Marshall Fire Mitigation Assessment Team: Decreasing Risk of Structure-to-Structure Fire Spread in a Wildfire

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1. Introduction

On December 30, 2021, a wind-driven wildfire affected over 2,000 residential structures and several commercial facilities in unincorporated Boulder County, the City of Louisville, and the Town of Superior, Colorado. Data gathered after the fire highlighted the importance of preventing or slowing down structure-to-structure fire spread. Such prevention begins with the selection of appropriate building systems and spacing between buildings. Foundations, roofing, siding, windows, and doors, and building configuration and siting all play into slowing or eliminating the ability of a fire to spread from an adjacent structure, shed, or fence.

Because of the unique nature of the incident, where extreme winds coupled with long term drought, high temperatures, and limited wildfire regulatory adoption, a fast-moving low-intensity grass fire became a highly destructive urban fire directly and indirectly impacting several communities and greater Boulder County area. The Federal Emergency Management Agency (FEMA) deployed its first-ever wildfire Mitigation Assessment Team (MAT) to evaluate building performance during the fire. The MAT was deployed to Louisville, Superior, and unincorporated areas in Boulder County, Colorado, to evaluate damaged homes and commercial structures. MAT members evaluated components and systems of primarily residential structures to determine the effectiveness of various building materials, design, and construction practices for wildfire resiliency. The MAT used the information gathered to evaluate how wildfire-urban interface (WUI) building codes and standards, as well as design, construction, and defensible space practices can be improved to increase community wildfire resilience. This is important as the landscape is continuously evolving due to changing weather patterns and putting more communities at risk.

2. Purpose

During a fully developed fire, temperatures can reach above 1,000° Celsius (about 1,800° Fahrenheit) which can lead to significant structural degradation of building structural systems. This degradation can lead to loss of capacity for structural elements and could potentially lead to life safety concerns in structures that remain standing. The purpose of this document is to provide recommendations to contractors and designers on new building construction that may prevent or slow the spread of a fire from structure-to-structure in densely-spaced neighborhoods.

3. Key Issues

Structure-to-structure fire spread is typically caused by one or both of the following:

- **Vulnerable building components**: Roof systems, composite siding, and single pane, or large glass panel windows can propagate fires due to radiant heat causing them to break and allow them to spread faster. Other combustible building components, such as attached structures (e.g., decks, balconies, fences), can ignite from embers or direct flame contact and spread fire to the building.

- **Building configuration, siting, and spacing**: Buildings with complex shapes can allow embers to collect on rooftops and cause fires to spread more rapidly to other buildings. Buildings sited along ridgetops or placed closely together in densely-developed areas can ignite one another by direct flame contact or radiant heat.

Debris from various household and outdoor items surrounding a building can act as wicks to spread the fire hazard from one structure to another. Such items may include propane tanks, firewood, outbuildings, vehicles, and filled dumpsters too close to a structure. To address the issue of debris, refer to Marshall Fire MAT document *Homeowner's Guide to Reducing Wildfire Risk Through Defensible Space*.

In a widespread or intense wildfire there may be limited firefighting resources available to defend structures to prevent the spread of fire between them. Homeowners, designers, and contractors in high wildfire risk areas should consider using fire-resistant and noncombustible construction materials and techniques to increase the likelihood a home will withstand a wildfire if firefighting resources are limited.

4. Vulnerable Building Components

Vulnerable building components that contribute to structure-to-structure fire spread through combustion or other means typically include one or more of the following:

- Roofing systems
- Wall system assemblies
- Vent protection
- Glazing systems
- Attachments

In addition, landscaping and vegetation surrounding the building can contribute to structure-to-structure fire spread. (Refer to Marshall Fire MAT document *Homeowner's Guide to Reducing Wildfire Risk Through Defensible Space* for more information on this topic.)

The following sections describe the conditions observed and recommended migration strategies for each component listed above.

4.1. Roofing Systems

Although there were no direct observations of roofing systems resulting in structure-to-structure fire spread during the Marshall Fire, residential roofing systems are a key area of known wildfire vulnerability. Many homes during a fire hazard event burn from the top down when roofing materials or combustible roof decking are ignited by embers that generated from other structures, the flame front (the wave of the fire heading toward a structure) or when embers enter through roof vents or other openings in the roof.

Recommended mitigation strategies for roofing systems include:

- Select tested roofing systems that meet ASTM E108 or UL 790 Class A requirements should be used. Systems include, but are not limited to, asphalt shingles, concrete, brick, or masonry tiles (with bird stops), or metal panel/shingles. Note that Class A roof systems include the entire roofing assembly and not just the roof covering.
- Avoid materials such as wood and fiberglass when selecting new or replacement building roofing systems.
- Use metal valley flashing to avoid debris accumulation between and below tiles and add an underlying mineral surface cap sheet into assemblies that use metal valley flashing.
- Limit the number of joints and elevation changes in the roof design. Use proper flashing at the joints between walls and porch roofs/lower roofs and roof edges. Use noncombustible materials to construct roof expansion joints. Refer to the Marshall Fire MAT documents *Guide to Reducing Risk of Structure Ignition from Wildfire* and *Wildfire Resilient Detailing, Joint Systems, and Interfaces of Building Components* for additional information.
- Use metal gutters and downspouts. Install corrosion-resistant noncombustible drip edge flashing from the roof to the gutter, tightly fitting the flashing against the gutter. Use gutter covers made from noncombustible materials to prevent debris from accumulating in gutters.
- Use enclosed soffits or appropriate vent screens and batts in soffits.
- Provide bird-stops or mortar at open ends of tiles on profile-tiled roof edges. For other types of roof edges, provide underlayment that is continuous to the roof edge and metal flashing at the roof edge.
- Install spark arresters on chimneys.

4.2. Wall System Assemblies

Residential construction consisted of mainly wood-frame building systems with either brick or stone veneer and vinyl or fiber cement exterior siding. Siding and veneers appeared to be built over wood framing, with plywood or oriented-strand-board (OSB) sheathing and building paper (Figure 1).

Figure 1. Examples of damaged wall assemblies.

Recommended mitigation strategies for wall system assemblies include:

- Provide additional layers of exterior gypsum (5/8-inch thick type X) board sheathing to create a fire-resistant wall assembly that can slow fire propagation and structure-to-structure fire spread (Figure 2).

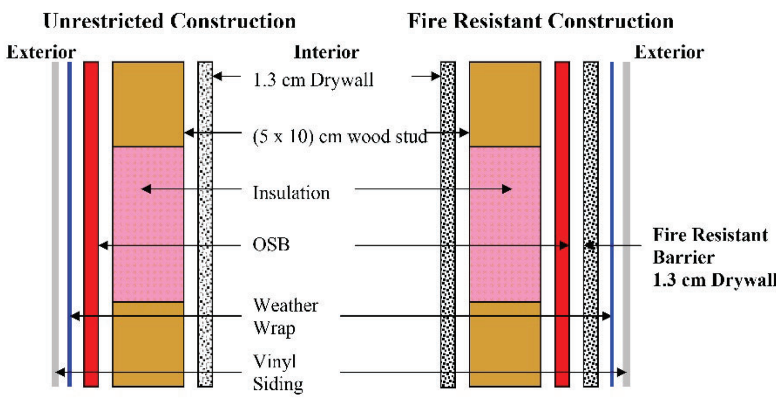


Figure 2. Fire-resistant wall assembly cross-section (NIST, 2008).

- Use non-combustible cement board cladding, masonry construction or veneer, stucco exterior or a combination of these three options, especially at head-of-wall locations.
- Designers should consider adding fire-resistant walls on sides of the building where fire hazards are within 25 to 50 feet to reduce or prevent fire spread (Figure 3).

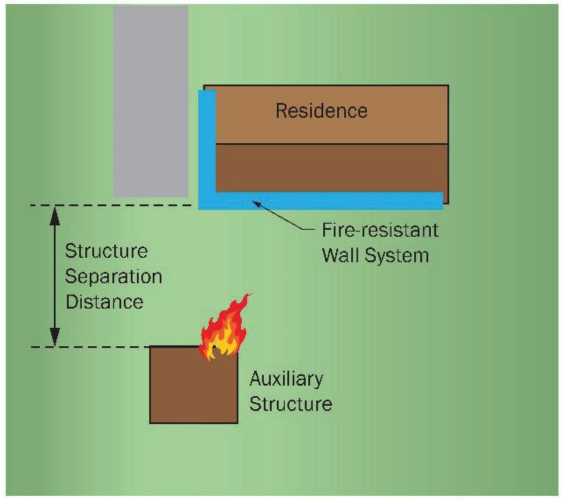


Figure 3. Fire-resistant wall system recommendations when desired structure separation distance (SSD) cannot be achieved (NIST, 2022).

- Use ignition-resistant fiberglass batt insulation inside wall cavities or ensure exterior walls are flashed/sealed with fire resistant caulk completely to prevent embers and hot gasses from entering the structure.
- Provide proper detailing at wall joints and interfaces along the base of the wall and the base of the roof to prevent gaps. Refer to the Marshall Fire MAT document *Homeowner's Guide to Reducing Risk of Structure Ignition from Wildfire* for additional details on addressing gaps at joints and interfaces.

4.3. Vent Protection

Plumbing and attic vents on existing construction did not appear to have proper screening to prevent ember intrusion into most of the observed structures. Soffit vents with opening sizes of more than 1/8-inch square mesh can allow embers to enter an attic that could cause a fire to propagate or continue. Crawlspace vents are typically covered with mesh screening that is 1/4-inch square to prevent rodents from getting in, but this can still allow embers to pass through and contribute to fire spread.

Recommended mitigation strategies for vent protection include:

- Cover all plumbing stacks, attic, crawlspace, soffit, and ridge vents with non-combustible mesh having opening sizes no larger than 1/8-inch square for new or retrofit construction (Figure 4).

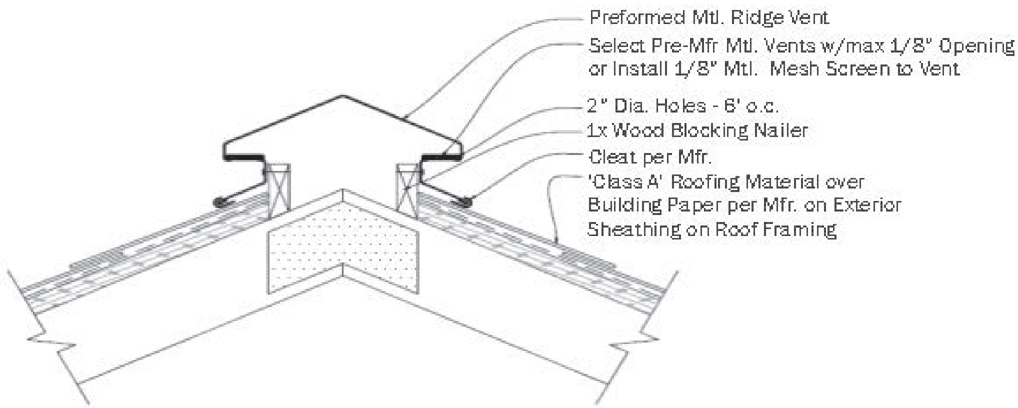


Figure 4. Example of ridge vent drawing with proper screening (Note: confirmation of proper attic ventilation by code still required) (City of Colorado Springs Fire Department, 2020).

Refer to the Marshall Fire MAT document *Homeowner's Guide to Reducing Risk of Structure Ignition from Wildfire* for additional details on protecting vents and other openings.

4.4. Glazing Systems

Glazing systems can break due to radiant heat or breakage from debris of single pane windows allow embers to enter and cause ignitions at the interior of a structure (Figure 5). Both single pane and multi-pane glazing systems were observed. In some cases where multi-pane glazing was present, the outer pane of glass was observed to be damaged.

Single-pane glazing will crack and fall out under intense heat and allow ember and flame spread into the structure and propagate the fire, especially if the window is located below or next to burning material or burning vegetation.

Figure 5. Example of glazing system failures.

Recommended mitigation strategies for glazing systems include:

- Use tempered-glass and double-pane glazing systems for windows and doors with glazing.
- Install aluminum coverings or use metal framing for window and door frames.
- Use fiberglass or metal screening on windows.

4.5. Attachments

In some cases, attachments such as decks, patios, porches, and balconies acted as "wicks" that, once ignited from embers or direct flame contact, provided a direct vehicle to igniting the home. Decks can provide a large surface area where embers can collect, which can lead to ignition of materials on the deck or of the deck itself. Many decks were observed to have materials stored on or underneath them that could - and in some cases did - provide fuel for ignition. See Marshall Fire MAT document *Homeowner's Guide to Reducing Risk of Structure Ignition from Wildfire* for more guidance on mitigating fire risk posed by attachments.

Recommended mitigation strategies for attachments include:

- Use noncombustible materials for deck framing, walking surfaces, railings, and stairs. All metal components must be corrosion resistant.
- Space deck boards with 1/4-inch gap. As an alternative, consider installing a solid walking surface, such as lightweight concrete, or use aluminum decking without gaps.
- For decks four feet or less above the ground, enclose the space under the deck from the walking surface to the ground using corrosion-resistant metal mesh having openings 1/8-inch or less (IBHS, 2023). Alternatively, fully enclose the space using noncombustible materials. If the deck is over a 10% or greater slope, the enclosure should stop within 6 inches above the ground surface to allow for drainage.
- Install metal flashing between or on top of the deck surface and the adjacent exterior wall. Extend the flashing at least 18 inches up the wall and tuck it in behind the lap joint (Fire Safe Marin, 2023).
- See Marshall Fire MAT document *Homeowner's Guide to Reducing Risk of Structure Ignition from Wildfire* for additional details.

5. Building Configuration, Siting and Spacing

The following sections describe the building configuration, siting and spacing conditions observed and recommended mitigation strategies for each.

5.1. Building Configuration

Although there were no direct observations of building configuration leading to structure fires, complex building geometries can lead to debris collecting at roof valleys and re-entrant corners, allowing embers to spread fire between structures (Figure 6). Structural overhangs are also a possible location for debris and embers to collect and hot gases to enter the building.

Recommended mitigation strategies related to building configuration include:

- Limit re-entrant corners on building designs to eliminate locations where debris could build up.
- At roof dormers, limit areas where debris could collect.

- Enclose the underside of structural projections from buildings with ignition resistant material to reduce the likelihood of fire spread in these areas.

5.2. Building Siting

Although there were no direct observations of siting issues (including set back) leading to structure fires, building siting plays an important role in preventing structure-to-structure fires. Orientation and location of buildings can help slow or prevent the spread. Understanding how topography can influence fire hazard behavior will allow designers to aid property owners in site selection to reduce the potential of fire hazard spread.

Recommended mitigation strategies related to building siting include:

- Avoid selecting a construction site in or adjacent to a topographic saddle or narrow mountain pass.
- Avoid constructing a home adjacent to or on a mild or steep slope. If a building is to be constructed at a ridgetop, the structure should be set back 50 feet from vegetation on the downslope side (Figure 7).

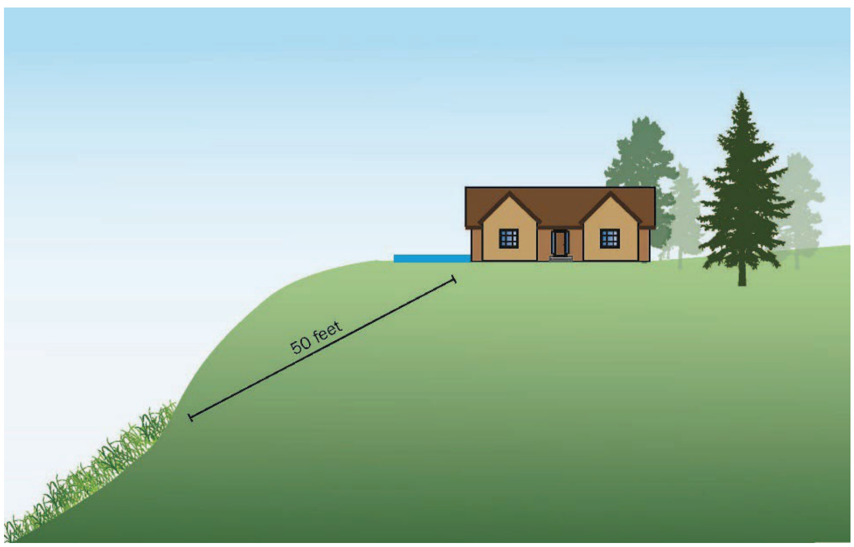
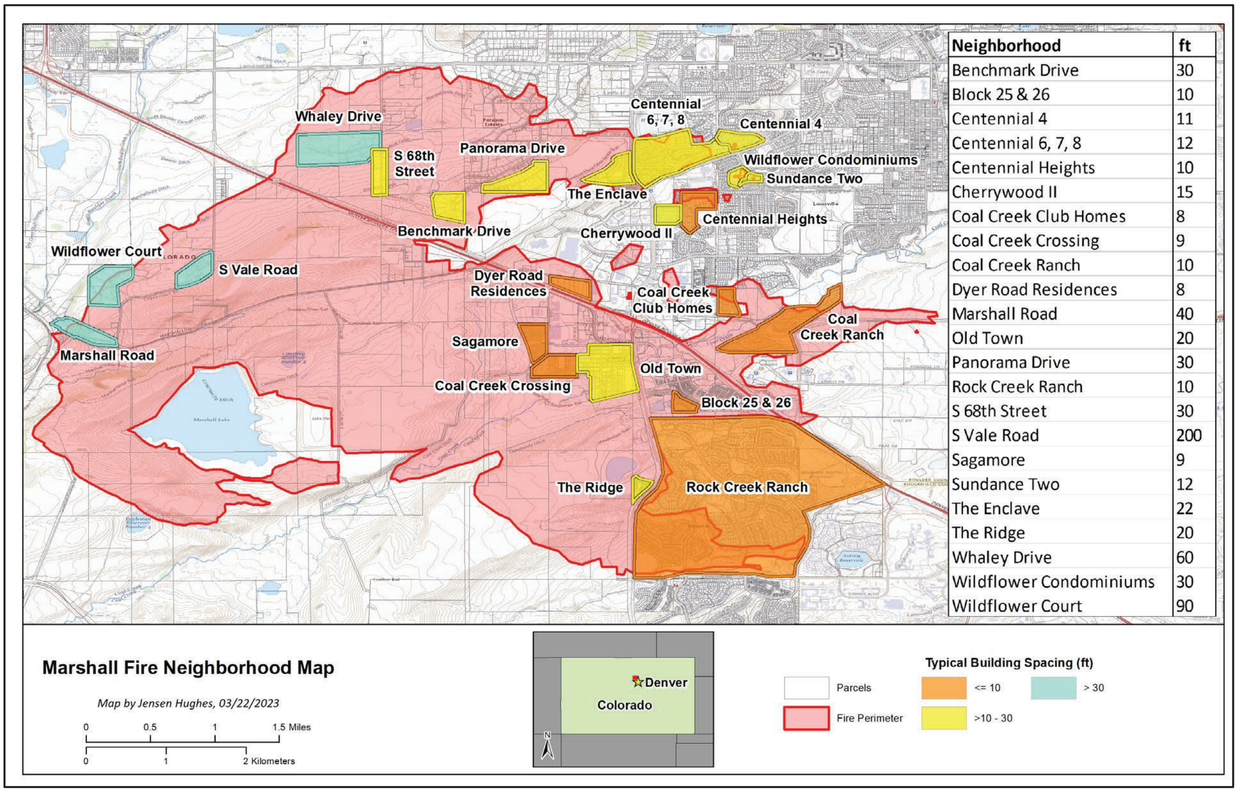


Figure 7. Example of recommended setback from a ridgetop (FEMA, 2008).

- Orient the narrowest wall of a structure toward the likely path of a fire hazard spread to minimize the risk of ignition. Orient the building based on prevailing wind and fuel sources nearby so that embers do not accumulate next to building walls.
- Pay close attention to building orientation with respect to inside corners and other offset walls.
- Refer to the Marshall Fire MAT document *Best Practices for Wildfire-Resilient Subdivision Planning* for additional details on building siting.

5.3. Building Spacing

Observations from the Marshall Fire indicated that the average spacing between buildings likely played a role in structure-to-structure fire spread (Figure 8). Although clustering homes together within a subdivision surrounded by community defensible space is generally considered beneficial for reducing wildfire risk, increasing the separation distance between individual buildings can help slow or prevent structure-to-structure fire spread. Note that increasing spacing between properties can drive up costs and impact affordability. This approach also may not be possible in more densely developed areas.



Neighborhood	ft
Benchmark Drive	30
Block 25 & 26	10
Centennial 4	11
Centennial 6, 7, 8	12
Centennial Heights	10
Cherrywood II	15
Coal Creek Club Homes	8
Coal Creek Crossing	9
Coal Creek Ranch	10
Dyer Road Residences	8
Marshall Road	40
Old Town	20
Panorama Drive	30
Rock Creek Ranch	10
S 68th Street	30
S Vale Road	200
Sagamore	9
Sundance Two	12
The Enclave	22
The Ridge	20
Whaley Drive	60
Wildflower Condominiums	30
Wildflower Court	90

Figure 8. Typical building spacing in Superior and Louisville, Colorado, neighborhoods impacted by the Marshall Fire.

Recommended mitigation strategies related to building spacing include:

- Provide a minimum spacing of 30 feet between structures when possible.
- Buildings in high-risk wildfire areas that are spaced within 30 feet of each other should be constructed with Class A roof systems and fire-resistant exterior wall assemblies. Placement of vegetation, fences, decks, vehicles, and outbuildings in areas where construction is close together can also contribute to structure-to-structure fire spread. Refer to the Marshall Fire MAT document *Homeowner's Guide to Reducing Risk of Structure Ignition from Wildfire* for more information on reducing risk of structure ignition from wildfires.
- Refer to the Marshall Fire MAT document *Best Practices for Wildfire-Resilient Subdivision Planning* for additional details on density of development.

6. Resources and Useful Links

City of Colorado Springs Fire Department. 2020. "Ignition Resistant Construction Design Manual"

Federal Emergency Management Agency. 2008. FEMA P-737: *Home Builder's Guide to Construction in Wildfire Zones.* Available at: https://basc.pnnl.gov/library/fema-p-737-home-builders-guide-construction-wildfire-zones-technical-fact-sheet-series

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National Institute of Standards and Technology. 2022. WUI Structure/Parcel/Community Fire Hazard Mitigation Methodology. NIST Technical Note 2205. Available at: https://nvlpubs.nist.gov/nistpubs/TechnicalNotes/NIST.TN.2205.pdf

Institute for Building and Home Safety. 2023. *Wildfire Prepared Technical Standard.* Available at: https://wildfireprepared.org/wp-content/uploads/WFPH-Standard-2022-Final.pdf

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Maranghides, A. and Erik Lewis Johnsson. 2008. "Residential Structure Separation Fire Experiments." National Institute of Standards and Technology (NIST) Technical Note 1600. Available at: .https://www.govinfo.gov/content/pkg/GOVPUB-C13-61ebeb4a9065a1584c3a9b0561bbb525/pdf/GOVPUB-C13-61ebeb4a9065a1584c3a9b0561bbb525.pdf

National Fire Protection Association® (2022). NFPA 1140, 2022 Edition: Standard for Wildland Fire Protection

Quarles, Stephen and Standohar-Alfano, Christine. 2018. Wildfire Research Ignition Potential of Decks Subjected to Ember Exposure. *Institute for Building and Home Safety.* Available at: https://ibhs.org/wp-content/uploads/member_docs/Ignition-Potential-of-Decks-Subjected-to-an-Ember-Exposure_IBHS.pdf

Society of Fire Protection Engineers and SFPE Foundation. "WUI Virtual Handbook for Property Fire Risk Assessment & Mitigation." SFPE.org. 2023. Available at: https://www.sfpe.org/wuihandbook/home