet.pdf.

National Alliance to End Homelessness. Permanent Supportive Housing Cost Study Map. http://www.endhomelessness.org/library/entry/permanent-supportive-housing-cost-study-map.

Gonzalez, Jennifer et al., "Criminal Justice System Involvement Among Homeless Adults." *American Journal of Criminal Justice* 19, no.11 (2017): https://doi.org/10.1007/s12103-017-9413-7.

Walton, Douglas et al., "Child Separation among Families Experiencing Homelessness, Homeless Families Research Brief, OPRE Report": https://www.acf.hhs.gov/sites/default/files/opre/opre_child_separation_brief_03_22_2018_508_2.pdf.

[9]Gubits, Daniel et al., "Family Options Study: 3-Year Impacts of Housing and Services Interventions for Homeless Families." (U.S. Department of Housing and Urban Development, October 2016): https://www.huduser.gov/portal/publications/Family-Options-Study.html.

[10]Gubits, Daniel et al., Family Options Study. (HUD, October 2016).

[11]Gubits, Daniel et al., Family Options Study. (HUD, October 2016).

[12]National Alliance to End Homelessness, "Permanent Supportive Housing Cost Study Map": http://www.endhomelessness.org/library/entry/permanent-supportive-housing-cost-study-map.

Sadowski, Laura et al., "Effect of a Housing and Case Management Program on Emergency Department Visits and Hospitalizations Among Chronically Homeless Adults." JAMA 301 (17), 1771-1778 (2009): https://doi.org/10.1001/jama.2009.561.

Basu, Anirban et al., "Comparative Cost Analysis of Housing and Case Management Program for Chronically Ill Homeless Adults Compared to Usual Care." *Journal of Health Services Research,* (2012): https://doi.org/10.1111/j.1475-6773.2011.01350.x.

Hall, Gerod et al., "Public Service Use and Costs Associated with NY/NY III's Supportive Housing for Active Substance Users." (Columbia University, 2014): https://www.centeronaddiction.org/sites/default/files/files/4_public-service-use-and-costs-associated-with-ny-ny-III-supportive-housing-for-active-substance-users.pdf.

Kidder, Daniel et al., "Access to Housing as a Structural Intervention for Homeless and Unstably Housed People Living with HIV: Rationale, Methods, and Implementation of the Housing and Health Study." (John Hopkins University, 2007): http://www.aidschicago.org/resources/legacy/pdf/2008/housing_plan_AccessHousing.pdf.

Aidala, Angela et al., "Frequent Users Service Enhancement 'FUSE' Initiative. New York City FUSE II Evaluation Report." (Columbia University, 2019): http://www.csh.org/wp-content/uploads/2014/01/FUSE-Eval-Report-Final_Linked.pdf.

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