TOWN OF PORTOLA VALLEY
Wildfire Preparedness Committee
Tuesday, December 7, 2021 4:00 PM
Virtual Meeting

SPECIAL VIDEOCONFERENCE MEETING AGENDA

Remote Meeting Covid-19 Advisory: On September 16, the Governor signed AB 361, amending the Ralph M. Brown Act (Brown Act) to allow legislative bodies to continue to meet virtually during the present public health emergency. AB 361 is an urgency bill which goes into effect on October 1, 2021. The bill extends the teleconference procedures authorized in Executive Order N-29-20, which expired on September 30, 2021, during the current COVID-19 pandemic and allows future teleconference procedures under limited circumstances defined in the bill. Portola Valley Town Council and commission and committee public meetings are being conducted electronically to prevent imminent risks to the health or safety of attendees. The meeting is not available for in-person attendance. Members of the public may attend the meeting by video or phone linked in this agenda.

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MEETING AGENDA

1. Call to Order
2. Open Communications for Items not on Agenda
3. Approval of Minutes from November 2, 2021, Meeting
4. Discuss and Consider Petition for Public Safety (D. Pfau)
5. Continue Discussion on NFPA 1140 / Building Separation (D. Pfau)
6. Discuss Budget Proposal to Support the Town's Fire Safety (J. Youstra)
7. Subcommittee Updates
    a. Resident Communications and Outreach/Evacuation Routes
    b. Home Hardening/Insurance/Infrastructure Back-up
    c. Vegetation Management/Defensible Space
8. Standing Items- As Needed
    a. Fire Marshal Update
    b. Staff Updates
    c. Review of Committee Correspondences/Items of Note
9. Adjourn

Wildfire Preparedness Committee Minutes

November 2, 2021

In attendance:

Committee Members:
Michael Tomars, Chair
Dale Pfau, Vice Chair
Marianne Plunder
Megan Koch
M.J. Lee
Karen Vahtra
Jennifer Youstra
Jeff Aalfs

Town Manager:
Jeremy Dennis

Fire Marshall:
Don Bullard

Members of the Public:
Ulrich Aldag
Karen Askey
Liz Babb
Valerie Baldwin
Danna Breen
Joe Grundfest
Dudley Carlson
Pete Chargin
Rita Comes
Kristy Corley
Lorrie Duval
Ron Eastman
Denise Enea
Marty Eng
Diana Fischer
Sarah Gilbert
Marshall Herd
Andy Hutchinson
Claire Jernick
Betsy Morgenthaler
Matt Muffly
Judith Murphy
David Polnaszek
Vic Schachter
Janet Smith
Stanley Smith
Craig Taylor
Onnolee Trapp
Bob Turcott
Sofie Vandeputte
Barbara Vetter
Alyson Wood

Item I - Call to Order:
The meeting was called to order at 4:02 pm.

Item 2 - Open Communications:
There were no open communications.

Item 3 - Approval of Minutes:
The following changes to the minutes of October 5th were requested:

- Marianne: Marianne Plunder was not present at the meeting.
- MJ: Spell MJ without periods to make searches easier.
- MJ: "PHOS-CHEK" is the proper spelling of the fire retardant used by All Risk Shield, please change to enable searches.
- Karen: Rancho Santa Fe is in San Diego.
- Karen: Her presentation should say the following:
    - Utilities Users' Tax is "not regressive" should be revised to reflect that it is regressive.
    - Parcel tax can be equitable if it was based on lot or building size.
- Megan: Please correct the spelling of her name.
- Rita Comes Whitney had a question about whether Council-member Aalfs was a Committee Member or a representative of the Town Council or both. Jeff Aalfs said he is both a committee member and is representing the council.

A motion was made to accept the minutes as amended by Dale. Motion was seconded by Karen. Marianne abstained because she was absent. Motion passes.

Item 4 - Follow-up Discussion of NFPA 1140 AHJ and Recommendation (D. Pfau)
Dale Pfau made a presentation on the 2022 edition of the NFPA 1140, focusing on the role of the AHJ (Authority Having Jurisdiction). An AHJ is the single point of contact and decision maker for all issues associated with fire safety. Dale outlined the responsibilities of an AHJ, as well as the pros and cons of having an AHJ. (See the meeting's agenda for Dale's presentation). Dale recommended that Portola Valley assign WFPD as the AHJ for all wildfire-related issues.

Don Bullard agreed in principle with the recommendation, and added that:

- WFPD would have to outline how this would be done and optimally have a single point of contact
- WFPD would need to know what resources are needed to perform this function
- WFPD is currently investigating the role as it relates to project approvals:
    - Phase 1: Compiling land use docs, codes, stakeholders list.
    - Phase 2: They will do a land use analysis of plans, codes, and policies applicable to each municipality.

- WFPD will expand the CA team that is working on implementing NFPA 1140 to include Dr. Steve Quarrels.
- Don agrees an expanded role of AHJ would be beneficial, and hopes to implement it by 2022.
- Don is now included in the design build review cycle but in a more limited fashion. The new purview of AHJ would need to develop the revised plan review cycle taking into account a number of items (e.g., building placement on the landscape).

Jeff said that WFPD is already responsible for all opinions regarding fire, and didn't note any change in the status quo.

Don replied that right now WFPD only looks at a limited set of issues that involve fire safety: driveway, water supply and defensible space. 2022 NFPA 1140 includes many more dimensions we need to put into the property review phase, so it will reflect the most up to date best practices.

Regarding home assessment, Karen was surprised by the short list of items being checked.

Don said that homes that have wood shake roofs and wood siding should not pass code. The building code needs to be revamped to reflect these items.

Dale asked if there are locations that shouldn't be developed. Don said he doesn't have specific information on these projects currently, but that he has heard anecdotally that there is an ADU being built at the top of a chimney with improper setbacks, but did not have enough detail to speak to that issue. He did not review the project.

Jennifer asked if there is an interface between the AHJ and Committees/Commissions.

Jeff explained that Committees are solely advisory to the council. Commissions make decisions but WFPD is always consulted.

Marianne said that nothing happens without the Town Council, so we need to move this forward and shouldn't wait until 2022.

Megan mentioned that the ASCC has been encouraging non-combustible material choices, but their recommendations are not enforceable. She would love to see that fast tracked. Currently, a wood structure is in the pipeline and is allowed. The ASCC cannot stop it.

Jeremy said there is confusion on who has the authority to implement code and what is in the code. On December 8th, the council will be looking at the home hardening code that WFPD has had under development. To approve new powers for the AHJ, we need to know what the expanded authority looks like in implementing the code.

Michael asked Don if there's an informal structure in place. Don said he is already the AHJ, but the level of engagement is less than desired.

Jeremy said the Town has a formal relationship with WFPD, and that WFPD serves as the fire code check organization. Dale added that potentially the AHJ could recommend something that is not yet in the code (e.g., building a structure without wood siding). Michael asked Don if he has the authority to make decisions of that nature. Don said that the new AHJ role, if adopted, contains many things. He does not know yet how his life would change, but he wants to do what NFPA 1140 requires for fire safety.

Jeremy mentioned that WFPD make recommendations on a regular basis regarding code that does not have the force of law. However, we need strong codes to not approve a project. Megan asked when we could adopt a new code. Jeremy said that the new Home Hardening code will have its first reading by the Council Code Dec 8th, 2021. So, by January it could be in place.

Karen asked if we could approve AHJ and have Don/WFPD go through a fire checklist with new projects to discourage them more thoroughly as a stop gap measure. Don said that WFPD already does this. The changes need to involve structure placement, and different aspects of the property review that aren't yet there.

Marshall Hood of WFPD encouraged all to think of fire review as something that should be happening before the property is sold.

Jennifer commented that after WFPD recommends the code, the Town can adopt a portion in pieces, and choose not to adopt pieces that WFPD recommends. Jeff said that they adopt everything in the fire code but that local ordinances can be more restrictive than fire code. Amendments are made because of the local conditions. Jeremy represented that the Town can ratify portions.

Don clarified that fire code and building code are two different things. 1140 is a standard, not a code. Dale asked how we got to a situation where we have building codes that are delayed in being implemented and people are squeaking through. Jeremy responded that criticism of staff is unwarranted, and that COVID-19 is to blame.

MJ asked if Woodside Fire is already our AHJ, and what the significance was of having a single point of contact for building projects.

Dale answered that, as he reads it, his objective is that the AHJ looks at everything that has to do with fire safety as projects move through the pipeline. Don added that WFPD has authority but needs to compile a fire friendly code that the town will accept. Jeremy said that the WFPD is hired by the Town and County understanding what the code might look like.

Michael said that NFPA 1140 stated plainly that WFPD can veto a project based on [any and all] fire concerns. That is the intent of this resolution. Jeremy said that enforcement of NFPA 1140 would require an increase in the number of code sections to provide additional layers of protection. Jeff explained that there's the code and the authority. The WFPD has the authority to amend the code and they also enforce it. The Town Council is waiting for the recommendation to approve the amended code.

Jennifer asked if we can pass an emergency stop gap measure to give the AFJ the ability to review all aspects of new projects, while review of the new code takes place. Jeff deferred to staff on that question: would this subject the Town to lawsuits? Jeremy said we can make an emergency ordinance to be reviewed on Dec 9th. Michael didn't see any more questions from the Committee, so opened the floor to public comment.

Public comment:
Craig Taylor: WFPD has relied on objective measures. We need to maintain that objectivity because of legal conflicts. What does the Town do if there's a conflict between committees?

Don added that when we ask WFPD to judge a site, they do need objective measures, i.e., a checklist. That's what he's looking to create. He hasn't done this before, and that's why he needs to build a code first.

Craig Taylor: If NFPA 1140 conflicts with state regulations, how do we rectify this? Who resolves conflicts?

Don: If WFPD deems that we need to adopt more restrictive codes, and we can prove that these codes are needed, then the Town will be asked to adopt the more restrictive code. WFPD always goes with the more restrictive option.

Jeremy: The state is placing more restrictions on local control. The language around safety is much more nuanced than has been portrayed in public conversation. This is not to say we shouldn't fight for it, but we do need to be realistic. New fire maps could have a major change on how we do things; may not be until 2023.

Jeff: The backdrop of this discussion is property rights, which requires a high standard of rigorous public process. Due process and a compelling reason to affect property rights is necessary.

Bob Turcott: The housing mandate from the state, passed by the legislature, is clear that areas can be excluded as needed for public safety. Findings and evidence are necessary. The Town Council can use clear data from the Moritz and Cal Fire reports as evidence of safety issues. Regarding 1140's description of the AHJ, his read is a little different, and gives the AFJ a much more holistic voice than current codes. 1140 says we should look at the site, it's hazards and recognize the structure as a source of fuel. The AHJ has the authority to deny structures using 1140; it is not limited to ordinances. The transition to new code will be a long one. He would like to see an AHJ for all of PV, Woodside and all of SMCO.

Jeremy: A quick correction to SB9 and its safety aspects - Local authority can do what was described but first must take measures to mitigate the fire risk of the project.

Danna Breen: She was on this committee in the beginning. She figured the new hardening measures would pass right through the Town Council and is amazed it hasn't happened yet. Hardening was the first thing that should have happened. Danna chaired

the ASCC 3 years ago when a property was going to be developed on Golden Oak and Bear Gulch. This property extended down into the canyon, and included a big cluster of eucalyptus trees. Danna wanted to make approval conditional on removal of those trees. She wrote to Denise Enea and found out that WFPD's hands were tied. The property was never built, the Eucalyptus grove is still there and it's very frightening. We don't want their hands tied.

Joe Grundfest: Joe mentioned it's his first time attending this meeting and stated: Mr. Turcott is entirely correct regarding ADUs. Mr. Aalfs observation in regard to property rights is right, but there is no right to build an unsafe structure. Joe strongly supports deferring to expertise. California recommendations were developed using a base case that isn't as extreme as the conditions in Portola Valley, with its droughts and limited evacuation routes. We need to take this seriously. We all have neighbors that have insurance problems and denials. We shouldn't be giving anyone a reason for denying coverage. This is a powerful reason to adopt this standard.

Dudley Carlson: Dudley particularly agrees with the last speaker. Thank you for considering and working through the moving parts. We should invite state legislators to Town to discuss the relationship between fire risk and ministerial review of ADUs and building codes. Most agree on the need for low-income housing especially for people who work in town, but not at the expense of the entire town if it violates NFPA new fire safety rules. We need the opportunity to explore these issues. We need to consider bringing legislators to PV.

Liz Babb: There is still confusion about what would change. The Committee can only encourage WFPD to adopt 1140 standards quickly. She is shocked to hear now that the new maps aren't coming out until 2023. Adoption of these maps is critical. She lives in Woodside Highlands. Public safety is paramount to property rights. What happens when ASCC disagrees with WFPD? We should defer to public safety. Let's not give insurance companies a reason to drop us.

Dale: The path forward is that we recommend that we continue to have WFPD be the AHJ for Portola Valley and we adopt 1140. What we really want is review of projects. This is not possible to do tomorrow. But we need to do it asap.

Jeremy: Recommendations go to the Council first then WFPD.

Aalfs: The Council recommends that WFPD moves forward. Is there anything concrete that can be recommended tonight?

Dale: There is no action on this proposal.

Marianne: Can't we recommend [that we follow the path forward that Dale defined] and send it to the council? I move that we send to the Council.

Jeremy: We need codes to recommend it to the Council.

Marianne: [1140 outlines AHJ authority over] new fire aspects. We would like these new aspects to go to the Council and get feedback on them.

Michael: Is there a document that formalizes the AHJ?

Don: We're looking to see if there's a formal document that follows NFPA standards to formalize what WFPD will be responsible for as AHJ. Then, it has to be ratified by the Town Council.

Jennifer: Can we put something in place that shows we are anticipating developing these?

Jeremy: It's premature to offer guidance given we haven't discussed these items.

Jeff: Guidance from the Committee is that we support WFPD to continue working on code and be AHJ in tandem with new code adoption.

Item 5 - Consider Recommendation to Adopt the NFPA 1140, Sections 12.2.1 and 12.2.2 (D. Pfau)

Dale presented another piece of NFPA 1140 for the Committee to consider. So far, the Committee has done ample work to:

- Look at Defensible Space
- Look at Vegetation Management

We now need to consider:

- Structure-to-structure proximity

Dale presented a study of houses that burned in the Campfire. See the agenda for the outline of the Campfire study results as it relates to structure-to-structure proximity. Biggest factor in predicting whether structures were lost was their proximity to other structures.

Dale made a recommendation to adopt two specific provisions of NFPA 1140:

- 30 ft. setback from property lines for structures and
- 30 ft separation between structures.

Megan asked if the 30 ft. setback was for properties of all sizes? If yes, the Corte Madera neighborhood, e.g., could be problematic. Dale said yes, but added that smaller lots could ask for a variance.

Megan asked if we have information or a map that will illustrate how setbacks would change?

Karen spoke up in support of Dale's thoughts, citing the Greenville fire which also clearly showed that dense neighborhoods will be impacted severely in wildfires.

Dale offered that we can't do anything about where the houses are currently. However, anything going forward should be protected as best we can.

Megan asked how we're thinking about the way the topography fits with meandering architecture that is somehow connected to the main building, and if 30ft is a structure-to-structure calculation that's enforced even if the structures are on different properties.

Jeremy clarified that 30ft would exceed current standards in most cases except for front setbacks. It's not dramatically different from property to property.

Karen commented that siting an individual home versus an ADU (if the intent is to rent it out) should be 30ft from the home.

Megan commented that this will dramatically affect the lower income sites in PV. They are already dense as it is. In these neighborhoods, she thinks home hardening and vegetation management will be key. There is already density there and we won't be invoking eminent domain since it's too invasive into property rights. I'm quite uncomfortable that a repair would be grandfathered but tear downs are not.

Dale countered that property owners can still apply for a variance.

Jeff asked for a clarification on whether this would apply to single family homes only, and not apply to a duplex or a multi-family structure that is one building.

Megan stated she is more comfortable with a tapered approach to setbacks that considers lot size.

Dale referred to the statistics that clearly showed that if you were outside of these recommended distances, you probably burned.

Public comment:

Craig Taylor: Echoed what Megan is saying. If you implement this, he would have no place to build. His lot is only 50 feet wide. Even if he added a heat pump, it would require a variance. This has a lot of unintended consequences. Currently, his neighborhood has 5 or 10 ft setbacks on the side.

Dudley Carlson: Lives in PV Ranch. The Ranch is a planned unit development with a set of rules that governed all of this - size of lots and setbacks, etc. In many cases, they are above the recommended space. We already have houses close together for safety, if there is not an ADU rule, we will be creating a really difficult situation.

Bob Turcott: To Dudley's point, this recommendation would recognize the Ranch is denser than current standards would allow. Bob again supported the AHJ as defined by 1140. The data demonstrates that wildfire doesn't care about other issues like need. To fight fire, we need to use every tool. We are facing an epidemic of insurance loss. If you're concerned about the middle class - wouldn't you still need building separation? To ignore this is a big mistake.

Karen Askey: Although I live on a smaller lot, I fear the day we have a fire. I believe we need to increase the setback size and area between the buildings. A tapered approach

makes sense, with grandfathering built in. We need to protect residents. It's a fast-moving environment. I'm willing to make sacrifices.

Kristi Corely: In January, SB9 will allow property owners to split every lot. She is concerned with how we ensure structures are 30 ft apart and how many parking spaces will be needed if we split lots. Woodside has different codes for different parts of Town based on lot size and if neighborhoods have access to buses. If we won't opt in now, do we later? SB10 allows 10 units on a lot.

Megan: I have lived here my entire life and have chosen to stay here for the community which has all of these different neighborhoods. We want all income levels to be able to stay here.

Jennifer: This is a worthy proposal. But, I wonder - where does it stop? Do we have to cut down trees to be consistent with the standards? What about fire traveling between two buildings on the same property, when they share a roof that connects the structures? What about bike sheds - are they subject to the same setback rules even if they don't contain a source of gas, or other problematic features that contribute to the combustible nature of the structure?

Jeff: This shows the effect of building distance and the age of a structure. Creating code is hard. Newer buildings will do better. NFPA should be used as a basis for the next fire code. We should consider and adopt pieces one at a time and allow Don time to continue the work.

Karen: Paradise was predominantly structures amidst pine trees so it's complicated. Maybe we need to start there with smaller lots under 1 acre.

Dale: The statistics are there; we need to adopt the resolution. Clearly, for 1 acre and larger, to increase [setbacks] makes sense. Existing structures need to be grandfathered. New structures need to be adopted.

Michael: We already treat homeowners differently. Our slope ordinance and large lot proposals are an example. All of these things impact different people in different ways.

MJ: I agree with Jeff. I also read the paper that Dale cited and they do say that homes built recently have a 48% survival rate, but before 1997 only a 11% survival rate. It's not statistically significant but directionally appropriate. We should not make a decision based on one paper.

Jeremy: I encourage everyone to read the study. The report does cite a number of studies - some say space is important, some say not as much. The ember storm was not in the scope of their study.

Don: If you want more knowledge, go to this month's Firesafe presentation on Zoom. Regarding continuous house architecture: Fire is caused by radiant heat and direct flame contact. If one catches fire, it will put out BTUs toward smaller adjacent structures and the fire will travel over a continuous roof to the smaller structure. So that will increase the speed of the fire's spread. If the fire starts at the smaller structure, you will

still have direct flame contact but smaller. [In this type of architecture] you can use non-flammable building materials to help mitigate the spread.

Karen: My first thought is can we do this for properties of one acre or more? Can we put a sunset clause and have this act as an emergency clause?

Kristi Corley: I want to add a comment regarding Fountain Grove fire. In this fire, five miles of water pipes were destroyed with benzyne. The repair costs 40 million dollars. What are our water pipes made of? Are we at risk of a similar disaster?

Jennifer: I support an emergency ordinance, but a resolution that covers only parcels greater than 1 acre does not address the density question. Mainly we're concerned about ADUs, and particularly in dense neighborhoods.

Michael: Until the building code adopts requirements for non-combustible materials, separation issues can be considered.

Don: Currently ADUs can't include decks, trellises, non-combustible materials, defensible space of 100ft. Current setbacks depend on the area: 20/20/50/25.

Karen: The current ADU law is not as aggressive as our current setbacks.

Danna Breen: Adding a comment about tonight's meeting. Why are we not enabling the chat this evening but Town staff is able to use it? If we don't use the chat, no one should be able to use the chat.

Dale: I motion that this committee recommend to the Town Council a 30ft setback between buildings and 30ft setback between property lines plus 50ft between buildings that are higher than 20ft. for properties greater than 1 acre.

Karen: I second.

Jeff: These issues are part of a fire code. The Council would need a process to evaluate this recommendation. We can't recommend something that is the same process that Don is going through right now. There is more work to be done here.

Jeremy: The question is can we do this? Is it legal? I have no clue. It is unclear what building we're talking about. This won't be ready for the council meeting next week. It could be ready in one month.

Marianne: I think it's OK. We just give advice. We don't write the law. We're responsible for advising.

Jeremy: Why 1 acre?

Michael: We have a motion on the table that's been seconded. Why one acre?

Karen: Alpine Hills is one acre or more as is Westridge. We could add an amendment that this doesn't include auxiliary buildings.

Megan: If the committee is trying to prohibit ADUs on small lots, this doesn't address the issue. There are already set backs. The numbers are off by 5 feet. Smaller lots now being omitted. So, we're not addressing the problem.

Jennifer: I'm uneasy with voting given the issue Megan mentioned and other outstanding unanswered issues. But I'm open to calling us together in a week or two on an emergency basis to make Jeremy's timeline.

Michael: Don where is the risk the greatest?

Don: On small lots where there is density, and the houses are built of wood. Materials to be used hold more weight.

Dale: [We've addressed home hardening and vegetation management.] Proximity of houses is the third leg of the stool.

Don: I agree.

Jeff: This is a very good discussion but a premature recommendation.

Jennifer: This wouldn't have affected the current ADU that is getting a lot of discussion.

Michael: We need to take a vote on the motion that's on the floor.

Jennifer	No
Michael	Yes
Karen	Yes
Dale	Yes
Marianne	Yes
MJ	No
Jeff	No
Megan	No

Jennifer: I misspoke. The current ADU does fall outside of the proposed property line setback but not the structure-to-structure setback. Can we reconvene in two weeks to reconsider? Can we call a special meeting?

Jeremy: A special meeting only requires 24-hour notice.

Dale: [To Jennifer] A 30-foot property line setback would ensure you're 60 feet away from the nearest structure. What would we learn before a special meeting?

Jennifer: We could study the neighborhoods and figure out the primary ways that each will need to address fire risk.

Jeremy: We need a specific proposal with types of buildings.

[Special meeting tabled.]

Item 6 - Status of Home Hardening Ordinance (J. Dennis)
Jeremy reported that the Home Hardening recommendations will go to the Town Council for the December meeting.

Item 7 - Subcommittee Updates
a. Resident Communications and Outreach/Evacuation Routes

Jeremy: The Evacuations team is still doing due diligence and has been in extensive conversations with the consultant.

b. Home Hardening/Insurance/Infrastructure Back-up

Jeff reported on a project to encourage Home Hardening assessments throughout the Town. He met with a few members of the committee and created an outline for a project that we think would be interesting. The proposal takes this neighborhood idea and, working through neighborhood watch or WPV-Ready, encourages assessments door-to-door for a one-to-two-week period for each neighborhood. The property owner gets an assessment and resources to follow up on assessment recommendations. We're thinking of it as a pilot project.

Jennifer: This is similar to the chipper program and we like to pilot it to see if it works.

MJ: The real issue is to get people to do the work. We'll try to encourage this by organizing group buys to get good pricing for a neighborhood.

c. Vegetation Management/Defensible Space

Karen reported that the vegetation management committee did not meet. Marianne has something to discuss in the next meeting.

Item 8 - Consider 2022 Committee Membership (M. Tomars)

Michael asked that committee members please express interest in serving on the committee next year. Their service has been invaluable. There are 40 people on this call. Please submit your application.

Karen Vahtra announced that she is resigning from the committee effective tonight.

Michael, Jennifer, Marianne and Jeff all thanked Karen for all of her service.

Item 9 - Standing Items- As Needed
a. Fire Marshal Update

Don said we've already talked a lot about his work on NFPA-compliant code. He wants to do this right, so it's going to take time to study all of the issues involved and to apply them to our neighborhoods.

b. Staff Updates

No staff updates.

c. Review of Committee Correspondences/Items of Note

Michael: Prior to the meeting we shared correspondence before the meeting regarding items 4 and 5 on tonight's agenda.

Item 10 - Adjournment
The Committee meeting was adjourned at 7:30 p.m.

To: Town Council
From: Bob Turcott
Date: November 30, 2021
Subject: Petition to Protect Public Safety

Dear Council Members,

Since SB 9 was first presented to the Town Council on October 13, 2021, and at every Town Council meeting since, you have heard residents call for the adoption of written, objective standards to determine whether proposed development projects would have specific adverse impacts on public safety.

I, and others, have been quite concerned that we have not heard the Council direct Staff to adopt such standards. The need is urgent. Your action during the December 8, 2021 Council meeting will affect our ability to protect the safety of all residents of Portola Valley and neighboring communities.

I, and many others, have prepared a Petition that calls for specific actions in order to protect our safety. In less than half a week more than 250 members of the community have added their names in support. We will continue recruiting supporters and will make a final submission with names included later, but we wanted to get the material into your hands as soon as possible.

I urge you to carefully read the attached documents. I urge you to adopt the measures in the Petition to Protect Public Safety.

The attachments to this letter are as follows:
Attachment 1: Cover Letter distributed to members of the community
Attachment 2: Background Statement
Attachment 3: FAQ
Attachment 4: Petition to Protect Public Safety
Attachment 5: Knapp et al., Fire Ecology, Oct 2021 17:25 (Peer-reviewed analysis of structure loss in Paradise, CA, showing that building separation was a leading determinant of structure survival.)

Thank you,
Bob Turcott

Cc: Planning Commission
Ad Hoc Housing Element Committee
Wildfire Preparedness Committee
Emergency Preparedness Committee

Attachment 1

Petition to Protect Public Safety in the Era of SB9

CZU fire viewed from Portola Valley on August 18, 2020. The CZU fire burned 86,000 acres, destroyed 1,500 buildings, claimed one life, took 5 weeks to contain, and came within 8 miles of Portola Valley.

"The protection of the public safety is the first responsibility of local government…"
- California Constitution, Article XIII, Section 35, paragraph 2

Dear member of the Portola Valley community,

As a fellow resident, I'm writing to you about an urgent public safety matter. Your involvement is important and it will make a difference.

Home hardening and vegetation management are important defenses against devastating wildfire, but they're not nearly enough. Experience and research both show that inadequate structure separation and excessive building density in wildland environments such as ours result in homes and neighborhoods that are not just "vulnerable" or "exposed" to wildfire; they are in fact an important *cause* of cataclysmic destruction.

Prudent development policy is critically important.

The State's housing mandates expect our local government to protect our public safety by excluding areas in which application of the mandates would be unsafe. The mandates expressly provide the statutory authority that is needed for such exclusion.

Our Town Council has not yet decided to exercise this authority in any of the many mandates it has implemented: the State Bonus Density Law, ADU mandates, and, now, Senate Bill 9.

Nor has the Town Council held public hearings so our local fire prevention and safety officials can provide professional guidance on the impact of housing mandates on public safety in Portola Valley.

These are complex issues, but they're worthy of your time and attention.

I urge you to read the accompanying Background Statement and to add your name to the Petition to Protect Public Safety if you agree that:

- Our families and our homes face an existential threat from wildfire.
- Adequate building separation, parcel size, and building setbacks are important fire prevention and public safety measures.
- The Woodside Fire Protection District (WFPD) should be authorized to evaluate the impact of land use and development projects on wildfire safety and certify their compliance with all fire prevention and safety standards before they are approved.
- Appropriate science-based, fire prevention and protection standards should be developed and required for WFPD approval of any land use, development or construction project in town
- Until such standards are developed and implemented, minimum building separation as specified by the current National Fire Protection Association Standard for Wildland Fire Protection should be adopted.

The Town Council will be deciding on the implementation of SB 9 on December 8, so time is short! We're planning a first submission of the Petition to the Town Council on November 29, and we're seeking to have the items of the Petition incorporated in the ordinance amendments to be implemented by January 1, 2022.

You can find the Petition here (bit.ly/PetitionForSafety), Background Statement here (bit.ly/PetitionBackground), and FAQ here (bit.ly/SafetyPetitionFAQ).

Thank you,

Bob Turcott

Ulrich Aldag
Karen Askey
Loni Austin
Liz Babb
Valerie Baldwin
Danna Breen
Monika Cheney
Rusty Day
Patty Dewes
John Donahoe
Eileen Donahoe
Ronald Eastman
Walli Finch
David Horn
Karen Horn
Alyson Illich
Majda Jones
Gil Kliman
Yasemin Kliman
Victoria Klein
Winnie Lu
Bill Lu
Janet Mountjoy
Matthew Muffly
Lori Muffly
John L Richardson
Bruce Roberts
Alice F Schenk
Andrew Thompson
Sylvia Thompson
Ellen Vernazza
Barbara Vetter
Ward W Woods
Priscilla B Woods
Rob Younge

Background Statement - Petition to Protect Public Safety

"The protection of the public safety is the first responsibility of local government…"
- California Constitution, Article XIII, Section 35, paragraph 2

Brief Factual Background

1. The severe wildfire hazards that exist throughout Portola Valley and the extreme risk such hazards pose to the community as a whole were thoroughly documented over a decade ago:

    - By Cal Fire's assessment in 2007-2008, 61% of Portola Valley's lands constituted High or Very High Fire Hazard Severity Zones[1] (Fig. 1).

    - Woodside Fire Protection District (WFPD) recommended in 2008 that four distinct areas of Town, encompassing most of the western hills, large portions of Westridge, Alpine Hills and Portola Valley Ranch, all be designated as Very High Fire Hazard Severity Zones.[2]

    - The Town's professional wildfire consultant, Moritz Arboricultural Consulting, independently identified and mapped 19 Highest Hazard wildfire areas throughout Portola Valley[3] (Fig. 2).

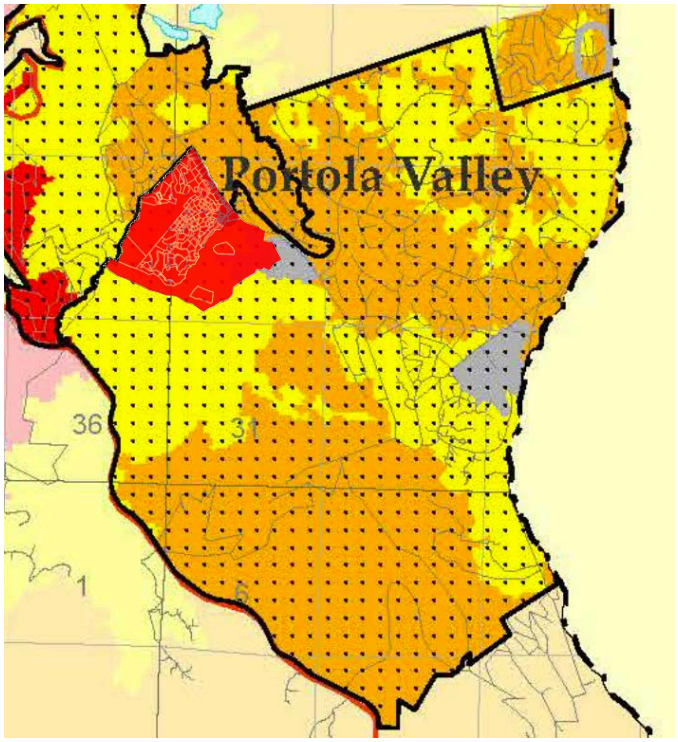

Fig. 1. Composite Cal Fire maps showing High (tan) and Very High (red) Fire Hazard Severity Zones, covering 61% of Portola Valley.

Fig. 2. Map from the 2008 Moritz Report. Circles show the areas within Portola Valley that the independent consultant deemed to be "highest hazard".

2. Citing concern over possible adverse effects on insurability and property values, the Town Council, under then Mayor Maryann Derwin, decided in 2008 not to designate any part of Portola Valley as a High or Very High Fire Hazard Severity Zone.

    - Instead, the Town adopted portions of Chapter 7A of the California Building Code requiring fire-resistant building materials and methods for new residential construction.

    - In doing so, however, the Town exempted certain structures from compliance with the code's fire hazard-reduction standards.

    - It also declined to adopt the California code's 100-foot vegetation removal and control requirements for defensible space around structures within Very High Fire Hazard Severity Zones.

3. Whatever the merit or wisdom of the Town Council's decision in 2008, it is abundantly clear today that a refusal to accept the recommendations of Cal Fire, WFPD and Moritz Arboricultural Consulting to identify and acknowledge the severe wildfire hazards in Portola Valley will not enhance future insurability or protect property values.

    - As Council Member Aalfs told Fortune Magazine this fall, 500 homeowners (1/3 of all Portola Valley households) have recently had their fire insurance cancelled.[4]

    - Although Town Mayor Derwin lives in an area of Westridge that is outside the Very High Fire Hazard Severity Zone identified by Cal Fire in 2008, her fire insurance has been cancelled twice due to excessive risk.

    - And, as Council Members Hughes and Richards recently informed three California State agencies, if current trends continue, new and existing structures within Portola Valley will become uninsurable.

    - The decreasing availability and increasing cost of fire insurance will adversely affect property values. It will also disproportionately harm the ability of lower income families to purchase and finance home ownership.

4. California's many recent wildfires amply demonstrate the extreme risk created by the intermix of dense vegetation and hundreds of structures and accessory buildings throughout Portola Valley. That risk is only heightened by the Town's steep hillsides, narrow ravines, dense, creek-fed vegetation and increasingly dry, extended fire season.

    - In Oakland, Santa Rosa and Paradise, wildland fires rapidly destroyed thousands of homes in a matter of hours—often with very little or no advance warning—killing scores of residents.

    - While extreme weather plays an important role in California's ever-more intense, ever-more frequent wildfires, such conditions alone do not cause the nearly

instantaneous combustion that has destroyed thousands of homes in coastal and central California.

- The 2018 Camp fire destroyed over 18,000 homes and structures in less than 24 hours, claimed 85 lives, and left the town of Paradise largely destroyed.
- Outside Santa Rosa, the 2017 Tubbs fire destroyed nearly 5,000 homes in less than 12 hours.
- And in the Oakland Hills, nearly 3,000 homes were destroyed in less than 6 hours in 1991.

- Denying the unwelcome hazards that confront us all will only exacerbate the risks we face.
- We can no longer afford to ignore or delay the difficult choices that wildfire hazards require us to make.

5. While our Town Council has recently begun to address vegetation management and home hardening, it has neglected the critical need for competent wildfire assessment and prevention in the design and approval of new development projects in Town.

   - The Town's recent adoption of an ordinance implementing the State's ADU mandates without any public testimony of the Fire District or any other competent, fire-prevention professional on the adverse impact of such amendments on wildfire hazards and risks in our community is just one of many examples.
   - No application for development in Portola Valley should proceed without
     - A prior written assessment by WFPD of the project's impact on wildfire hazard and risk, and
     - The written confirmation of WFPD's public safety officer that the project fully complies with or satisfies all wildfire prevention and protection standards.

6. Homes and neighborhoods built in and among the wildlands are not just "vulnerable" or "exposed" to wildfire; they are in fact an important *cause* of cataclysmic destruction.

   - Compelling evidence clearly demonstrates that inadequate separation of buildings from one another can be the most significant cause of home-to-home ignition and fire spread.
   - By placing ever-more man-made structural fuels on hazardous lands in hazardous locations in hazardous ways, we are exacerbating—indeed creating—the very fire hazards that should concern us most.

7. An exhaustive, well-controlled study[5] of the home destruction caused by the 2018 Camp Fire in Paradise found that

   - Radiant heat from burning nearby structures was by far the most significant cause of home damage,

- Structures separated by less than 59 feet from neighboring structures were much more likely to be ignited and destroyed, and

- Increased density of buildings within 100 meters of a residential structure greatly increased the likelihood the structure would be ignited and destroyed.

- As the authors concluded, "[d]istance to nearest destroyed structure and the total number of destroyed structures within 100 meters were consistently the strongest predictors" of home destruction. (Fig. 3, 4)

- Proximity to dense vegetative canopy was found to be the next most important predictor of home destruction in Paradise.

- With respect to home-hardening, the authors found that Chapter 7A's fire-resistant construction standards did not significantly improve the survival of recently constructed buildings.

- Indeed, more than 50% of the homes built after Chapter 7A's adoption in Paradise were destroyed.

- This finding is consistent with an independent Cal Fire investigation, which estimated that Chapter 7A standards reduced the rate of home destruction by only 40%.

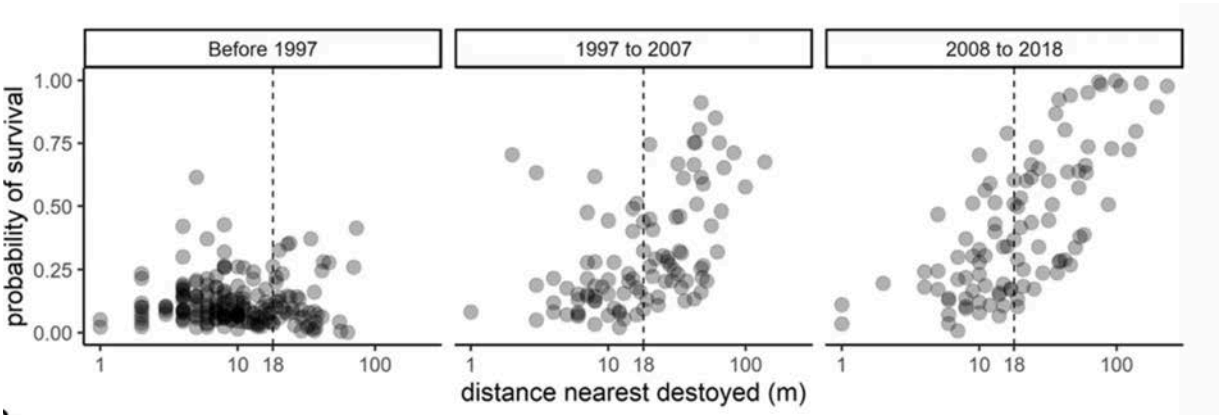

Fig. 3. The strongest predictor of structure survival in the Paradise fire was building separation, and the distance that optimally discriminated between survival and destruction was 18 meters - 59 feet. From Knapp et al., reference in endnotes.

Fig. 4. Canopies don't ignite structures. Rather, structures ignite canopies. While anecdotal, this image from Knapp et al. highlights the effects of intense radiant heat from burning buildings and suggests that, like homes, survival of trees increases the further they are from structures. Reference in endnotes.

8. To diminish the hazard of structure-to-structure fire ignition and spread, the National Fire Protection Association's (NFPA's) Wildland Fire Protection Standard 1140 calls for a minimum building setback from property lines of 30 feet for each building, resulting in a 60-foot separation between buildings located on adjoining parcels.

    - Where multiple structures are built on the same parcel, NFPA 1140 calls for a minimum separation distance between buildings of 30 feet.

    - The best scientific evidence currently available demonstrates buildings separated by less than 60 feet have a significantly increased risk of structure-to-structure ignition and wildfire spread.

    - The best scientific evidence currently available also demonstrates that houses built since Chapter 7A's adoption in 2008 do not have a significantly greater likelihood of survival than homes built in the eleven years prior to the Code's adoption.

9. Various provisions of Portola Valley's municipal code can reduce the hazard of structure-to-structure fire ignition and spread in Portola Valley by requiring a minimum separation

distance between buildings on adjacent parcels and restricting the ratio of building floor area to parcel size. For example,

- MC 18.48.010 establishes
    - Minimum parcel sizes for development of single-family residential structures within areas of town whose terrain and condition pose different hazards and risk;
    - Minimum front, side and rear building setbacks from property lines and public right-of-ways based on minimum parcel size;
    - Maximum floor area of construction that may be built based on parcel size, average slope and geological classification of soils
- MC 17.40.100 establishes minimum paved surface and street right-of-way widths

Properly construed and enforced, these provisions of the Town's Municipal Code reduce the hazard of structure-to-structure fire ignition and spread by requiring minimum separation between buildings and affording adequate defensible space around buildings as well as adequate access and egress for emergency response and evacuation.

10. At present, WFPD's fire safety review of applications is limited.
    - WFPD can only verify the compliance with specific Fire Code and Building Code provisions such as:
        - Is a fire hydrant within 600 feet of the front door that is capable of the required flow?
        - Are smoke and CO detectors installed?
        - Are spark arrestors on chimney outlets?
        - Is permanent addressing in place?
    - Currently WFPD has no authority under our municipal code to evaluate the impact of proposed development projects on wildfire hazards and risk or to enforce building separation and other fire prevention standards that mitigate such hazards and risk.

11. The Petition to Protect Public Safety would
    - Grant WFPD the authority to interpret and apply specific provisions of our municipal code to protect public safety by requiring adequate separation of structures;
    - Require WFPD's prior wildfire safety review and approval of every development application in Town;

- Adopt minimum separation distances between buildings on the same parcel or adjacent parcels;
- Require development and adoption by next fall such additional wildfire prevention and protection standards as WFPD recommends;
- Pending adoption of such additional standards, adopt the 30-foot building separation standard of NFPA 1140; and
- Provide WFPD the funding needed to fulfill its expanded authority and responsibility.

12. Three important changes in State law make the adoption of all of the provisions of the Petition to Protect Public Safety especially urgent and important:
    - The State's Regional Housing Needs Allocation (RHNA allocation) seeks to mandate the construction of 253 additional housing units in Portola Valley by 2030.
    - Recently enacted State law prohibits the enforcement of local land use, site development and setback requirements against proposed accessory dwelling units ***unless***
        - the local authority determines that such enforcement is necessary to protect public health or safety.
    - Newly enacted Senate Bill 9 (SB 9) prohibits local enforcement of land use, subdivision, site development and zoning requirements that would prohibit the subdivision of parcels zoned for single family use into two additional building parcels and allow four structures on the original site (Fig. 5) ***unless***
        - the local authority determines that such enforcement is necessary to protect public health or safety, or
        - the newly sub-divided parcels would be located in a Very High Fire Hazard Severity Zone.
13. In Portola Valley's hazardous, fire-prone terrain, a reduction in separation distances between buildings can significantly increase fire hazard and structure-to-structure ignition and fire spread throughout our residential neighborhoods.
14. The California Constitution and the State Legislature both recognize that the primary responsibility of local government is to protect public safety
    - The State's housing mandates clearly provide Portola Valley's Town Council the legal authority and regulatory means to protect our public safety.
    - CalFire is poised to adopt new Fire Hazard Assessment maps, which are widely expected to bring much greater scrutiny and analysis to the hazards and risk of

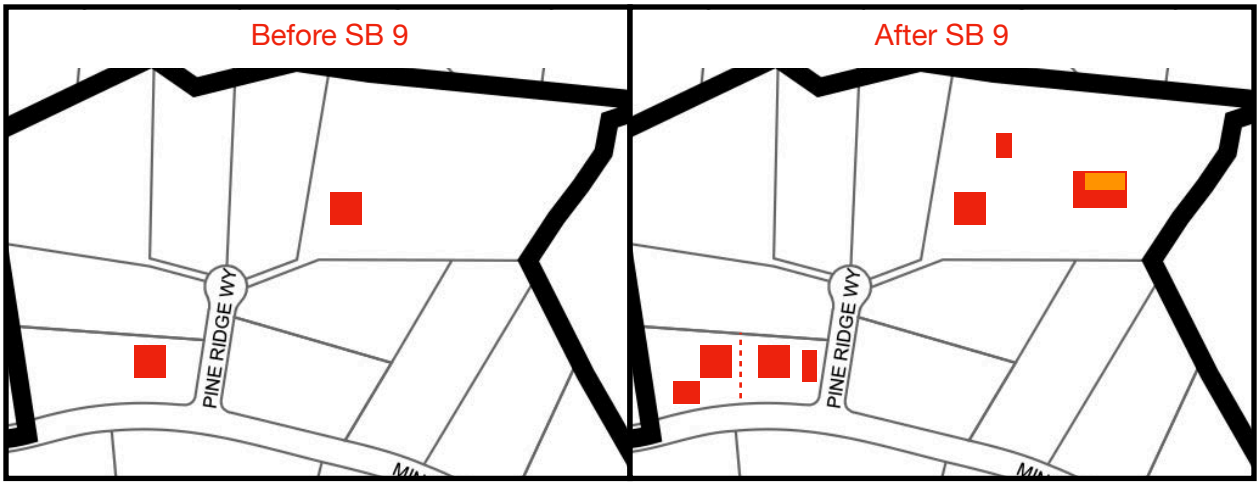

Fig. 5. Unregulated development under SB 9 can increase wildfire hazard and risk in our community. Pine Ridge Way, off Minoca Rd., occupies a narrow ridgeline surrounded on three sides by steep canyons. SB 9 would allow construction on each single-family parcel along Pine Ridge Way of up to 4 dwellings, with or without lot subdivision. (Some sources interpret SB9 as allowing up to 8 dwellings after a lot split - 4 'residential units' plus 2 ADUs plus 2 JADUs, though our Town Attorney believes this interpretation is incorrect.) Under SB 9, approval of such applications would become mandatory if certain conditions are met, unless an authorized local official determines, based on objective public safety standards, that the proposed development would adversely impact public safety. This is why the Town Council must act now to protect public safety by adopting the measures proposed in the Petition to Protect Public Safety.

structure-to-structure ignition and fire spread in populated communities such as Portola Valley.

- To protect public safety in Portola Valley, the Town Council should immediately

    - Require each application for land use, subdivision, development or building within Portola Valley to obtain the final written determination by WFPD's public safety officer that the application fully complies with and/or satisfies the fire prevention and protection objectives of the Building Code and Municipal Code sections 18.48.010 and 17.40.100; and

    - Authorize the public safety officer of WFPD to interpret and enforce the fire prevention and public safety fire protection objectives of the Building Code and Municipal Code sections 18.48.010 and 17.40.100.

- To further protect public safety in Portola Valley, the Town Council should, by September 1, 2022, adopt science-based standards to reduce the wildfire hazard and risk of all future land use, subdivision, development and construction in Portola Valley.

- Pending publication of CalFire's updated fire hazard assessment, and pending also the Town's adoption of science-based land use, zoning, subdivision, development and building standards to protect public safety, the Town Council should adopt by ordinance the 30 foot minimum building separation and 30 foot minimum setback standards specified by the NFPA in section 12.2 of its Wildland Fire Protection Standard 1140.

Endnotes

[1] To our knowledge, the only public disclosure of Cal Fire's assessment of High Fire Hazard Severity Zones in Local Responsibility Areas (LRAs) (ie, areas under the jurisdiction of local municipalities) was published in 2007 in draft form and is available here: osfm.fire.ca.gov/media/6611/fhszl06_1_map41.jpg

While Cal Fire designated High and Very High Fire Hazard Severity Zones for State Responsibility Areas (SRAs), it made no such designations for LRAs. Rather, it identified specific areas that it assessed as being Very High Fire Hazard Severity Zones, and recommended that the local municipality formally designate them as such. Cal Fire made no formal identification or recommendation regarding High Fire Hazard Severity Zones in LRAs. Cal Fire's recommended Very High Fire Hazard Severity Zone for Portola Valley can be found here: osfm.fire.ca.gov/media/5985/portola_valley.pdf

State law makes clear that it is the responsibility of the local municipality to designate High and Very High Fire Hazard Severity Zones, and that Cal Fire's assessments and recommendations are not limiting. The local municipality can designate areas at higher hazard severity than Cal Fire's assessment if evidence supports such a designation.

[2] Findings from WFPD's 2008 analysis were reported in a letter from Town Attorney Cara Silver, dated June 17, 2021 that appeared in the June 23, 2021 Town Council agenda packet red page number 161. The letter can be found here: drive.google.com/file/d/10XyXcMfdTYkfa1VCoOPN5VRjaI_ZFSTw/view?usp=sharing

[3] As of November 19, 2021, neither the 2008 Moritz report nor the report's map is publicly available on the Town's website. The report can be found here: drive.google.com/file/d/1ZK-7Yf86bKvsR16Ggh5fDeYu9vgdo-xC/view?usp=sharing

[4] Council Member Aalfs is quoted in a fascinating article that focuses on Portola Valley while examining the effect of climate change on the economy. It can be found here: fortune.com/2021/09/28/california-wildfires-homeowner-insurance-premiums-fire-risk/

[5] Knapp, E.E., Valachovic, Y.S., Quarles, S.L. *et al.* Housing arrangement and vegetation factors associated with single-family home survival in the 2018 Camp Fire, California. *fire ecol* **17,** 25 (2021). doi.org/10.1186/s42408-021-00117-0

FAQ Petition to Protect Public Safety

What is the purpose of the petition?

The Petition has two goals:

1. To provide objective, science-based standards to prevent and protect against the spread of wildfire in Portola Valley, and
2. To require written certification by Woodside Fire Protection District that any application for new land use, subdivision, development, or construction in Portola Valley meets or satisfies the fire prevention and protection objectives of those standards.

Isn't the true purpose of the Petition simply to increase the cost of development and thereby inhibit growth in Portola Valley? Isn't this a NIMBY effort cloaked in fire safety?

No. The Petition seeks to promote *safe* growth.

There is overwhelming evidence from multiple sources that wildfire poses an existential threat to Portola Valley:

1. Cal Fire, WFPD, and the Town's fire safety consultant all documented extensive areas of highest hazard throughout Portola Valley.
2. The insurance industry is fleeing Portola Valley due to excessive risk:
   - Council Member Aalfs estimates that approximately 1/3 of PV households have lost insurance due to excessive risk
   - Mayor Derwin reports having twice had her insurance cancelled, despite living well outside the area Cal Fire assessed as being highest hazard;
   - Council Members Hughes and Richards believe that if trends continue new and existing homes will become uninsurable.
3. The 2020 CZU fire, caused by dry lightening, came within 8 miles of Portola Valley. It burned 86,000 acres, destroyed 1500 structures, took one life, and was uncontained for 5 weeks.

It would be a grave mistake to ignore this evidence and to ignore the role of poor development planning in the catastrophic fires that have destroyed countless neighborhoods.

What's the rationale behind the 30' structure separation?

Adequate separation between buildings is needed to prevent structure-to-structure spread of fire, to provide sufficient defensible space around structures in order to access and suppress fire, and to facilitate evacuation and escape.

30' separation is the National Fire Protection Association (NFPA) standard as defined in its publication 1140 Standard for Wildland Protection. The best analysis of the Paradise, CA fire shows that building separation was the primary determinant of structure survival and that the optimum separation distance is likely much greater than 60'. 30' separation is thus a modest step in the direction of safe development, yet would go a long way toward preventing the most dangerous site plans in hazardous wildlands such as Portola Valley.

The 30' separation requirement is a temporary, interim measure designed to address an immediate need until comprehensive standards can be developed and adopted next year. Although the best scientific evidence demonstrates that the separation distance between buildings should be at least 60', the Petition would temporarily require only 30' of separation until comprehensive standards are developed and implemented.

Won't a 30' minimum building separation prohibit many of the buildings that already exist in town?

All of the Petition's provisions apply prospectively only to applications for land use, subdivision, development or construction. They do not apply to or affect affect existing land uses or buildings.

Won't a 30' minimum separation prevent small parcel owners from developing their properties?

No. A requirement for 30 feet of separation between buildings would entail a maximum property setback of 15 feet if buildings on adjacent parcels are directly aligned with one another, or a smaller setback if the buildings are offset from one another.

Furthermore, the Petition allows flexibility in the Fire District's application of wildfire prevention standards. The Petition would require "a final written determination by WFPD that the [development] proposal complies with or *otherwise satisfies* the fire prevention and protection objectives of the building code and municipal code sections 18.48.010 and 17.40.100." Thus, a proposed development that does not literally comply with a fire prevention standard as written may nonetheless be shown to otherwise satisfy the fire prevention objective of the standard through other means.

How would this Petition affect smaller parcels in Portola Valley?

Under our Zoning Map (link) the district having the smallest parcel size requires parcels having 15,000 square feet per parcel. Our Zoning Ordinance permits parcels as small as 7,500 square feet per parcel. While there will always be deviations and variations in the sizes and dimensions of parcels, a parcel of 100 feet in width and 150 feet in length would have 15,000 square feet. A parcel having 75 feet in width and 100 feet in length would have 7,500 square feet.

Taking the smallest allowed parcel size, three 75x100 foot parcels side-by-side would enable each parcel to position a 45x45 foot residence (2,025 sf or more) on each parcel with 30 feet of separation between each of them, while still allowing room for small secondary structures 30 feet distant from each residence.

To accommodate the variability in parcel size and dimension that will necessarily occur, the Petition provides that applications which do not literally comply with the separation standard as written may nonetheless be shown to otherwise satisfy the wildfire prevention objectives of the standard through other means.

FAQ Petition to Protect Public Safety

Won't enhanced building standards compensate for less separation between buildings and allow greater density than the Petition would allow?

The available data don't support this. In fact, in the best analysis of the 2018 Paradise, CA fire, building separation and vegetative canopy cover were the strongest predictors of structure survival. Home hardening, as reflected in the adoption of California's Chapter 7A Building Codes, did not have a statistically significant effect on home survival. In other words, if these home hardening materials and techniques had an effect, it wasn't apparent in the data. Building separation matters, and the data suggest it matters much more than Chapter 7A standards.

That said, there are doubtless approaches to residential construction that would allow improved survival at shorter distances. But to our knowledge, such approaches have not been demonstrated.

Would Woodside Fire Protection District (WFPD) be able to fulfill the duties outlined in the petition?

WFPD's expanded duties would no doubt require additional staff and funding. Portola Valley should provide the funding and grant WFPD the authority to administer the funds.

Is WFPD supportive of the Petition?

WFPD operates within the mandate defined for it by the areas it serves: Portola Valley, Woodside, and portions of unincorporated San Mateo County. It is not in a position to lobby for an expansion or contraction of its authority. Rather, it strives to best fulfill its mandate as defined by the jurisdictions it serves.

The process by which the Town Council will decide whether to enact the proposals of the Petition is a political one. It is not the role of WFPD to participate in political processes, nor would it be appropriate to seek advocacy from fire safety professionals who are employed by WFPD.

If WFPD's mandate is to be expanded, it is up to the residents of Portola Valley to lobby for this, and for the Town Council to adopt the measures of the Petition and to provide adequate additional funding to enable WFPD to fulfill its additional responsibilities.

What questions should we be asking WFPD?

1. Does the hazard of structure-to-structure fire ignition and spread increase when buildings are not adequately separated from one another?
2. Does the District believe
   - An ordinance requiring adequate separation between — and defensible space around — buildings would reduce the hazard of structure-to-structure wildfire ignition and spread?
   - New land use, subdivision, and construction projects should comply with or otherwise satisfy written wildfire prevention and protection standards prior to their approval?
3. Is the District willing and able to
   - Assist in the preparation of written, science-based wildfire prevention and protection standards for new land use, subdivision and construction projects?
   - Review and certify whether such projects comply with or satisfy such written wildfire fire prevention and protection standards?

PETITION TO PROTECT PUBLIC SAFETY

"The protection of the public safety is the first responsibility of local government…"
- California Constitution, Article XIII, Section 35, paragraph 2

1. Wildfire poses an existential threat to Portola Valley and its neighboring communities. The Town's fire-prone terrain, dense vegetation, changing climate, built-environment and limited evacuation capacity expose its many residents to severe hazards of rapid, uncontrolled spread of intense fire.

2. Excessively dense development and inadequate building separation will increase wildfire hazards and risk, degrade evacuation capacity and hinder emergency response, especially in Portola Valley's fire-prone terrain and ecosystem.

3. Properly construed and enforced, the following provisions of Portola Valley's municipal code can reduce the hazard of structure-to-structure fire ignition and spread in Portola Valley by requiring a minimum separation distance between buildings on adjacent parcels, regulating the ratio of building floor area to parcel size and protecting unobstructed emergency access and evacuation routes.

   (a) MC 18.48.010 establishes

      - Minimum parcel sizes for development of single-family residential structures within areas of town whose terrain, development and vegetation pose different hazards and risk;

      - Minimum front, side and rear building setbacks from property lines and public right-of-ways based on minimum parcel size;

      - Maximum floor area of construction that may be built on parcels based on parcel size, average slope and geological classification of soils.

   (b) MC 17.40.100 establishes minimum paved surface and right-of-way widths for streets.

4. The proper interpretation, application and enforcement of these and other public safety provisions of the municipal code is necessary to protect and promote the public safety of Portola Valley residents.

5. State housing mandates, including Senate Bill 9, recognize the Town's authority and primary responsibility to protect public safety through prudent, science-based regulation of land use, subdivision, development and building.

PETITION TO PROTECT PUBLIC SAFETY

We, the undersigned members of the Portola Valley community, urgently call upon the Town Council to acknowledge its responsibility and exercise its authority to protect public safety by:

(a) Requiring, effective January 1, 2022, before any land use, subdivision, development or building application in Portola Valley is deemed complete, a final written determination by Woodside Fire Protection District (WFPD) that the proposal complies with or otherwise satisfies the fire prevention and protection objectives of the building code and municipal code sections 18.48.010 and 17.40.100;

(b) Designating WFPD, effective January 1, 2022, as the authority within Portola Valley having jurisdiction to interpret and enforce the fire prevention and public safety fire protection objectives of the building code and municipal code sections 18.48.010 and 17.40.100;

(c) Adopting by ordinance by September 1, 2022 such additional land use, zoning, subdivision, development, and building standards as WFPD develops in conjunction with the Town to establish minimum, science-based wildfire prevention and protection standards required for WFPD approval of any land use, subdivision, development or building proposal;

(d) Providing sufficient additional budgetary authority and funding for WFPD to fulfill its expanded authority; and

(e) Pending adoption of supervening wildfire prevention and protection standards, adopting by ordinance effective January 1, 2022 the 30 foot minimum building separation specified in section 12.2 of the National Fire Protection Association's Standard 1140 for Wildland Fire Protection.

To add your name electronically (preferred), go to bit.ly/SafetySigner or use the QR code. Or, send the information below to Bob Turcott at btur913@gmail.com, 60 Pine Ridge Way, PV, 94028.

Name	Address	Date	Email

Knapp *et al. Fire Ecology* (2021) 17:25
https://doi.org/10.1186/s42408-021-00117-0

Fire Ecology

ORIGINAL RESEARCH Open Access

Housing arrangement and vegetation factors associated with single-family home survival in the 2018 Camp Fire, California

Eric E. Knapp[1*], Yana S. Valachovic[2], Stephen L. Quarles[3] and Nels G. Johnson[4]

Abstract

Background: The 2018 Camp Fire, which destroyed 18,804 structures in northern California, including most of the town of Paradise, provided an opportunity to investigate housing arrangement and vegetation-related factors associated with home loss and determine whether California's 2008 adoption of exterior building codes for homes located in the wildland-urban-interface (WUI) improved survival. We randomly sampled single-family homes constructed: before 1997, 1997 to 2007, and 2008 to 2018, the latter two time periods being before and after changes to the building code. We then quantified the nearby pre-fire overstory canopy cover and the distance to the nearest destroyed home and structure from aerial imagery. Using post-fire photographs, we also assessed fire damage and assigned a cause for damaged but not destroyed homes.

Results: Homes built prior to 1997 fared poorly, with only 11.5% surviving, compared with 38.5% survival for homes built in 1997 and after. The difference in survival percentage for homes built immediately before and after the adoption of Chapter 7A in the California Building Code (37% and 44%, respectively) was not statistically significant. Distance to nearest destroyed structure, number of structures destroyed within 100 m, and pre-fire overstory canopy cover within 100 m of the home were the strongest predictors of survival, but significant interactions with the construction time period suggested that factors contributing to survival differed for homes of different ages. Homes >18 m from a destroyed structure and in areas with pre-fire overstory canopy cover within 30–100 m of the home of <53% survived at a substantially higher rate than homes in closer proximity to a destroyed structure or in areas with higher pre-fire overstory canopy cover. Most fire damage to surviving homes appeared to result from radiant heat from nearby burning structures or flame impingement from the ignition of near-home combustible materials.

Conclusions: Strong associations between both distance to nearest destroyed structure and vegetation within 100 m and home survival in the Camp Fire indicate building and vegetation modifications are possible that would substantially improve outcomes. Among those include improvements to windows and siding in closest proximity to neighboring structures, treatment of wildland fuels, and eliminating near-home combustibles, especially in areas closest to the home (0–1.5 m).

Keywords: Building codes, Defensible space, Flame impingement, Fuels, Radiant heat, Structure loss, Wildfire, Wildland-urban interface

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Full list of author information is available at the end of the article

Resumen

Antecedentes: El incendio de Camp Fire, el cual destruyó 18.804 estructuras en el norte de California, incluido la mayor parte del pueblo de Paradise, proveyó una oportunidad de investigar la ubicación de las casas y factores vegetales asociados con la pérdida de hogares, y determinar si la adopción de los códigos de construcción de California de 2008 para el exterior de las viviendas ubicadas en las áreas de interfaz urbano rural, mejoraban su supervivencia. Muestreamos al azar casas individuales construidas antes de 1997, de 1997 a 2007, y de 2008 a 2018, las últimas por dos períodos, anterior y posterior a los cambios en los códigos de construcción. Luego cuantificamos los doseles de la vegetación aledaña y la distancia a la vivienda y estructura más cercana destruidas por el fuego usando imágenes satelitales. Usando fotografías post-fuego, también determinamos el daño por fuego y asignamos una causa de daño, pero no casas destruidas.

Resultados: Las casas construidas antes de 1997 se desempeñaron pobremente, con solo un 11,5% de supervivencia, comparado con un 38,5% de supervivencia de aquellas construidas en 1997 y a posteriori. La diferencia en el porcentaje de supervivencia para las casas construidas antes y después de la adopción del Capítulo 7A del código de Construcción de California (37% y 44%, respectivamente), no fue estadísticamente significativa. La distancia a la estructura más cercana destruida por el fuego, el número de estructuras destruidas dentro de los 100 m, y la cobertura del dosel vegetal previo al fuego fueron los predictores de supervivencia más importantes, aunque las interacciones más significativas con el período de construcción sugieren que los factores que contribuyeron a la supervivencia difirieron para casas de diferentes edades. Las casas distantes > 18 m de una estructura destruida y en áreas con cobertura de vegetación previa dentro de los 20-100 m de esa casa < 53% sobrevivió a tasas superiores que aquellas en proximidad de una estructura destruida o en áreas con mayor cobertura vegetal pre-fuego. La mayoría de los daños a las casas supervivientes parece resultar del calor radiante de las estructuras quemadas próximas o por el impacto de las llamas de igniciones de materiales combustibles cercanos a las casas.

Conclusiones: Las fuertes asociaciones entre la distancia de la estructura destruida más cercana y la vegetación dentro de los 100 m y la supervivencia de las casas en el incendio de Camp Fire indican que es posible que las modificaciones en las construcciones y en la estructura de la vegetación mejoren los resultados en relación a su supervivencia. Entre ellos se incluye el mejoramiento de las ventanas y paredes en la proximidad de estructuras vecinas, el tratamiento de los combustibles vegetales, y la eliminación de combustibles cercanos, especialmente en áreas muy cercanas a las casas (entre 0 y 1,5 m).

Background

California, like many other regions having a Mediterranean climate, is set up to burn. Cool, wet winters, which promote vegetation growth, are followed by long, hot, nearly rain-free summers during which these wildland fuels are primed for combustion (Sugihara et al. 2018). In forested areas such as the northern Sierra Nevada, where the town of Paradise is located, wildfires ignited by indigenous peoples and lightning were historically frequent (mean fire return interval of mostly <15 years) (Van de Water and Safford 2011) and integral to shaping vegetation composition and structure (Leiberg 1902; Sugihara et al. 2018). The historical fire return interval in shrub-dominated chaparral vegetation was somewhat longer—15 to 90 years (Van de Water and Safford 2011). While overall acres burned in wildfires today is still substantially less than what burned historically (Stephens et al. 2007), both acres burned and associated losses to infrastructure have been increasing in recent times with 15 of the 20 most destructive events in modern California history, based on the number of structures destroyed, occurring since 2014 *(see California Fire Statistics:* https://www.fire.ca.gov/media/t1rdhizr/top20_destruction.pdf*)*.

The increase in destructive wildfire events has been linked to changes in fire frequency, development patterns, and climate. Loss of indigenous burning and active fire suppression over the past 150 or more years following Euro-American expansion into California reduced the incidence of fire in many forested areas. Where fire historically burned most frequently, surface and vegetative fuels have increased, often leading to more severe fire when it does burn (Steel et al. 2015). Such fires are also frequently more intense because fire suppression has effectively eliminated much of the lower intensity burning under more benign weather conditions. When landscapes now experience fire, most often it is when wildfire escapes initial attack under worst-case scenario weather conditions (Calkin et al. 2014). In addition, over the last several decades, warmer temperatures and longer fire seasons (Westerling et al. 2006) have increased fuel volatility and the probability of ignitions coinciding with extreme weather conditions. In other areas such as

chaparral ecosystems in southern California, fire suppression has had less influence on the fire regime—fire frequency has increased in some areas on account of numerous human ignitions, but stand-replacing fire was and still is the norm (Conard and Weise 1998). Further complicating the wildfire challenges, human populations have increased nearly ten-fold over the last 150 years, with a substantial proportion of houses built within or among wildland vegetation (Radeloff et al. 2018). Partly due to the effectiveness of fire suppression, most of these homes were not built or maintained with the goal of being able to withstand wildfire in the absence of fire suppression resources. In addition, home design or construction codes and standards to enhance a building's exterior resistance to wildfire are relatively recent (International Code Council 2003), with substantial development having occurred prior.

Post-wildfire analyses provide an opportunity to investigate why some houses survive and learn how to better co-exist with wildfire in fire-prone environments. During wildfire, buildings can be subjected to three different wildfire exposures—wind-blown embers, radiant heat, and direct flame contact (Caton et al. 2017). Embers are produced when vegetation ignites and burns (Koo et al. 2010). In large, fast-moving wildfires burning under extreme conditions, embers can be transported several kilometers or more (Koo et al. 2010) and ignite buildings directly or indirectly (Caton et al. 2017). A direct ember ignition includes embers igniting decking or siding by accumulating on or next to the material or penetrating vents or open windows and entering the building (Quarles et al. 2010; Hakes et al. 2017). In contrast, indirect ignitions occur when embers ignite combustible materials such as vegetation, bark mulch, leaf litter, neighboring buildings, or near-home objects such as stored materials, decks, or wood fences (Quarles et al. 2010; Hakes et al. 2017). Indirect ignition scenarios ultimately result in radiant heat and/or flame contact to the home or building. Direct flame contact and extended radiant heat exposures can ignite siding and other exterior-use construction materials or break glass in windows. Radiant heat exposure often occurs when a neighboring structure ignites. The dominant mechanism of home loss in numerous particularly destructive wildfires has been described as initial direct or indirect ember ignitions, with burning homes then leading to house-to-house fire spread (Murphy et al. 2007; Cohen and Stratton 2008). However, the potential influence of housing density on structure losses in wildfires has varied, with some studies finding a greater probability of loss at higher housing densities (Price and Bradstock 2013; Penman et al. 2019), while other studies have reported a greater risk at lower housing densities (Syphard et al. 2012, 2014, 2017). Amount of near-home combustible vegetation has also been linked to the probability of home loss in wildfires (Price and Bradstock 2013; Syphard et al. 2014; Penman et al. 2019).

California leads the USA in having a building code with the objective of limiting the impact of wildfires on the built environment. In the 1960s, the state began requiring homeowners to implement defensible space fuel modifications, initially within the first 9 m (30 ft) of a building, but since expanded to 30 m (100 ft) (https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?sectionNum=4291.&lawCode=PRC). Work on standardized test methods to evaluate exterior-use construction materials for fire performance began in the late 1990s and later incorporated into Chapter 7A, an addition to the California Building Code which was adopted in 2008. Chapter 7A provides prescriptive and performance-based options for exterior construction materials used for roof coverings, vents, exterior walls, and decks (https://codes.iccsafe.org/content/CBC2019P4/chapter-7a-sfm-materials-and-construction-methods-for-exterior-wildfire-exposure) and applies to new construction of residential and commercial buildings in designated fire hazard severity zones. In some jurisdictions, provisions of Chapter 7A also apply to "significant remodels" of existing buildings. The 2018 Camp Fire, which destroyed much of Paradise, California, provided an opportunity to evaluate the performance of buildings constructed after the adoption of Chapter 7A and explore factors associated with home survival.

The Camp Fire started on the morning of November 8, 2018, with the failure of an electrical transmission line and spread rapidly through wildland fuels comprised of mixed conifer forest, brush, grass, and dead and down surface fuels (Maranghides et al. 2021). Surface fuels were unusually dry due to persistently low relative humidity throughout the summer and fall and the late onset of fall rains (Brewer and Clements 2019). Driven by strong NE winds, the fast-moving fire quickly reached the towns of Concow, Paradise, and Magalia and became the most destructive wildfire in California history. At least 85 people were killed and 18,804 structures were destroyed. A high proportion of the home and business losses occurred in Paradise—the largest town within the fire footprint. The fire passed from one side of Paradise to the other during one burn period over less than 12 h (Maranghides et al. 2021). With the focus on saving people's lives, very few homes were subject to firefighting efforts, and survival was therefore largely a function of characteristics of the home and surrounding environment. Previous similar analyses have typically combined data across multiple fires and years, with an unknown extent of defensive intervention.

While conditions as the Camp Fire burned through Paradise were still highly variable, the massive home loss in a single burn period presents an opportunity to investigate factors with potentially lesser confounding by differences in geography, weather, and defensive action by firefighters or civilians.

The objective of this research was to answer three questions as follows: (1) did proximity to nearby burning structures factor into the probability of home survival, (2) did fuels associated with nearby vegetation factor into the probability of home survival, and (3) was the full adoption in 2008 of Chapter 7A into the California Building Code associated with improved odds of home survival?

Methods

The Butte County Assessor's database, dated June 1, 2018, was used to extract 11,515 parcels within the Paradise city limits (Fig. 1). Parcels were sorted by use code and 7949 single-family dwellings were selected, after discarding 89 without a listed build year. Mobile homes, businesses, and other non-single-family structures were excluded. We then linked Damage Inspection (DINS) data, obtained from CAL FIRE, to parcel number to ascertain damage sustained in the Camp Fire and whether the building was destroyed, partially damaged, or had no impact from the Camp Fire. We lumped homes classified as "damaged" into the "survived" category, because in most instances, the damage, based on photos included with the DINS data, was minor—e.g., cracked windows, bubbled exterior paint, or melted vinyl gutters and window frames, with the structure itself intact.

Sample population

For our analyses, we randomly selected 400 single-family dwellings in Paradise, stratified by three time periods (Fig. 1): time 1 = homes built before 1997, while time 2 (homes built from 1997 to 2007) and time 3 (homes built from 2008 to 2018) represented the two 11-year periods on either side of the 2008 adoption of Chapter 7A in the California Building Code. If the changes to the building code improved home survival, survival percentage in time 3 should be significantly higher than survival in time 2, especially after adjusting for any potentially confounding variables. The stratification was done to ensure a large enough sample size in time period 3. Two hundred homes (out of 7288) were randomly selected in time 1, one hundred homes (out of 519) were selected in time 2, and 100 homes (out of 142) were selected in time 3 (Fig. 1). More homes were selected during time 1 because such a low percentage (13%) of older (pre-1997) homes survived. Of the population of homes that were randomly selected by the construction period, 24 of the surviving homes were noted as damaged in the DINS report, the rest undamaged. Damage was listed as "affected (1–9%)" for 23 of the damaged homes and "minor (10–25%)" for one.

Variables

For each randomly selected home, we used Google Earth to measure the distance from the edge of the home (as defined by edge of the roof, using pre-fire images when destroyed) to the closest edge of the nearest home and nearest structure, as well as the nearest home and nearest structure that burned. "Nearest structure" was in most cases another single-family home, but also

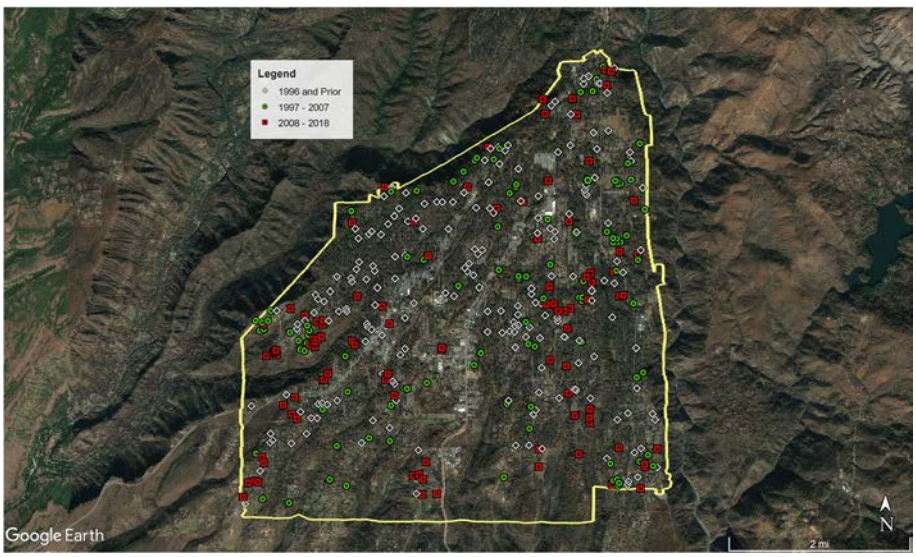

Fig. 1 Map showing the perimeter of Paradise, California, with the location of 400 randomly selected homes built during three time periods (pre-1997, 1997–2007, and 2008–2018)

included mobile homes, businesses, detached garages, or outbuildings such as larger sheds. Small sheds—those <120 ft^2, where a building permit is not required—were excluded. Such smaller sheds may have posed a threat to the home as well but were more challenging to consistently quantify, especially if under a tree canopy. We determined the density of structures in the surrounding area by counting the number of single-family homes, partially-built homes, mobile homes, and businesses (excluding small sheds) with midpoints (based on a visual estimate) included within a 100-m radius centered on the target home. We then counted how many of those structures were destroyed. We visually estimated the percentage cover of overstory vegetation from Google Earth images taken prior to the fire in 2018 and/or 2017 within a 30-m radius circle centered on the selected home and between 30 m and 100 m from the selected home. Cover of the understory of grass and/or shrubs or landscape plantings was not estimated, as pre-fire overstory canopy cover was relatively high, and this often obscured the understory. Some larger mid-story shrubs might have been included with the tree overstory due to the difficulty in distinguishing them from trees. The lot size was provided in the Butte County Assessor's data. Whether the house was located in the Wildland Urban Interface (defined as developed areas that have sparse or no wildland vegetation but are near a large patch of wildland) or the Wildland Urban Intermix (defined as areas where houses and wildlands intermingle) was determined by overlaying a University of Wisconsin data layer on the city of Paradise (Radeloff et al. 2005). We used Radeloff et al. (2005) to define the interface as census blocks with at least 6.17 housing units km^{-2} that contained <50% wildland vegetation but were within 2.4 km of a heavily vegetated area (>75% wildland vegetation) larger than 5 km^2. Intermix was defined as an area with more than 6.17 housing units km^{-2} but dominated by wildland vegetation. Percent slope was calculated as the rise between the lowest and highest point along a 100-m radius circle centered on the home.

Analysis approach

Possible explanatory variables (S1 Table) were first analyzed individually using a generalized linear model in SAS PROC GENMOD and assuming a normal distribution to evaluate whether they differed by time period or by outcome (survived, destroyed). To account for the sampling scheme, in this and all subsequent analyses, each observation was weighted by the inverse of its probability of selection—i.e., homes from time period 1 had a weight of 7288/200, homes from time period 2 had a weight of 519/100, and homes from time period 3 had a weight of 142/100. Comparisons among main effects (outcome, time period) and interactions (outcome × time period) were determined using Tukey's HSD test for multiple comparisons, when significant.

To determine the relative strength of factors associated with home survival, we used a generalized linear model fit for binary response data, with a logit link function and weighting to account for the sampling scheme. Variables in the initial model were as follows:

1. Y-variable: Outcome (Survived/Destroyed); X-variables: construction time period, year built, Wildland Urban Interface/Intermix category, distance to nearest destroyed structure, total structures destroyed within 100 m, overstory canopy cover within 30 m, overstory canopy cover between 30 m and 100 m, slope, and the interaction of each with the construction time period.

When independent variables were highly correlated ($R > 0.6$), only the one most clearly mechanistically linked to outcome was included. For example, "distance to nearest structure" was highly correlated with "distance to the nearest destroyed structure," and "total structures–100 m" was highly correlated to "total structures destroyed—100 m" (Table 1), so only the latter were included. Lot size was not included as there was no clear mechanistic link with home survival, and we hypothesized that elements contributing to fire behavior would be captured by correlated variables. The Wildland Urban Interface/Intermix category was included to quantify differences in vegetation and housing arrangement at scales larger than 100 m. Non-significant interactions and non-significant main effects for variables that did not have a significant interaction with time were sequentially removed to produce the final model. To determine whether homes constructed after the Chapter 7A building code update survived at a significantly higher rate after factoring in all other possible confounding variables, the same analysis was conducted except without interactions with the construction time period.

We then designed models to first test the effect of variables that may have directly influenced home survival during the fire and second, to test the effect of just the variables available prior to the fire. The latter variables were ones that might be mitigated preemptively through planning, retrofitting, or vegetation management. For each of these models, we determined the effect size and performed a regression tree analysis. Variables included for each approach (accounting for the fire, pre-fire only):

1. Y-variable, accounting for the fire: Outcome (Survived/Destroyed); X-variables: year built, distance to nearest destroyed structure, total structures destroyed within 100 m, canopy cover within 30 m,

Table 1 Significance of individual factors by time period, outcome (destroyed, survived), and outcome × time period for a subset of single-family homes in Paradise, CA. Means for time period, outcome, and outcome × time period (when interaction was significant) are provided below (standard error in parentheses). Levels within variables followed by different letters were significantly different ($P<0.05$)

	N	Lot size (ha)	Dist. nearest struct. (m)	Dist. nearest destr. struct. (m)	Total structures 100 m	Total structures destr. 100 m	% Canopy cover 0–30 m	% Canopy cover 30–100 m	Slope (%)
		P							
Outcome		*0.946*	*0.971*	*<0.001*	*0.004*	*<0.001*	*0.154*	*0.001*	*0.532*
Time period		*0.153*	*0.010*	*<0.001*	*0.002*	*<0.001*	*<0.001*	*0.664*	*0.290*
Outcome × time period		-	-	*0.026*	-	-	-	-	-
		Average (standard error)							
Destroyed	296	0.42 (0.07)	15.4 (1.6)	-	10.3^{a} (0.8)	8.9^{a} (0.7)	40.5 (3.1)	49.1^{a} (2.8)	6.9 (0.6)
Survived	104	0.42 (0.08)	15.5 (1.9)	-	8.1^{b} (0.9)	5.5^{b} (0.9)	36.0 (3.7)	40.0^{b} (3.3)	7.2 (0.6)
Before 1997	200	0.30 (0.04)	10.9^{b} (0.8)	-	11.4^{a} (0.4)	9.4^{a} (0.4)	49.5^{a} (1.6)	46.7 (1.4)	6.4 (0.3)
1997-2007	100	0.45 (0.09)	16.1^{a} (2.1)	-	8.0^{b} (1.0)	5.9^{b} (1.0)	35.7^{b} (4.1)	43.7 (3.7)	7.5 (0.7)
2008-2018	100	0.51 (0.17)	19.3^{ab} (4.0)	-	8.1^{ab} (1.9)	6.3^{ab} (1.8)	29.5^{b} (7.9)	43.2 (7.0)	7.2 (1.4)
<1997 Dest.	177	-	-	12.3^{c} (0.8)	-	-	-	-	-
<1997 Surv.	23	-	-	22.3^{b} (2.1)	-	-	-	-	-
1997–2007 Dest.	63	-	-	20.0^{bc} (3.4)	-	-	-	-	-
1997–2007 Surv.	37	-	-	34.6^{ab} (4.4)	-	-	-	-	-
2008–2018 Dest.	56	-	-	16.1^{bc} (6.8)	-	-	-	-	-
2008–2018 Surv.	44	-	-	54.0^{a} (7.7)	-	-	-	-	-

canopy cover between 30 m and 100 m, wildland urban interface/intermix category, slope.

2. Y-variable, pre-fire only: Outcome (Survived/Destroyed); X-variables: year built, distance to nearest structure, total structures within 100 m, canopy cover within 30 m, canopy cover between 30 m and 100 m, wildland urban interface/intermix category, slope.

To quantify the relative strength of continuous variables for explaining home survival, each of the dependent (x) variables were centered and scaled to have a mean of zero and standard deviation of one. Logistic regression (McCullagh and Nelder 1989) was then used to calculate coefficients and compare effect sizes. The logistic regression models were fit using the *svyglm* function from the *survey* package in R (Lumly 2020). A decision tree for predicting home survival was produced using the *rpart* function in the *rpart* package (Therneau and Atkinson 2019) in R, fit for binary response data with a logit link function (Breiman 1998). This approach is similar to logistic regression, where the linear predictor is a decision tree model. To determine the number of splits in the decision trees, we performed cross-validation 10,000 times to compute the optimal pruning parameters. We then used the average of the 10,000 optimal pruning parameters as the pruning parameter in the final decision tree. The latter group of statistical analyses was completed using R version 4.0.0 (R Core Team 2020). Figures were made in R using the *ggplot2* package (Wickham 2016).

Visual evaluation of damaged homes

To learn more about vulnerabilities of the Paradise home sample and gain insight into potential points of fire entry, we reviewed the CAL FIRE damage inspection (DINS) spreadsheet (obtained from CAL FIRE 12/18/2018) and obtained photographs of all damaged homes (N=310 homes with pictures).

Photographs typically keyed in on the damage, and we reviewed each, along with notes about damage in the DINS summary. Observed home damage was assigned to radiant heat, direct ember ignition, or flame impingement categories (S2 Table), based on the nature of the damage, location on the home, and visual as well as photographic (aerial imagery) evidence of other burned fuels, including homes, in the immediate vicinity. Homes where flame impingement was recorded were further split into three categories: (1) caused by fuel continuity with the broader landscape (which allowed fire to reach the home), (2) indirect ember ignition (e.g., gutter contents, near-home fuels) with flames then impacting the home, or (3) unknown/undetermined. [The DINS assessment gathered similar information, but the full suite of data was not collected for over a quarter of homes and ember ignition was not separated into direct and indirect categories.] Where DINS data were collected, our evaluation was often in agreement, but there were a few instances where we differed. For example, if the DINS assessment noted "direct flame impingement" but the photo showed no charring or near home fuels consumed, we listed the damage caused as "radiant heat." Gutter fires were variously categorized but we assigned them all to the "indirect ember ignition" category. The DINS assessment also only lists a single cause of fire damage when a considerable number of homes displayed multiple causes.

Results

Overall, most (86%) of the single-family homes in Paradise were built before 1990, and homes of this age fared poorly, with only 11.6% surviving the Camp Fire (Fig. 2). Survival increased to 20.6% for homes built between 1990 and 1996, 34.3% for homes built between 1997 and 2007, and 43.0% for homes built between 2008 and 2018. The 400 randomly selected homes in our sample had similar survival rates to the full population of single-family homes—11.5% vs. 13.3%, respectively, for the <1997 time period (time = 1), 37.0% vs. 34.3%, respectively, for the 1997–2007 time period (time = 2), and 44.0% vs. 43.0%, respectively, for the 2008 to 2018 time period (time = 3). Many of the potential explanatory variables differed over the three time periods as well and were therefore confounded with potential construction or building code differences (Table 1). Older homes (<1997) were on average in areas with higher housing density and had more homes burn within 100 m than homes built from 1997 to 2007 (Table 1). Homes built prior to 1997 had a higher average pre-fire overstory canopy cover in the first 0–30 m from the home than homes

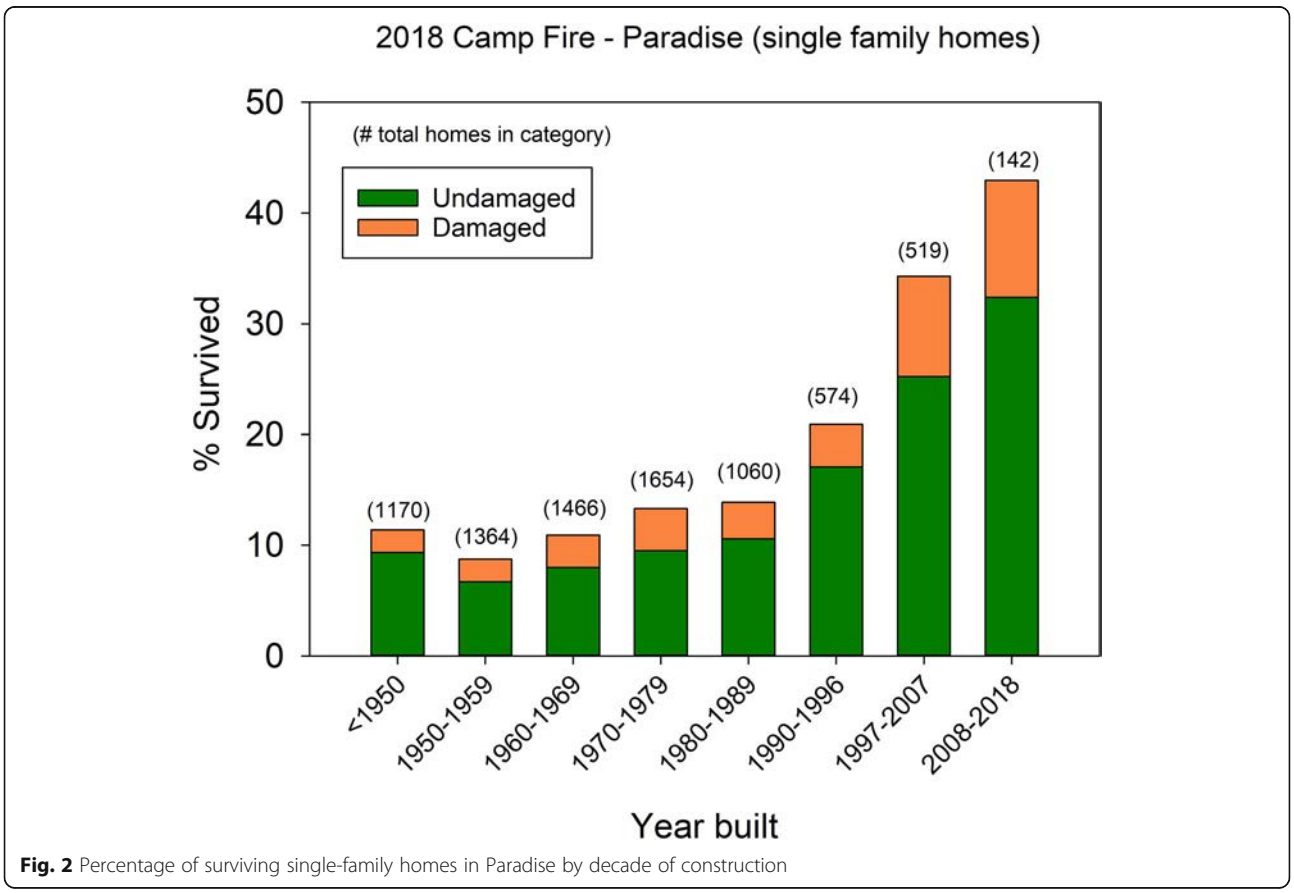

Fig. 2 Percentage of surviving single-family homes in Paradise by decade of construction

built afterwards (Table 1). The "distance to nearest destroyed structure" × time interaction was significant, with surviving homes a greater distance from the nearest destroyed structure in time periods one and three. This difference was especially pronounced for the newest homes (Table 1). While average lot size trended larger over time, the differences were not significant (Table 1). Pre-fire overstory canopy cover 30–100 m from the home was significantly lower for surviving homes (37.0%) than destroyed homes (50.4%) but did not differ between time periods (Table 1). With most houses situated on top of a plateau, the average percent slope was relatively low and did not differ significantly among outcomes or time periods (Table 1). None of the variables differed between time periods 2 and 3—immediately pre- and post-Chapter 7A adoption.

Many of the continuous variables we analyzed were significantly correlated with each other, with distance to nearest structure and distance to nearest destroyed structure (r = 0.625) and total structures within 100m and total structures destroyed within 100m (r = 0.926) being the most strongly correlated (Table 2).

Factors influencing home survival

Eliminating the two most highly correlated variables (distance to nearest structure and total structures per 100m) and analyzing the remaining variables together in the same model showed that both nearby destroyed structures and overstory canopy cover within 100 m were significantly associated with home survival. The "distance to nearest destroyed structure" × construction time period interaction was significant (Table 3), with a much higher survival probability when homes were a larger distance from a destroyed structure, especially for homes built 1997–2007 and 2008–2018 (Fig. 3a). Total structures destroyed within 100 m also was strongly linked to home survival (Table 3), with a much higher survival probability when fewer surrounding homes burned (Fig. 3b). For the vegetation variables, the "CanopyCover 0–30m" × construction time period interaction was significant (Table 3). Higher survival was noted with lower canopy cover for homes built since in 1997 and after but was not related to survival in older (<1997) homes (Fig. 3c). CanopyCover 30–100m also was highly significant, with a higher survival probability at lower canopy cover percentages across times (Table 3, Fig. 3d). Wildland urban interface/intermix category was significant, with a higher survival rate for homes in the wildland urban intermix (29.3%) than homes in the wildland urban interface (16.0%). Year built [within construction time period] and slope were not significant and did not make it into the final model (Table 3).

When the same analysis was conducted without interactions to test the effect of construction time period after correcting for covariates, homes built between 1997–2007 and 2008–2018 both survived at a significantly higher rate than homes built prior to 1997 ($P < 0.001$). Even though the survival rate was numerically higher for homes built after the 2008 building code update (44%) than homes built in an equivalent time period

Table 2 Correlation matrix of variables considered in the analyses of factors potentially contributing to home survival. The correlation coefficient (R) is above the diagonal, with statistical significance below. Distance to nearest destroyed home includes only single-family homes. Distance to nearest destroyed structure includes single-family homes, mobile homes, businesses, outbuildings, detached garages, and other large buildings

	Lot size	Year built	Dist. nearest structure	Dist. nearest dest. structure	Total struct. 100 m	Structures destroyed 100 m	Canopy Cover (%) 0–30 m	Canopy cover (%) 30–100 m	Slope (%)
Lot size		0.166	0.544	0.462	−0.499	−0.435	−0.111	−0.001	0.368
Year built	*<0.001*		0.262	0.283	−0.406	−0.424	−0.419	−0.146	0.156
Dist. nearest structure	*<0.001*	*<0.001*		0.625	−0.497	−0.432	−0.069	0.009	0.260
Dist. nearest dest. structure	*<0.001*	*<0.001*	*<0.001*		−0.471	−0.537	−0.263	−0.226	0.216
Total struct_ 100m	*<0.001*	*<0.001*	*<0.001*	*<0.001*		0.926	0.215	−0.007	−0.299
Struct. destroyed_ 100m	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*		0.300	0.134	−0.233
Canopy Cover 0-30m	*0.026*	*<0.001*	*0.171*	*<0.001*	*<0.001*	*<0.001*		0.571	−0.001
Canopy Cover 30-100m	*0.983*	*0.003*	*0.853*	*<0.001*	*0.890*	*0.007*	*<0.001*		0.135
Slope (%)	*<0.001*	*0.002*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.984*	*0.007*	

Table 3 Fixed effects in a generalized linear mixed model (PROC GENMOD) analysis of variance of the influence of nearby destroyed structures and pre-fire overstory canopy cover on Paradise single-family home loss in the Camp Fire, taking into account other potentially confounding variables. All variables plus their interactions with time period were put in the preliminary model with non-significant interactions and main effects sequentially dropped for the final model

Variable	DF	Chi-square	*P*
Construction time period	2	68.84	*<0.001*
Dist. nearest destroyed structure	1	57.10	*<0.001*
Tot. structures destroyed 100 m	1	179.77	*<0.001*
Canopy cover_0–30 m	1	1.61	*0.205*
Canopy cover_30–100 m	1	162.48	*<0.001*
Wildland urban intermix/interface category	1	4.54	*0.033*
Dist. nearest destroyed structure × time	2	16.45	*<0.001*
Canopy cover_0–30 m × time	2	25.35	*<0.001*

immediately before (37%), the difference was not statistically significant (adjusted $P = 0.309$).

For the next set of analyses, separate models (this time without specifying construction time period) were run on normalized data for (1) variables in play during the Camp Fire (including fire-related variables) and (2) variables present prior to the Camp Fire (i.e., variables that might factor into pre-fire planning). For the first model, distance to the nearest destroyed structure had the largest effect size, suggesting that the greater the distance to a burning structure, the higher the probability of survival (Fig. 4a). Also significant were canopy cover within 30–100 m and the number of destroyed structures within 100 m. Both the latter two variables had a negative relationship with survival, with higher survival where canopy cover within a 30–100 distance was lower, and number of destroyed structures within 100 m was fewer (Fig. 4a). Year built, slope, and canopy cover within 0–30 m all had confidence intervals that overlapped with zero. When only pre-fire variables were included, housing density had the largest effect size, with greater survival when the number of structures within 100 m was low (Fig. 4b). Canopy cover within 30–100 m had the second largest effect size, with greater survival at lower canopy cover levels (Fig. 4b). Distance to nearest structure, year built, slope, and canopy cover within 0–30 m all had confidence intervals that overlapped with zero (Fig. 4b).

Decision tree analysis using variables present during the fire indicated a threshold of 18 m from nearest destroyed structure best predicted whether a home survived or not. Survival probability for homes <18 m to the nearest destroyed structure was very low (0.058), compared with a 0.354 survival probability for homes ≥18 m from the nearest destroyed structure (Fig. 5a). Based on our sample, a majority (73.6%) of the homes in Paradise were <18 m from a destroyed structure. For the 26.3% of homes ≥18 m from a destroyed structure, if the pre-fire overstory canopy cover was also < 53% within 30–100 m, the survival probability improved to 0.481 (Fig. 5a). If the home was also built during or after 1973, the survival probability improved to 0.606 (Fig. 5a). The final split, involving just 10.2% of the homes in Paradise, suggested that for homes meeting these criteria (i.e., ≥18 m from the nearest destroyed structure, <53% canopy cover within 30–100 m, and built ≥1973), the survival probability improved to 0.733 if slope was less than 8.2%. For the decision tree including just pre-fire variables, year built was the first split, with a probability of survival of only 0.111 for homes built before 1996 (90.8% of homes in Paradise), compared with 0.396 for homes built during or after 1996 (9.2% of homes) (Fig. 5b). For homes in this latter category, survival probability improved to 0.766 if the pre-fire overstory canopy cover within 30–100 m was <33%. If pre-fire canopy cover within 30–100 was ≥33%, the survival probability fell to 0.239.

Damaged homes—nature of damage and cause

In our review of photographs of the 310 fire-damaged homes in Paradise, 63% had radiant heat damage (Fig. 6a), mostly to windows and exterior walls (Fig. 6b). Window damage consisted of cracked or broken glass and damaged window framing, but frequently included both. Blistered paint or melted/sagging vinyl siding were the most common wall (siding) damages. In most cases, the source of the radiant heat was difficult to assess, as the photos focused on the damage. However, a closer investigation of 20% of randomly sampled of homes where radiant heat damage was identified demonstrated that all had at least one neighboring structure that was destroyed during the fire, with an average distance to the destroyed structure of 12.1 m. Flame impingement was the next most common cause of damage (44% of damaged homes) (Fig. 6a). In most flame impingement cases (28% of the total damaged homes), the damage was interpreted to be the result of indirect ember ignition. For only 10% of damaged homes was the continuity of fuels from the broader surroundings (often needle or leaf litter) identified as the likely reason for flame impingement. For another 10% of damaged homes, whether needle or leaf litter was continuous with the surroundings or just localized next to the home could not be determined from the photograph. [Note—these three flame impingement categories do not add to 44% because some houses showed evidence of multiple flame impingement causes.] For the cases of flame impingement via indirect ember ignition, embers ignited near home flammable objects (e.g., fences, patio furniture, stored lumber), near home leaf litter, near home vegetation (or litter under that vegetation), leaf litter in gutters, or wood bark mulch, in order of frequency from most to least (S2 Table). Direct

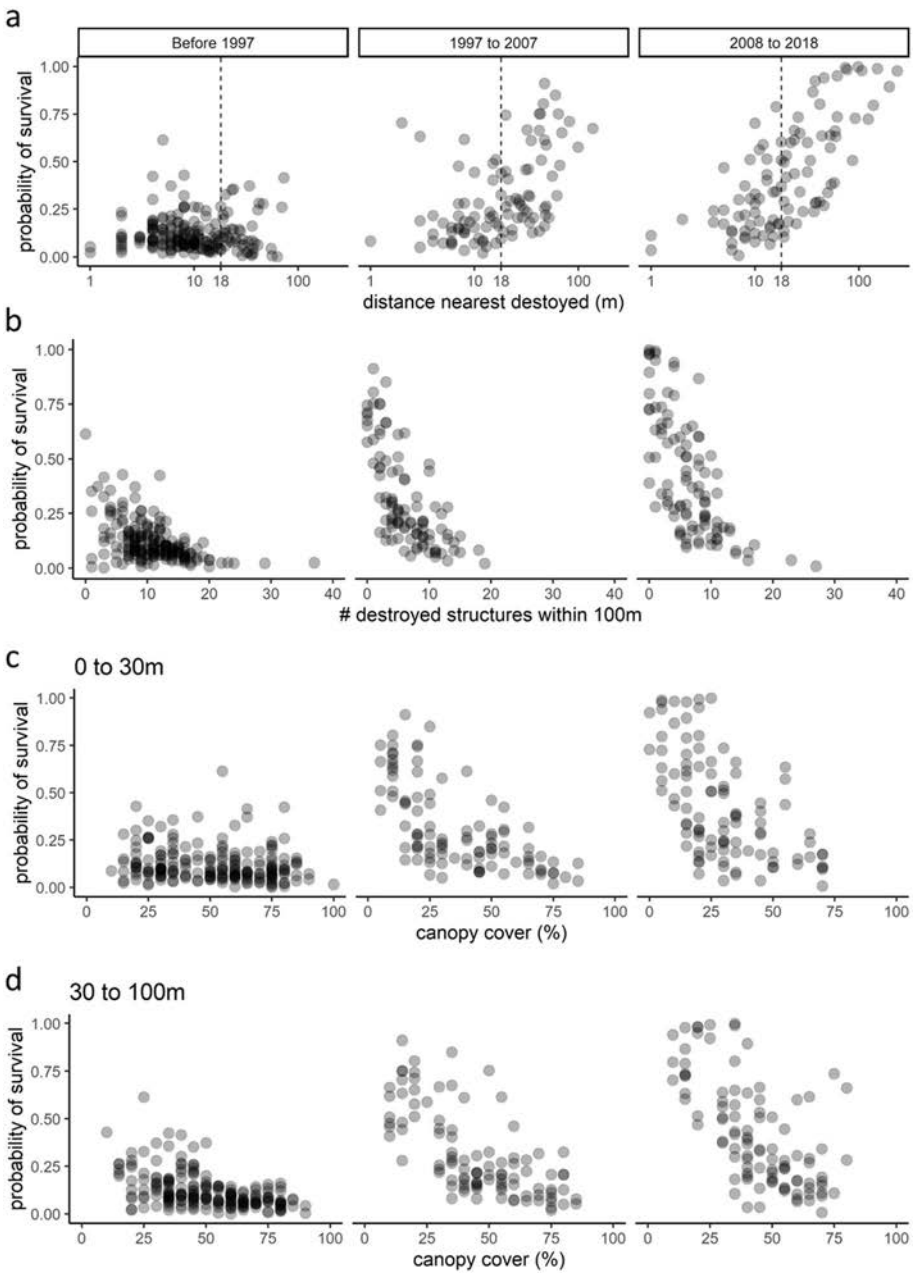

Fig. 3 Probability of home survival with **a** distance (m) to nearest destroyed structure, **b** the number of destroyed structures within a 100-m radius, **c** pre-fire overstory canopy cover within 0–30 m, and **d** pre-fire overstory canopy cover within 30–100 m, for homes built during three time periods (before 1997, 1997–2007, and 2008–2018). A vertical dotted line in **a** shows the 18-m threshold between survival and destruction identified by the regression tree analysis (Fig. 5a)

ember ignition was identified as the likely cause of damage for fewer than 6% of homes (Fig. 6a). The most common locations for embers to ignite were attached wood stairs, decking, and window trim. Counting either direct ember ignition or flame impingement due to indirect ember ignition, embers were implicated as a cause in 33% of damaged homes.

Discussion

Burning structures and wildland fuels both influence home survival

Our analysis of post-fire outcomes in the town of Paradise suggested that both the proximity to other burning structures and nearby wildland fuels factored in the probability of home survival, with several measures of

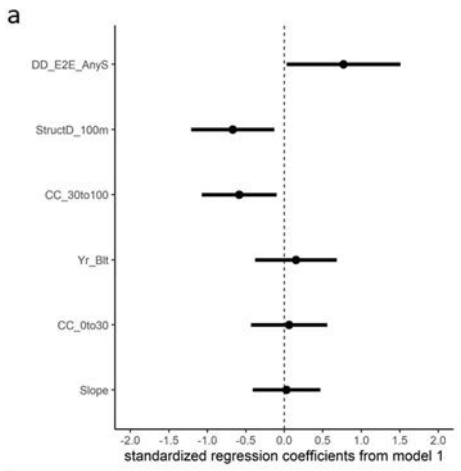

Fig. 4 Effect sizes for two logistic regression models of home survival in the town of Paradise during the 2018 Camp Fire, including continuous variables **a** present during the fire and **b** only variables present pre-fire. Regressions were based on a random sample of 400 homes

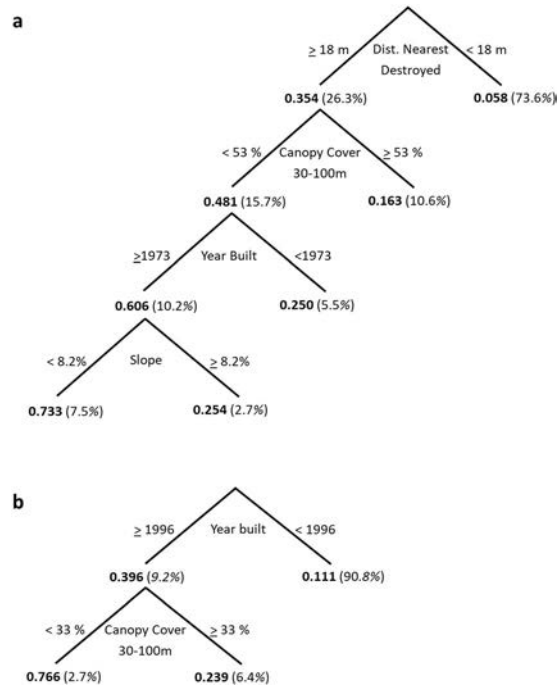

Fig. 5 Regression trees for predicting home survival in the town of Paradise in the 2018 Camp Fire, with models including continuous variables **a** present during the fire and **b** only variables present pre-fire, both based on a random sample of 400 homes. Survival proportion is listed in bold under each branch, along with the percentage of homes in Paradise that each branch applied to (in parenthesis)

distance and density of destroyed structures and nearby pre-fire overstory canopy cover emerging as significant explanatory variables. The relative importance of nearby burning home variables versus surrounding vegetation in explaining outcomes has varied among studies, with Gibbons et al. (2012) reporting canopy cover within 40m of the home to be the strongest predictor. Number of buildings within 40m was also a significant variable in their analysis. Even though nearby burning structure and vegetation variables were both included in the models in our study, interpretations about relative strength of these two sets of factors are tempered by limitations of the vegetation data, with overstory canopy cover an imperfect measure of wildland fuel hazard.

One possible clue to the relative importance of adjacent structures burning comes from the different outcomes for wildland urban intermix and interface homes. Houses built amongst wildland vegetation (intermix) survived at a higher rate (29%) than houses built in more of a subdivision arrangement with wildland fuels nearby (interface) (16%). Average pre-fire overstory canopy cover within 0–30 m was similar for intermix and interface homes (42% and 43%, respectively), but pre-fire overstory canopy cover within 30–100 m was higher for intermix than interface homes (49% vs. 42%, respectively). If proximity to wildland fuels had been the dominant driver, greater percentage losses in the wildland urban intermix would have been expected. The higher survival of intermix homes may therefore have been more a function of greater average distance to the nearest destroyed structure (24 m vs. 11 m in the intermix and interface, respectively) and lower average density (7.7 vs. 11.1 structures within 100 m in the intermix and interface, respectively). (Kramer et al. 2019) in an analysis of three-decade's worth of wildfires in California, also reported higher survival of homes in the wildland-urban intermix compared to the wildland-urban interface, and together with our results provide some additional evidence of the importance of nearby burning structures to home loss, relative to variables associated with wildland fuels. However, in our study, other factors

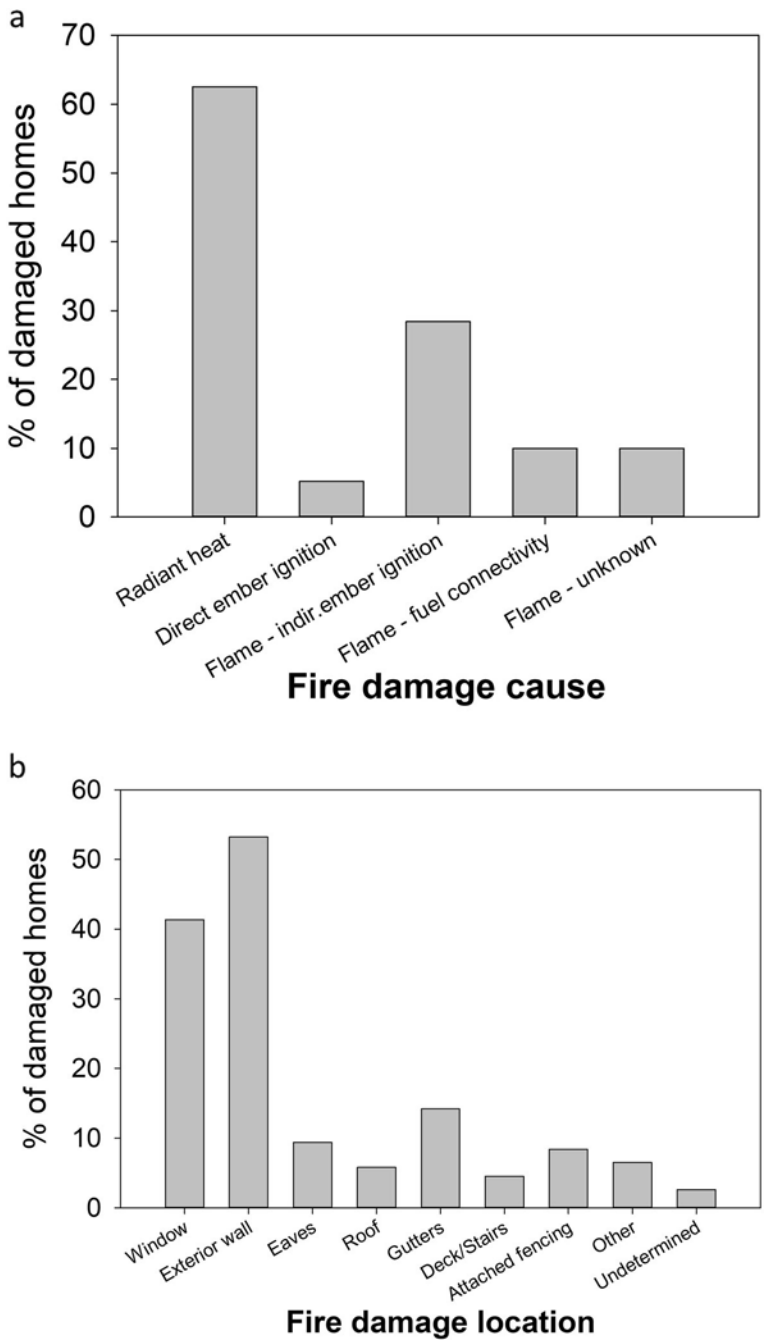

Fig. 6 Percentage of damaged but not destroyed homes in Paradise by **a** fire damage cause category and **b** fire damage location. Fire damage cause was either radiant heat, direct ember ignition, or flame impingement. Flame impingement was further subdivided into flame impingement due to indirect ember ignition, fuel continuity with the broader landscape, or unknown. Numbers were based on visual assessment of photos taken by the CAL FIRE inspectors and information in the CAL FIRE DINS (damage inspection) data. Totals exceed 100% because some homes had multiple sources of fire damage

were likely in play as well, with intermix homes being somewhat newer. In Paradise, an increasing percentage of homes were located in the intermix vs. the interface over time: 66% in time period 1, 80% in time period 2, and 88% in time period 3.

Homes as fuel

Distance to nearest destroyed structure and the total number of destroyed structures within 100 m were consistently the strongest predictors in our analyses. This makes intuitive sense because burning structures

produce a substantial amount of radiant heat, which can ignite adjacent homes or break glass in windows, allowing embers to enter the home. Nearby burning structures are also a source of embers, which can result in direct or indirect ember ignitions of nearby structures. Our visual analysis of 310 damaged homes corroborated the results of the statistical analyses, with more homes showing evidence of damage from radiant heat exposure (often from adjacent structures burning) than from flame impingement. Our findings are consistent with other analyses of destructive wildfires showing housing density to be strongly associated with home loss (Price and Bradstock 2013; Penman et al. 2019), but in contrast to Syphard et al. (2012, 2014, 2017) and Syphard and Keeley (2020), who have reported reduced probability of home loss at higher housing densities. The difference between studies likely has to do with variation in density ranges evaluated, as well as variation in vegetation type and housing arrangement. Syphard et al. (2012) sampled large fire-prone regions with shrub-dominated vegetation in southern California, ranging from outlying WUI areas to denser cities that did not burn to answer the question of housing arrangements most prone to loss in a wildfire. Since the entire scope of our analysis was within the Camp Fire perimeter, our research question differs: when burned, what factors influenced survival? In any case, the interpretation of Syphard et al. (2012, 2014, 2017) of lower loss probability with higher density development may not apply to different development patterns, including those present in Paradise. Such intermediate to low density wildland urban intermix and interface development interspersed with native (and non-native) vegetation is prevalent in foothills and lower mountainous regions of central and northern California (Hammer et al. 2007). In chaparral dominated ecosystems of southern California, high-density housing might result in more of the proximate shrub vegetation being removed, but in Paradise, overstory canopy cover within 0–30 m of the home was actually positively correlated with housing density.

At what distance an adjacent burning structure presents a vulnerability is not well studied. Our analyses identified a threshold of 18 m from the nearest destroyed structure that best differentiated surviving and destroyed homes (Fig. 5a). Price and Bradstock (2013) found the presence of houses within 50 m to be predictive of loss. Radiant heat flux, which is inversely related to distance from the flaming source, can be a factor up to 40 m from a burning structure (Cohen 2000). Cohen (2004) reported that models predicted ignition of wood walls when less than 28 m from a crown fire in forested vegetation, with actual experimental crown fires finding ignition at a 10-m distance, but not 20 m or 30 m. The radiant heat flux adjacent to burning structures is different and likely more sustained than a similar heat flux adjacent to crowning wildland vegetation.

Between home spacing has been evaluated in post-fire assessments conducted after the Witch Fire in San Diego County, California (Insurance Institute for Business and Home Safety 2008), the Waldo Canyon Fire in Colorado Springs, Colorado (Quarles et al. 2013), and the Black Bear Cub Fire in Sevier County, Tennessee (Quarles and Konz 2016). During each of these fires, home-to-home spread was observed with spacing less than 10 m. The IBHS Witch Fire report (Insurance Institute for Business and Home Safety 2008) referred to home-to-home spread as "cluster burning," which was not observed when homes were located more than 14 m apart. Our finding of an 18-m threshold is similar to the IBHS Witch Fire results. Regardless of the actual ideal home separation level, many homes in fire-prone areas of the western USA are on lot sizes that do not permit more than 18 m of separation between buildings.

Wildland fuels and defensible space actions

Pre-fire overstory canopy cover was a significant predictor of home survival in the statistical models, with the canopy cover 30–100 m away having a larger effect size than canopy cover in the immediate vicinity of the home (0–30 m) (Fig. 4a, b). This result (and other evidence, below) suggests that overstory canopy cover may only be correlated to factors that contributed to fire spread and increased the threat to homes, rather than a direct contributor. The often indirect influence of tree canopies on home survival, mediated by the litter fuels produced rather than canopy combustion, has been noted by others (Keeley et al. 2013). Wildland fire spread is dependent on surface fuels—litter, duff, and dead and down woody material, which would be expected to be most abundant and continuous under or adjacent to overstory tree canopy. The link between overstory canopy cover and surface fuel abundance may have been weaker from 0 to 30 m than distances farther removed from the home because of the greater likelihood that such surface fuels were better managed near homes, perhaps as a result of defensible space activities. In addition, the continuity of vegetative fuels is more likely to be broken up by lawns, driveways, or irrigated landscaping near the home. While vegetation abundance within 30 m has been reported to be associated home loss in southern California fires burning in shrubland vegetation types (Syphard et al. 2014, 2017), Alexandre et al. (2016) found vegetation near a building not to be a strong factor in models of loss for fires in southern California and Colorado. They theorized that the connectivity of vegetation to the home was more critical than vegetative cover.

While burning trees and associated vegetation may generate substantial flame lengths and embers which can

then threaten homes, the overstory tree canopies themselves did not appear to drive fire intensity in most cases. With the Camp Fire, many overstory trees located away from burning homes survived (Keeley and Syphard 2019; Cohen and Strohmaier 2020) (Fig. 7). Rather than tree torching directly impacting nearby structures, the torching of trees and other vegetation appeared from photographs and personal observation to frequently be caused by heat from nearby burning structures. Additionally, a substantial proportion of the canopy of native tree vegetation in Paradise at the time of the fire was comprised of California black oak (*Quercus kelloggii* Newb.), a native deciduous species that would have shed at least a portion of its leaves by the time of year when the Camp Fire burned through Paradise. Even when fully leafed out, the crowns of black oak trees are relatively open with low canopy bulk density. Deciduous oak litter breaks down faster than conifer litter, and the light fuel loads in pure black oak stands tend to promote low-intensity surface fire rather than crown fire (Skinner et al. 2006). Ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson) was the other major native tree species. Leaf and needle litter can carry flames to the home or provide receptive fuels for ember ignitions and would likely have been positively correlated to pre-fire overstory tree canopy cover, especially in the fall. Embers can also ignite litter that has accumulated in gutters and roofs. High pre-fire overstory canopy cover may also indicate areas where associated vegetation and surface fuels had developed to the greatest extent in the absence of fire and active management, especially at a distance from homes. With the lands in the Paradise area having no record of fire in modern recorded history (Maranghides et al. 2021), considerable vegetative ingrowth and accumulation of dead and down surface fuels was likely, especially relative to historical amounts. Ingrowth could have included brush and smaller conifers that acted as ladder fuels, leading to torching and ember generation.

Even though our data showed a stronger association between pre-fire overstory tree cover and home survival for distances beyond which defensible space is typically mandated (100 ft or 30 m), this does not mean that vegetation modification within 30 m is any less important. For reasons described earlier, the fuel hazards contributing to outcome were likely not well captured by the overstory canopy cover variable, especially in this near-home zone. In addition, once structures become involved, defensible space vegetation modification to 30 m (100 ft) may be insufficient to mitigate ember and radiant heat exposures contributing to home loss. In an analysis of CAL FIRE DINS data over multiple fires, including the Camp Fire, Syphard and Keeley (2019) reported that defensible space was a poor predictor of outcome, with structural variables (e.g., eave construction details, numbers of windowpanes (double vs. single), vent screen size) more highly correlated with home survival. The low predictive power of defensible space may be partially due to the coarseness with which defensible space is classified in the DINS data, with broad distance categories not fully capturing spacing, composition, or flammability of the vegetation. In addition, in many destructive wildfires, a large portion of homes are lost through direct or indirect ember ignition and not flame impingement associated with the continuity with

Fig. 7 Aerial image showing a portion of Magalia just NW of Paradise, illustrating a gradient of fire damage to overstory vegetation with distance from destroyed homes. At least in some areas, burning homes may have influenced the effects to overstory vegetation more so than burning overstory vegetation influenced the outcome to homes. Photo: Owen Bettis, Deer Creek Resources

wildland fuels (Murphy et al. 2007; Cohen and Stratton 2008). With embers capable of igniting fuels over 1–2 km away, the protective effect of vegetation modification within 30 m of the house does not guarantee survival when fire-fighting resources are not present. Vegetation modifications in this zone, however, do provide access and a safer means of protecting a home when firefighting resources are available.

Our analysis relied upon aerial photo interpretation, and we could not assess surface fuels under dense tree canopies. As a result, and because of the likely indirect effect of leaf litter coming from the canopy, we caution against using cover percentages in the decision trees as forest thinning targets. Furthermore, surface and near-ground live fuels are considered the priority for altering fire behavior and influencing fire hazard (Agee and Skinner 2005). Higher canopy cover may be correlated to the rate of surface litter and woody fuel accumulation but does not necessarily directly translate to high fire hazard if these surface fuels are managed and maintained at low levels. In other words, higher overstory canopy cover can provide important amenities (e.g., shade, habitat—Gibbons et al. 2018) without undue fire hazard as long as the resulting litter and surface fuels are maintained and gutters are cleaned. Gibbons et al. 2018 also noted that patchiness and arrangement relative to prevailing winds can also reduce threat posed by near-home vegetation.

Did the adoption of Chapter 7A into the California Building Code influence survival?

While the survival rate for homes built in the 11 years after the adoption of Chapter 7A to the California Building Code in 2008 was numerically slightly higher than the survival rate of homes built in the 11 years immediately before, the difference was not statistically significant. It is possible that significance might have been found with a larger sample size, but even so, any influence of the building code update was likely overwhelmed by other factors. This was not a surprise because of the many interacting variables that affect building performance, in addition to building products rated to resist exterior fire exposures. The 2008 Chapter 7A building code update institutionalized several important and worthwhile changes to construction in high fire hazard zones, including the use of ember and flame-resistant vents. These changes may improve the probability of survival for some types of wildfire (e.g., vegetation and wind-driven fires); however, the changes were apparently not sufficient to fully protect buildings from radiant heat exposures from nearby burning structures. One of the primary mechanisms for radiant heat impact is the breaking of window glass, which can allow embers to enter the building (Penman et al. 2019). A common method for complying with Chapter 7A is through the use of tempered glass in one pane of a double-paned window. However, the magnitude of radiant heat exposure was likely still too much in many cases, or other vulnerabilities remained.

Variation in factors contributing to home loss across construction time periods

In models for predicting survival, the significant interaction of several of the potential explanatory variables with construction time period suggested that factors most strongly influencing home vulnerability differed for homes of different ages. Homes built in the most recent two 11-year periods (1997–2007 and 2008–2018) survived at a significantly higher rate than homes built prior to 1997. Factors potentially contributing to this increase include trends towards a longer average distance to the nearest structure and nearest destroyed structure, and a larger average lot size. Newer homes had lower pre-fire overstory canopy cover in the immediate vicinity (0–30m), whereas the older homes tended to be concentrated near the center of Paradise, where pre-fire overstory tree cover was higher. The two most recent construction time periods also saw changes in building construction including roofing materials having longer periods of robust performance (i.e., 30–50 years of service life), double-pane windows (as a result of changes to the energy code), and increased use of noncombustible fiber-cement siding. Many of these improvements, which potentially make newer homes less vulnerable to wildfire exposures, occurred well before the 2008 Chapter 7A update to the building code. Older homes may also have developed vulnerabilities resulting from overdue home maintenance. We speculate that with a higher proportion of newer homes surviving the ember onslaught, outcome then depended to a greater extent on degree of radiant heat exposure from nearby burned structures. This hypothesis is supported by the much stronger influence of distance to nearest burned structure and the number of structures burned within 100 m for newer (1997 and after) than older <1997) homes. A substantially lower proportion of older homes survived regardless of the distance to or density of nearby burned structures, suggesting other vulnerabilities (such as maintenance issues). Another factor that may have increased the survival probability of newer homes was simply less time for occupants to accumulate combustible items on their properties (e.g., sheds, stored objects, wood piles, play structures). The difference between distance to nearest home and distance to nearest structure was much greater for older than newer homes (data not shown), indicative of structures such as sheds, detached garages, or other outbuildings being added to properties over time. Our summary of damage location and cause

for damaged homes as well as first-hand accounts (Maranghides et al. (2021); N. Wallingford, personal communication) indicated such non-vegetative items were frequently ignited by embers and the reason for a flame impingement exposure.

Difficulties in post-wildfire interpretation

A primary challenge in determining the potential causes for building survival after wildfire can be the variation in fire behavior experienced. The Camp Fire was no exception, with considerable observed differences in fire spread rates driven by ember-ignited spot fires, along with complex topography and local variation in wind speed (Maranghides et al. 2021). However, the Camp Fire burning through Paradise in 1 day may still have provided a more homogenous burn environment than present in many other post-fire evaluations of home survival, most of which combined data across multiple fires in different geographic locations and years (e.g., Syphard et al. 2012, 2017; Alexandre et al. 2016; Penman et al. 2019; Syphard and Keeley 2019)). Another factor that can often complicate interpretation is variation in the extent of firefighter intervention (McNamara et al. 2019). In the case of the Camp Fire, with the focus of first responders initially on evacuation, relatively few homes experienced defensive action by firefighters or civilians (according to the DINS assessment, defensive action was noted for only seven of the 400 randomly selected homes (1.7%), six of which survived). More broadly, while similar factors as those analyzed in this study may be pertinent in other wildfires, it is important to recognize that the variables identified here were specific to the housing, vegetation, and topographic conditions found in Paradise and may not apply elsewhere.

Determining pre-fire structural characteristics post-fire is difficult and availability of such data is generally limited (Syphard and Keeley 2019). Details about near-home vegetation, especially within the first 1.5 m of the structure, which has been shown to be an especially vulnerable location for ember ignition, were not available. We were also not able to quantify the presence and distance to small sheds and other storage structures, the age and condition of the roofing, or individual residents' maintenance practices. The DINS data (e.g., extent of vegetation clearing for defensible space, siding type, type of window glass (single or multi-pane), deck construction, and presence of attached fencing) have value, but missing data and lack of information for structures not damaged or destroyed limit the utility for some analyses. We instead focused on variables that could be consistently evaluated on every home, such as pre-fire overstory canopy cover and distance to the nearest destroyed structure. Our vegetation variables were, however, coarse, and likely missed factors that contributed to home survival.

Lastly, for the damaged home cause and area of damage summary, it is important to acknowledge that the vulnerabilities may differ for damaged and destroyed homes. With evidence for what contributed to loss no longer available for destroyed homes, damaged homes provide a picture of the different vulnerabilities, but the relative contribution of factors involved may not be the same.

Conclusions

The results of this study support the idea that both proximities to neighboring burning structures and surrounding vegetation influence home survival with wildfire. Denser developments, built to the highest standards, may protect subdivisions against direct flame impingement of a vegetation fire, but density becomes a detriment once buildings ignite and burn. Recent examples of losses in areas of higher density housing include the wind-driven 2017 Tubbs Fire in northern California, where house-to-house spread resulted in the loss of over 1400 homes in the Coffey Park neighborhood (Keeley and Syphard 2019), and the wind-driven 2020 Almeda Fire in southern Oregon, which destroyed nearly 2800 structures, many in denser areas in the towns of Talent and Phoenix (Cohen and Strohmaier 2020). Once fire becomes an urban conflagration, proximity to nearby burned structures becomes especially important because occupied structures contain significant quantities of fuel, produce substantial heat when burned, and are a source of additional embers. For density to be protective, home and other structure ignitions would need to be rare. Fifty-six percent of homes in Paradise built during or after 2008 did not survive, illustrating that much improvement is needed in both current building codes and how we live in wildfire prone WUI areas before proximity to nearby structures becomes a benefit rather than a vulnerability. The threat posed by nearby burning structures as well as our finding of an apparent strong influence of vegetation 30–100 m from the home—a distance that in most cases encompasses multiple adjacent properties—demonstrates that neighbors need to work together to improve the overall ability of homes and communities to resist wildfire exposures.

To maximize survivability, homes need to be designed and maintained to minimize the chance of a direct flame contact, resist ember ignition, and survive extended radiant heat exposure. Our analyses demonstrating the strong influence of nearby burning structures on home survival suggests improvements to resist radiant heat exposures may be warranted in the California Building Code—i.e., increasing the standards for buildings within a certain minimum distance of other structures. Some possible improvements might include noncombustible siding with rating minimums tied to proximity to other

structures, both panes in windows consisting of tempered glass, or installation of deployable non-combustible shutter systems. Additionally, certain options for complying with Chapter 7A are better for resisting radiant heat and flame contact exposures and could minimize fire spread to other components. Whereas the International Code Council's Wildland Urban Interface Building Code (International Code Council 2017) provides three ignition-resistant construction classes to allow for material restrictions as a function of exposure level, Chapter 7A consists of one level, so is binary in nature in that a building either needs to comply, or it does not. The Australian building code for construction in bushfire prone areas, AS 3959 (Standards Australia 2018), incorporates six different construction classes based on anticipated radiant heat, flame, and ember exposure levels. Interaction between components, for example, siding, window, and the undereave area on an exterior wall, is not considered.

Our summary of damaged but not destroyed homes in Paradise was in line with other reports showing a high proportion of home ignitions indirectly resulting from embers (Mell et al. 2010). Embers frequently ignited near home combustibles such as woody mulch, fences, and receptive vegetative fuels with flames and/or associated radiant heat then impacting the home itself, supporting awareness of the importance of combustibles within the first 1.5 m (5 ft) of the building on home survival. A re-interpretation of defensible space fuel modifications is needed to increase the building's resistance and exposure to embers and direct flame contact, especially in the area immediately around a building and under any attached deck or steps. This does not diminish the value of defensible space fuel modifications 9 to 30 m (30 to 100 ft) away from the home, which not only reduces fuel continuity and the probability of direct flame contact to the home, but also provides firefighters a chance to intervene.

While our data show a relationship between home loss and vegetative fuels (high pre-fire overstory canopy cover likely associated with a greater litter and woody fuel abundance, as well as other wildland understory vegetation) that can contribute to fire intensity and ember generation, the WUI fire loss issue has been described as home ignition problem more so than a wildland fire problem (Cohen 2000; Calkin et al. 2014). The damaged home data were in line with this view, with few homes showing evidence of continuity with wildland fuels that would contribute to flame impingement, but numerous homes with near home fuels, both from manmade and natural sources, that led to direct or indirect ember ignitions.

California's Mediterranean climate will continue to challenge its residents with regular wildfire exposure throughout the state. Whether through modifying the nearby surface and vegetative wildland fuels or the home itself, adapting to wildfire will take time. The good news is that the trend in survival is improving with newer construction practices. However, with 56% of houses built after 2008 still succumbing to the Camp Fire, much room for improvement remains. Our data suggest it is possible to build (and maintain) buildings that have a high probability of surviving a worst-case scenario type of wildfire, even in fire-prone landscapes such as the Paradise area. Newer homes built after 1972, where the nearest burning structure was >18 m away, and fuels associated with vegetation 30–100 m from the home kept at moderate and lower levels (<53% canopy cover) had a 61% survival rate—an approximately 5-fold improvement over the Paradise housing population as a whole. Survival percentages substantially higher still are potentially possible if all components of risk, including ember generation in nearby wildland fuels, continuity of wildland and other fuels on the property, and home ignitability are sufficiently mitigated.

Abbreviations

DINS: Damage inspection; WUI: Wildland urban interface

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42408-021-00117-0.

Additional file 1: S1 Table. Raw data for the random sample of 400 single-family homes in Paradise.

Additional file 2: S2 Table. Summary of fire damage cause and damage location for damaged by not destroyed single-family homes in Paradise.

Additional file 3: S3 Text. Metadata for the two data tables used in the analyses for this paper.

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Authors' contributions

EK, YV, and SQ developed the research questions and designed the study, with statistical guidance provided by NJ. Statistical analyses were performed by NJ and EK. All authors contributed to writing the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials

All data generated or analyzed during the study are included in the published article and its supplementary information files.

Declarations

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Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

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