Quantifying Insurance Benefits of a Nature-based Approach to Reducing Risk:

WILDFIRE RISK REDUCTION BUFFERS

The Nature Conservancy

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ACKNOWLEDGEMENTS

Marsh McLennan and The Nature Conservancy thank the following for their contribution to the development and preparation of this paper: Alex Bernhardt, Global Head of Sustainability Research, BNP Paribas Asset Management (formerly Director, Marsh McLennan Advantage); Elizabeth Hiroyasu, Landscape Scientist, The Nature Conservancy; Daniel Kaniewski, Managing Director, Public Sector, Marsh McLennan; Lucy Nottingham, Director, Marsh McLennan Advantage; Michelle Passero, Director, Climate and Nature-based Solutions, The Nature Conservancy; Deanne DiPietro, Senior Science Coordinator, Conservation Biology Institute; Kai Foster, Project Manager/GIS Analyst, Conservation Biology Institute; Alexandra Syphard, Senior Research Scientist, Conservation Biology Institute; Dan Efseaff, Paradise Recreation and Park District; Andy Read, Global Head of Government Solutions, ICEYE (formerly Vice President, Public Sector, Guy Carpenter); Robert Reader, Managing Director, Guy Carpenter; and Carolyn Kousky, Executive Director, Wharton Risk Center, University of Pennsylvania. We also thank Stacey Solie for editorial services.

ABOUT

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Contents

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I Key Take-Aways

- The small town of Paradise, California made world news in 2018 when the Camp Fire caused eighty-six deaths and destroyed 95% of the town's structures, including 11,000 homes. By the end of 2020, only 500 homes had been rebuilt and the impacts linger today. Many other communities throughout California and the western United States (U.S.) face wildfire risk that makes their economic viability uncertain. New approaches are needed that will help provide more sustainable paths forward.
- Using the town of Paradise as a case study, this paper lays out a novel way to increase wildfire survivability and reduce the risk of property loss. If adopted, the framework can enable the risk transfer chain and increase accessibility and affordability of fire insurance in areas that may currently be viewed as uninsurable. The framework is replicable in other communities facing similar problems, especially those located in fire-dependent forest ecosystems.
- Building on previous research conducted by The Nature Conservancy, Conservation Biology Institute, and Paradise Recreation and Park District on Paradise, California, this paper applies a U.S. wildfire catastrophe model to quantify the financial benefits of ignition reductions, including the potential impacts of spotting embers, in terms of avoided property loss and lower expected insurance premium costs for a range of wildland buffering strategies.
- Results indicate that placing a fire buffer—an area of reduced fire fuel that could include areas such as green space or community parklands—along one corridor in Paradise could significantly reduce average annual losses and be as effective at reducing fire risk as the enforcement of updated fire resilient building codes. Updating and enforcing modern building codes is universally effective at reducing wildfire risk. Taken together, fire buffer strategies and code updates would have reduced the value-at-risk across most probabilities by 42%, converting a one in 100-year loss level into a much rarer one in 350-year loss level.
- Investments in community-scale mitigation measures, such as a fire buffer, can also be linked to community-driven insurance programs. Community-Based Catastrophe Insurance (CBCI) is a new approach where coverage is arranged or made available by the community for homes within its jurisdiction. The pricing of insurance through a CBCI program can help to capture the financial benefits of risk reduction measures and potentially improve pricing for insureds in the community. Linking insurance to mitigation incentivizes investment in risk reduction.
- If comprehensive zoning schemes accompany fire buffers so that they also serve as urban growth boundaries, denser, clustered developments could begin to replace sprawl into the wildland-urban interface (WUI) as the predominant community design trend. With fewer homes dispersed in wildlands, other key risk reduction strategies such as controlled burning, could be expanded (in fire-dependent ecosystems), which could help restore habitats while further reducing the risk of catastrophic wildfire.

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II Introduction

Catastrophic wildfires are an increasing threat to communities across the United States (U.S.) and the world. In 2018, the small town of Paradise, California, made international news when a wildfire swept through, killing eighty-six people, and burning 95% of the town's structures to the ground. The tragedy was of extraordinary proportions.

Today, towns throughout California and the western United States face similar risks to those that led to the devastating disaster in Paradise. Fire is a natural and necessary part of the California landscape. However, over the last several decades, population growth and market-driven real estate trends have encouraged development to sprawl into fire-prone wildland areas, intensifying damages. In the U.S., since 1990, more than 12.7 million additional homes have been built and 25 million more people now live in wildland-adjacent zones (Radeloff et al., 2018). Wildland-adjacent zones are areas known as the wildland-urban interface (WUI). In addition to expanded development in the WUI, past logging practices, the forceful elimination of Indigenous burning practices, active suppression of lightning-ignited wildfires, and elevated incidences of hot, dry conditions wrought by climate change are all factors amplifying wildfires' destructive powers (Westerling and Bryant, 2008).

In recent years, wildfires have burned record numbers of acres and destroyed record numbers of homes across the state of California (California Department of Insurance, 2021). In fact, eight of the top ten costliest wildfires in the U.S. have occurred since 2017, and all of the top ten wildfires were in California (Insurance Information Institute, 2021). Strikingly, five of the six largest wildfires in California state history occurred in 2020 alone (Insurance Information Institute, 2021), and the 2021 wildfire season brought even more losses of catastrophic scale. By mid-July 2021, more than 95% of land in the western U.S. was experiencing moderate to severe drought (Drought Monitor, 2021). The dry conditions for the first half of 2021 outpaced an already catastrophic 2020 wildfire season with more than 5,000 new fires igniting since January 1 (National Interagency Fire Center, 2021). Of note, the 2021 Dixie Fire, which burned from July to October 2021 and impacted over 960,000 acres, is—at time of writing—now the largest single wildfire in California history.

The increased intensity and frequency of fires have led to insurers making record payouts. Carriers paid claims totaling USD 20 billion in 2017 and 2018 for wildfire losses, more than twice their profits since 1991 (Milliman, 2019). This has caused some insurers to drop coverage and raise premiums in high-risk areas, heightening community vulnerability as insurance plays a critical role in disaster recovery by safeguarding policyholders from devastating financial consequences. Even companies, state agencies and non-governmental organizations (NGOs) that perform controlled burns, a major tool for reducing the risks of wildland fires, are being denied coverage.

Land use policy and land acquisition may help reduce future risks by limiting new development in unsafe locations (Godschalk, 2009; Syphard et al., 2012; Syphard and Keeley, 2020). Yet, California already has extensive development interspersed within flammable wildland vegetation and there is pressure to continue with "business as usual" practices. An estimated 2.7 million Californians currently live in areas deemed very high-risk wildfire hazard zones (Reese, 2019). Urban planning and zoning schemes, driven more by the real estate market than by community health and safety considerations, have exacerbated the problem. Wealth inequality and the lack of affordable urban housing are also contributors, as many people priced out of housing

in cities and suburban markets have sought cheaper housing outside of the urban core (Mann et al., 2014). Some people relocate to or near the wildlands simply because they are attracted to the natural beauty of the areas.

Unfortunately, development in the WUI degrades the natural elements that attract so many inhabitants. Urban expansion into wildlands fragments habitats and increases detrimental "edge effects" (Murcia, 1995; Parkins et al., 2018). An edge effect cuts both ways: homes within the WUI experience increased exposure to wildfire, while the presence of people also increases the probability of wildfire ignition rates (Radeloff, 2018). Sprawl into wildlands also increases the chance that natural wildfires will be suppressed in an effort to reduce risk to existing homes and infrastructure. This practice can lead to the buildup of woody debris, increasing the likelihood that the next fire will burn hotter and cause greater property damage (Berry, Donovan and Hesseln, 2006). Adjacent natural habitats are also further degraded by other human influences, such as changes in runoff, night lighting, nitrogen deposition, pollution, impacts of pets and trampling, and weedy invasions (Bar-Massada et al., 2014).

When the Camp Fire destroyed the town of Paradise, it resulted in USD 12.5 billion of insured property loss, and USD 16.5 billion in total property losses, making it the costliest single natural disaster in the world that year (Reyes-Velarde, 2019). While estimates of property loss are generally easiest to find, it is also worthwhile to recognize that there are real costs in addition to rebuilding property. On the human side, there were 86 deaths and 17 reported injuries. Wildland buffering, discussed later, create escape routes. Additionally, other real costs involves the spike around mental health issues (Russell et al., 2020), especially for children (Theis, 2019). While this paper explores strategies to reduce property loss, it is also useful to note that reducing wildfire ignition also provides a tangible public policy benefit in the form of decreased mental health traumas.

When communities such as Paradise decide to rebuild following a catastrophic event they endure many challenges, but they also gain a unique opportunity. Towns have the ability to make strategic rebuilding choices that better serve the community as it moves forward. Both communities who are confronted with these perils and the insurance industry are in dire need of tools to reduce wildfire risks to keep policies available and premiums affordable.

Acting now, by building back to reduce wildfire risk at community-scale, has become imperative to help ensure future viability. To this end, the Paradise Recreation and Park District (PRPD) collaborated with the Conservation Biology Institute and The Nature Conservancy to evaluate the ignition-reduction potential of creating wildfire risk-reduction buffer zones at the perimeter of town (DiPietro et al., 2020). The study examined the concept of creating buffers through the acquisition of select parcels by the PRPD. The work proposed that the parcels, many of which once harbored structures that burned in the fire, would be converted to parkland or other greenspaces and managed to maintain low flammability. This largely qualitative analysis used simple modeling methods that took ember cast into account with a wind-driven risk analysis. It did not use fire behavior or dynamic ember transport modeling. The results indicated that wildfire risk-reduction buffers would offer significant ignition-reduction benefits.

Aiming to build off the previous buffer scenario results, The Nature Conservancy partnered with Marsh McLennan to use sophisticated catastrophe models to translate the modeled ignition risk reduction into loss reduction terms used by insurers. Quantifying the benefits of a disaster risk reduction intervention in terms that can be understood and accepted by the insurance community can provide material benefits to the residents of the target area in the form of lower insurance premiums or even availability of insurance altogether.

A novel way to increase survivability and reduce the risk of property loss from wildfires using wildfire risk-reduction buffers is discussed. This innovative approach will enable the risk transfer chain, thereby increasing access and affordability of fire insurance in areas that may currently be viewed as uninsurable. This examination centers on Paradise, but the framework is replicable in other communities confronting similar problems. These approaches would be most beneficial if combined with other ecological management tools such as prescribed burning and the strategic removal of surface fuels (Moritz et al., 2014) that can also reduce the risk of catastrophic fires in the future. The outlined methodology could increase community safety, decrease costs associated with fire suppression and insured property losses, and improve the ecological health of surrounding wildlands.

III Evidence of Buffers Reducing Wildfire Losses

Commonly implemented strategies for diminishing the risk of catastrophic fire often involve reducing the fuels that fires consume. Forest management practices, such as thinning, removing invasive weedy species, and controlled burns all aim to reduce fuels. Another strategy frequently used by firefighters is the creation of fuel breaks. Fuel breaks serve several purposes: they reduce the likelihood of ignition, give firefighters a safe place to work to stop an unwanted wildfire, and increase the distance between homes and dense, burnable vegetation. The use of fuel breaks to reduce community fire risk has a strong foundation in both science and practice (Cal Fire, 2019). These breaks are typically made by changing vegetation, using thinning or mastication, allowing grazing, or having controlled burns so that fires burning into the breaks can be more readily controlled. Often installed as a linear feature near valued assets, fuel break maintenance may involve intense vegetation management or complete vegetation removal.

While not traditionally intended as fuel breaks, green land uses such as orchards, vineyards, greenways, parks, and golf courses can serve as de facto fuel breaks, or fire buffers. In Paradise, PRPD is exploring implementing fire buffer areas in strategically sited corridors at the perimeter of the town. Vegetation would be intensely managed to decrease flammability. These designated areas could reduce the risk of ignition from incoming fires while simultaneously functioning as places of recreation for the community.

Creating structure-free buffer zones that are managed to be less flammable (e.g., by irrigation, using plants that maintain higher moisture content and/or removing surface fuels) on the perimeter of a community reduces home ignition risks in two ways. First, buffer zones work by reducing direct pathways for the flame front to reach structures located within the community, while at the same time having lower flammability. The majority of structure losses occur during wind-

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driven fires with new ignitions occurring rapidly both at the flame front and by "spotting" from wind-borne burning embers (Quarles et al., 2010; Keeley and Syphard, 2019). Second, if the buffer zones are managed for fuel reduction, these areas would reduce fire severity, thereby limiting the amount of embers produced. If buffer zones are maintained under alternative uses such as parks or soccer fields with irrigated lawns, any wind-borne embers that reach the site would naturally extinguish.[1]

Anecdotal evidence suggests that green land uses such as orchards, vineyards, parks, and golf courses can indeed serve as de facto buffers from oncoming fire if they are well-managed and cleared of the fuel continuity of wildlands[2]. In one anecdotal instance, after the Camp Fire, landowners described the phenomenon of their apple orchard remaining unburned while the fire moved around it (Van der Leun, 2018). Another account describes how large, irrigated turf areas have stopped wildfires from reaching homes, in addition to serving as temporary refuges for community members escaping a fire, and as staging areas for firefighters (Gross, 2009). In southern California, citrus and avocado orchards, as well as vineyards, have also served as fire buffers where embers die out instead of igniting fires. Other research promotes the concept of using planning and zoning to decrease community wildfire exposure and vulnerability, and advocates for "using public lands, parks and playing fields to create buffer zones" (Norton et al., 2019).[3]

When looking to mitigate wildfire exposure another key consideration is to enact zoning schemes in concurrence with buffers. Development beyond a buffer or outside of a buffer compromises the ignition risk-reduction benefits that a buffer provides. Additionally, such development hinders ecological forest management practices such as thinning and prescribed burns that in turn reduce the risk of fires burning at high severity. By using buffers as an urban growth boundary, ignition risk reduction and the ecological forest management benefits associated with buffers can be maintained.

When combined with urban growth boundaries, buffers can also provide significant conservation benefits. Reduced sprawl can protect adjacent wildlands from human edge effects, such as trampling, roadkill, noise, chemical pollution, and light pollution. If the desire to reduce fire risk drives housing development patterns toward high-density clusters, research suggests these patterns substantially reduce the overall impact of development on wildlife habitat (Odell, Theobald and Knight, 2003). In a simulated study (Syphard et al., 2016), clustered, infill-type development resulted in less edge and fragmentation, both of which have long been associated with biodiversity decline (Turner, 1989). Curran et al. (2017) calls for field experiments that would quantify the utility of green belts as biodiversity-friendly fuel breaks.

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IV Methods For Estimating Ignition Reduction

In their evaluation of the ignition-reduction potential of perimeter-encircling fire buffer zones, the Conservation Biology Institute, The Nature Conservancy, and PRPD used wildland fire probability modeling and data specific to Paradise (e.g. topography, wind direction) to calculate the levels of fire risk reduction that could be achieved under varied management scenarios (DiPietro, 2020). It is critical to understand this qualitative analysis as it serves as a foundation for the financial catastrophe modeling process.

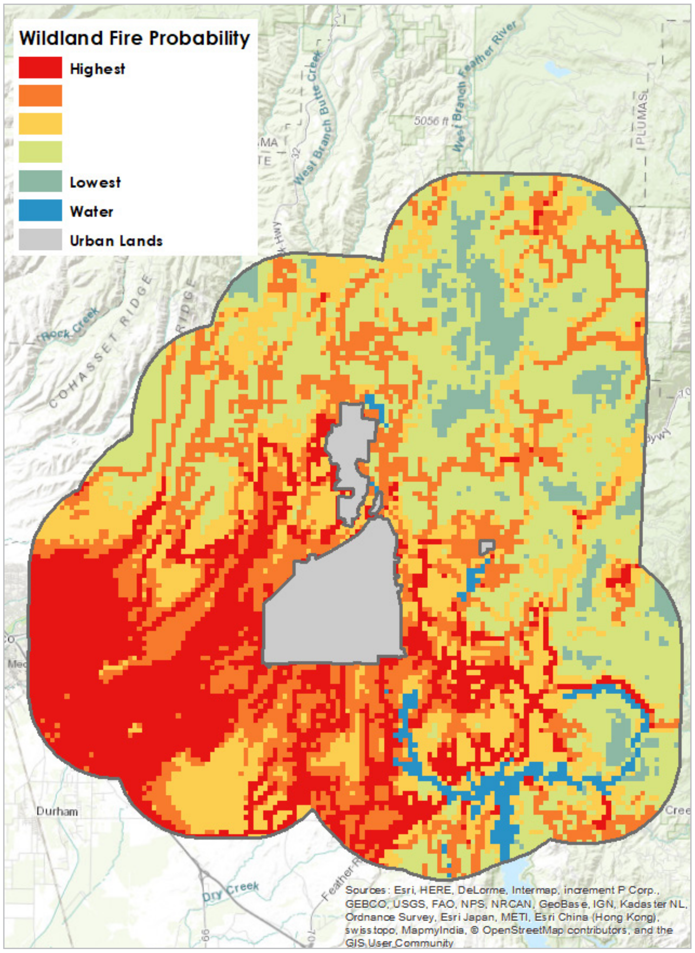
The CBI analysis determined how well buffer zones would reduce risk of ignition in Paradise by linking fire probability in the surrounding wildland area, where the Camp Fire and other past large, destructive wildfires have originated, to the risk of urban ignitions. A three-step approach was used to develop a modeling framework. First, fire risk was mapped in the wildland area to establish a Wildland Fire Probability model. *See Figure 1*. Second, the authors mapped the risk of ignition in urban areas coming from fires in the wildland area, resulting in an Urban Ignition Risk Model. *See Figure 2*. Finally, the authors ranked urban parcels according to their risk of ignitions. *See Figure 3*. Each of these steps are described in detail below.

First, for the Wildland Fire Probability model, selected model outputs from Syphard et al. (2018) were used. Two different climate scenarios (CNRM-CM5 and MIROC5 RCP 8.5) were considered for the 30-year time period of 2010-2039, along with a related emissions scenario designed to be relevant in California.[4] Data from these scenarios were reclassified into three categories using model-specific thresholds and combined to obtain a single Wildland Fire Probability index with possible values ranging from two (lowest fire probability) to six (highest fire probability).[5,6]

Next, Urban Ignition Risk was estimated using two scenarios for ignition from wildfire occurring outside of the urban area: ignition by proximity to the flame front, and ignition by wind-borne embers.

- Risk of **direct ignition** from the flame front was mapped by identifying parcels that are adjacent to high-risk cells from the Wildland Fire Probability map. See Figure 1. A binary classification was applied (yes or no); urban parcels adjacent to high-risk wildland cells were assigned a value of three for high ignition risk and zero for low or no ignition risk.
- The **wind-driven ignition** risk input was created by selecting high-risk cells in the Wildland Fire Probability map (*See Figure 1*) and using Santa Ana Wind Direction data from the Desert Research Institute. Parcels that are a short distance from a high-risk wildland cell and are downwind of a typical Santa Ana wind direction were assigned the highest ignition risk value. It is worth noting that ember-creation properties for predominant tree species in the Sierra Nevada, including wind speed and

FIGURE 1: **WILDLAND FIRE PROBABILITY MAP FOR THE PARADISE REGION**



Source: Conservation Biology Institute properties of downwind vegetation, and widely accepted ember spotting distances developed by the National Wildfire Coordinating Group (NWCG) for western United States tree species, are consistent with the values assigned in the CBI analysis. According to this dataset, Ponderosa Pine, the most common tree species in the Sierra Nevada foothills region, is unlikely to produce embers that travel beyond 1.1 miles, even under very high wind speed conditions. *See Table 1.*

TABLE 1: MAXIMUM SPOTTING DISTANCES FOR WESTERN U.S. TREE SPECIES

MAXIMUM SPOTTING DISTANCE, IN MILES, 20 FT WINDSPEED, IN MPH											
Tree Species	**0**	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**
Balsam Fir	0	0.1	0.3	0.4	0.6	0.7	0.8	1	1.1	1.3	1.4
Grand Fir	0	0.1	0.3	0.4	0.6	0.7	0.8	1	1.1	1.3	1.4
Subalpinc Fir	0	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1	1.1	1.2
Lodgepole Pine	0	0.1	0.2	0.3	0.5	0.6	0.7	0.8	0.9	1	1.1
Emgelmann Spruce	0	0.1	0.3	0.4	0.5	0.7	0.8	0.9	1	1.2	1.3
Ponderosa Pina	0	0.1	0.2	0.3	0.5	0.6	0.7	0.8	0.9	1	1.1
Douglas-Fir	0	0.1	0.2	0.4	0.5	0.6	0.7	0.9	1	1.1	1.2

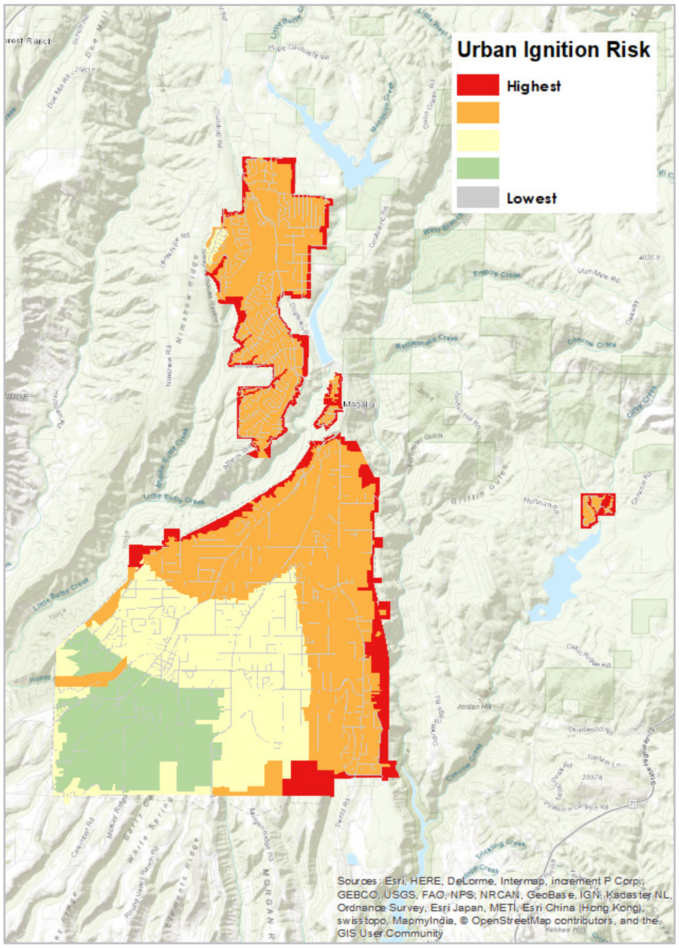
Source: National Wildfire Coordinating Group (NWCG).

These two Ignition Risk inputs were summed to obtain a single Urban Ignition Risk index: adjacency to high fire risk wildland areas were given a value of one, while downwind from high fire risk wildland areas values ranged from one-to-three, for a total possible of four.

Wildland parcels were analyzed and ranked across the region for fire risk reduction management action. The parcels were ranked based on fire risk, recreational opportunities, potential opportunities afforded by public ownership, or local interest in land use change as identified by the PRPD District Manager.

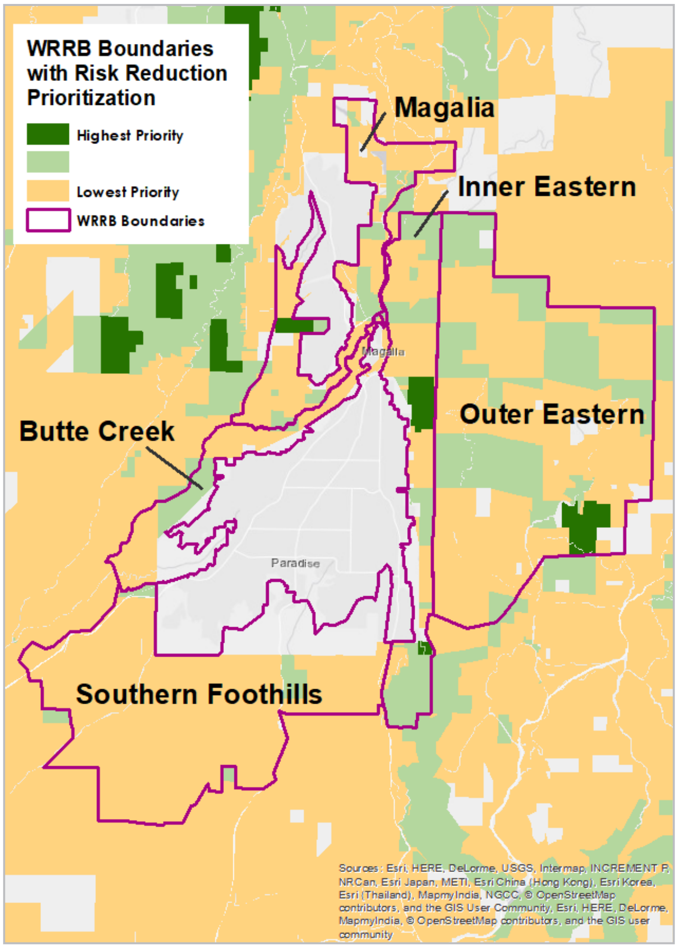
Five Wildfire Risk-Reduction Buffers (WRRBs) were delineated in an expert-driven process in collaboration with PRPD and The Nature Conservancy. *See Figure 3*. Edges of the WRRBs were defined using significant geographic features, and in areas without significant features, the edge of parcel boundaries were followed. Land ownership within the five WRRBs varies, but the majority of land in all five WRRBs is privately owned.

FIGURE 2: MAP OF URBAN IGNITION RISK IN THE TOWNS OF PARADISE AND MAGALIA



Source: Conservation Biology Institute

FIGURE 3: PRIORITIZED WILDFIRE RISK REDUCTION BUFFER SCENARIOS



Source: Conservation Biology Institute

To simulate the impacts of risk-reduction management, fire probability values were reduced in the WRRB parcels chosen for the scenarios to reflect risk reduction actions in those parcels. Wildland Fire Probability values that were initially ranked “highest” were changed to “medium” and “medium” to “lowest.” These new values were used to recalculate the Urban Ignition Risk in the same manner described above, using a downwind simulation and analyzing adjacency. The new Urban Ignition Risk map was then compared to the original map to quantify change in ignition risk due to changes in the fire probabilities within the WRRBs due to the risk-reduction actions.

The results show that by managing vegetation on medium and/or high-priority parcels within distinct zones at the perimeter of Paradise so they effectively serve as WRRBs, risk of fire ignition within the town would be significantly reduced. *See Table 2* and *Appendix 3*. Under the highest-performing buffer management scenario WRRB: Inner Eastern, acres within Paradise parcels deemed at medium-high risk of ignition would be reduced by 36% and acres of parcels deemed at highest risk of ignition would be reduced by 64%.

TABLE 2: SUMMARY OF URBAN IGNITION RISK CHANGE AS PERCENT OF ACRES FOR WRRB MANAGEMENT SCENARIOS

WRRB MANAGEMENT SCENARIO		MED-HIGH IGNITION RISK CATEGORY	HIGHEST IGNITION RISK CATEGORY
Inner Easter	High + Medium Priority Parcels	-36%	-64%
Magalia	High + Medium Priority Parcels	-22%	-47%
Inner + Outer Eastern	High Priority Parcels	-28%	-15%
Inner Eastern	High Priority Parcels	-27%	-13%
Butte Creek	High Priority Parcels	-5%	-1%
Southern Foothill	High Priority Parcels	+1%	-5%

Source: Conservation Biology Institute

Among the various locations for buffers that were tested, most locations showed some level of improvement in risk, but one scenario clearly offered exceptionally high rates of risk reduction. The results indicate that if risk-reduction buffer creation efforts were targeted within the Inner Eastern corridor, transforming all of the pre-identified high and medium priority parcels (a total of 4030 acres) into managed, low-flammability parkland in the urban parcels or lower-flammability shaded fuel breaks in the wildland parcels, the modeled property losses within the town of Paradise in the event of a wildfire could be reduced by as much as 42%. *See Table 3.*

Several of the other management scenarios also offer significant reductions in urban ignition rates. These reduction factors became the basis for the catastrophe modeling process conducted by Marsh McLennan in partnership with The Nature Conservancy.

V Financial Catastrophe Modeling Process

Quantifying the benefits of a disaster risk reduction intervention in terms that can be understood and accepted by the insurance industry can result in material benefits for communities in the form of lower insurance premiums or continued availability of insurance. The results are especially true if the benefits are estimated via risk models utilized by the insurance industry. Using industry risk models enables the risk transfer chain whereby insurers cede risk to reinsurers. Reinsurance is a practice in which an insurance company purchases insurance from another party, thereby spreading risk. This increases insurers' capacity to assume more risk themselves through the sale of additional policies, thus increasing insurance availability to potential buyers (e.g., residents, businesses).

Catastrophe modeling is the basis of quantification of property catastrophe losses in the insurance industry. In this study, it is the primary tool to translate the quantified benefits of resilience enhancements to (re)insurers given its broad adoption as an instrument to measure both absolute and relative changes in risk profile.

BACKGROUND ON CATASTROPHE MODELS

Catastrophe models are employed by the insurance industry to estimate and manage the probability of loss posed by natural disasters and other catastrophic events. While the insurance industry has utilized models since 1987, their importance as a risk management tool gained prominence after Hurricane Andrew struck Southern Florida in 1992. This devastating storm pushed at least seven insurance companies into insolvency and prompted an evolutionary change in how the industry started measuring catastrophic exposures (McChristian, 2021). By the late 1990s, catastrophe models had been adopted across the insurance industry to model high-severity, low-frequency events such as hurricanes and earthquakes, before expanding further into other perils such as severe convective storms, winter storms and wildfires. Catastrophe models have since become an integral part of an insurance company's operations, and are relied upon for decision-making, pricing, underwriting, reinsurance buying, rating agency discussions, and general portfolio management.

To provide the most accurate loss estimates, catastrophe models rely heavily on detailed risk exposure information. Exposure is the basic unit used by insurance companies to determine premiums, and includes information on a location from its postal code down to the spatial coordinates of the property and structure-specific characteristics such as construction type, year built, cladding type, and roofing material. The models also contemplate the terms of the insurance policy (in particular limits and deductibles) to arrive at their loss estimates. While models can leverage postal code level averages to augment coarse inputs, their results line up best with historical claims data when detailed information is provided for every risk written. *See Appendix 2*.[7]

Currently, the (re)insurance community leverages three main models to estimate wildfire losses in California. *See Box 1*. Each of these models uses slightly different parameters that can affect estimates.

BOX 1: MODELS USED TO ESTIMATE WILDFIRE LOSSES

CORELOGIC	AIR	RMS
First probabilistic wildfire model ever released for California (2004) Last updated in 2018	First version released in 2006 Last major release in 2018 10,000 year event catalogue Includes fire, ember and smoke (in fire footprint)	First version released in 2020 50,000 years of simulation Includes fire, ember, urban conflagration, smoke dispersion

Source: Guy Carpenter

Wildfire risk is receiving increased attention from the research and modeling community and a number of new models are being developed by insurtechs (e.g., KCC, Delos and KettleRe).

CATASTROPHE MODELING FOR THE TOWN OF PARADISE

The AIR model was selected for this project, based on its wide usage in California, including by the California Wildfire Fund. As noted above, exposure data is the most important user input for catastrophe models. Capturing exposure data in a way that effectively models risk involves three potential approaches:

- The **macro** approach uses zip code level industry modeling results to estimate the impact of risk reduction measures. This is relatively easy to do, but in some cases such as Paradise, a single zip code may cover a larger area than the zone under consideration. As a result, this provides a rough estimate at best.
- The **notional** approach leverages third-party data to build a synthetic portfolio deemed to realistically reflect exposures within and outside of buffer zones. While this approach is more likely to be defensible to (re)insurers than the macro approach, its lack of actual exposure data introduces additional uncertainty into results.
- The **ground-truth** approach involves obtaining detailed spatial data (e.g., tax parcels) directly from the community and complementing that information with third-party data. This approach is often the most accurate, but can require substantial community investments in both time and resources to acquire needed third-party data.

With the collaboration of The Nature Conservancy and the Town of Paradise, Guy Carpenter implemented the ground-truth approach, leveraging a number of datasets to estimate exposures within the City of Paradise. *See Box 2*. In addition to proprietary data from Guy Carpenter, the data included reconstruction cost estimates, a destroyed structures survey, and county-level parcel information.

BOX 2: DATASETS TO ASSESS WILDFIRE EXPOSURE IN PARADISE

Guy Carpenter Industry Exposure Database

- Building footprint data from Microsoft US Building Footprints initiative
- Processed latitude, longitude, square footage
- Augmented with external data sources
- Assigned APN, within / outside of Paradise Town limits
- Postal code, county
- Valuation
- Year built

Valley Contractors Exchange

- Reconstruction cost estimates per square foot

Destroyed structures survey

- Structure type
- Occupancy type
- Roof construction
- Year built
- Wall siding
- Window panes

Guy Carpenter Proprietary Data

- Buildings / Contents / Additional Living Expenses splits
- Specific to Butte County
- By occupancy type

County-level parcel data

- Address
- Building value
- Year built
- Square footage
- Occupancy type

Source: Guy Carpenter

These datasets were combined using the logic below to build a baseline view of Paradise (e.g., pre-Camp Fire):

1

The destroyed structures survey (which contained the most detailed data) was used to retrieve information on location, occupancy type, roof material, eaves, wall siding and windowpanes.

2

When not available or for missing attributes, County Tax Assessor parcel data were used.

3

When not available or for missing attributes, data from the Guy Carpenter Industry Exposure Database were used.

After the datasets were appropriately combined, each property included in the analysis underwent a valuation process based on the following criteria:

Building Value = square footage * reconstruction cost per square foot.

Appurtenant Structures (such as a detached garage), Contents and Additional Living Expenses were derived from an analysis of Guy Carpenter exposure data in adjacent counties, by land use type.

Finally, two versions of the post-Camp exposures for Paradise were built. Both share the following assumptions:

A

Structures destroyed by the Camp Fire were assumed to be rebuilt with a rebuild date beyond 2020.

B

Structures with a square footage of less than 1,200 square feet were assumed to be slightly expanded with an additional 300 square feet of building structure, and their valuation updated accordingly.

C

Roofing materials, wall siding, and window panes were assumed to be asphalt shingles, ignition resistant, and multi-pane, respectively.

While similar, the two post-Camp Fire exposure datasets differ in that one assumes a scenario involving a partial rebuild (only 1,000 destroyed structures rebuilt) while the other assumes a scenario with a full-rebuild (all structures rebuilt).

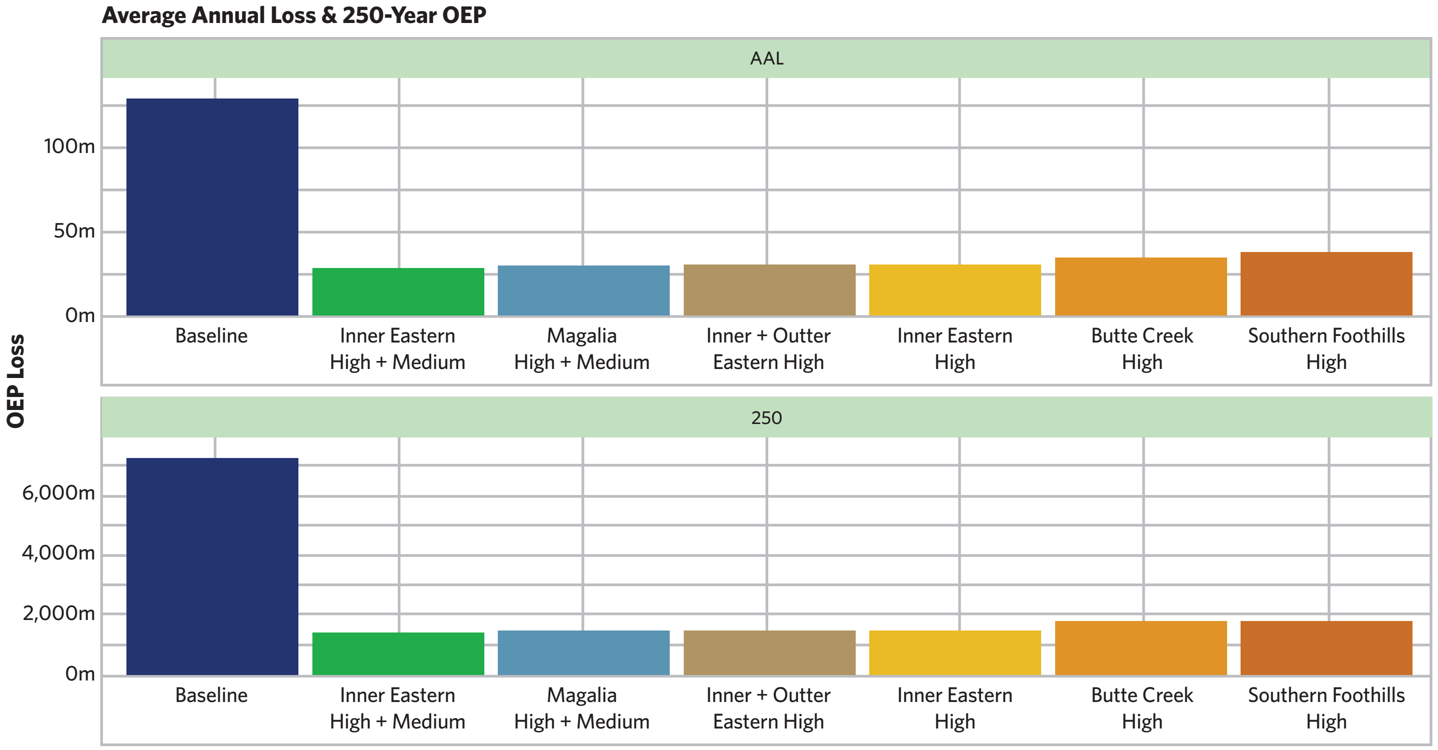
Once the entirety of the building stock for the Town of Paradise prior to the Camp Fire was determined, each property was flagged based on its location relative to the WRRB management scenarios and then imported into AIR Touchstone 7.3 for modeling.

The modeling platform was set to produce a modeled loss for each simulated event and each property. For each WRRB Management Scenario, losses were then aggregated by change in ignition risk as estimated by the previously described analysis. The change in ignition risk was then applied as a scalar factor to the event-level losses, equating to assuming that an equivalent proportion of the building stock within that risk category would not be impacted by the fire due to a decrease in fire penetration into the built-up areas.

In total, six different buffering scenarios, with two different exposure extents (full rebuild vs. rebuild of just 1,000 properties), were considered along with the "pre-Camp Fire" results (which do not include buffer scenarios).

Each set of results included event-specific outcomes, as well as summary metrics. The summary metrics include loss *occurrence exceedance probabilities (OEP)*, which express the probability that loss levels will be exceeded by any event in any given year, and *average annual losses (AAL)*, the average derived from this distribution—expressing the expected loss per year, averaged over many years. Both OEP and AAL are key outputs of the AIR catastrophe models and are each important tools used by the (re)insurance industry to calculate risk. High-level results for a combination of variables follow. *See Table 3.* Modeling results were produced based on the methodology described above.

FIGURE 4: WRRB SCENARIO LOSS IMPACT (PARTIAL REBUILD)

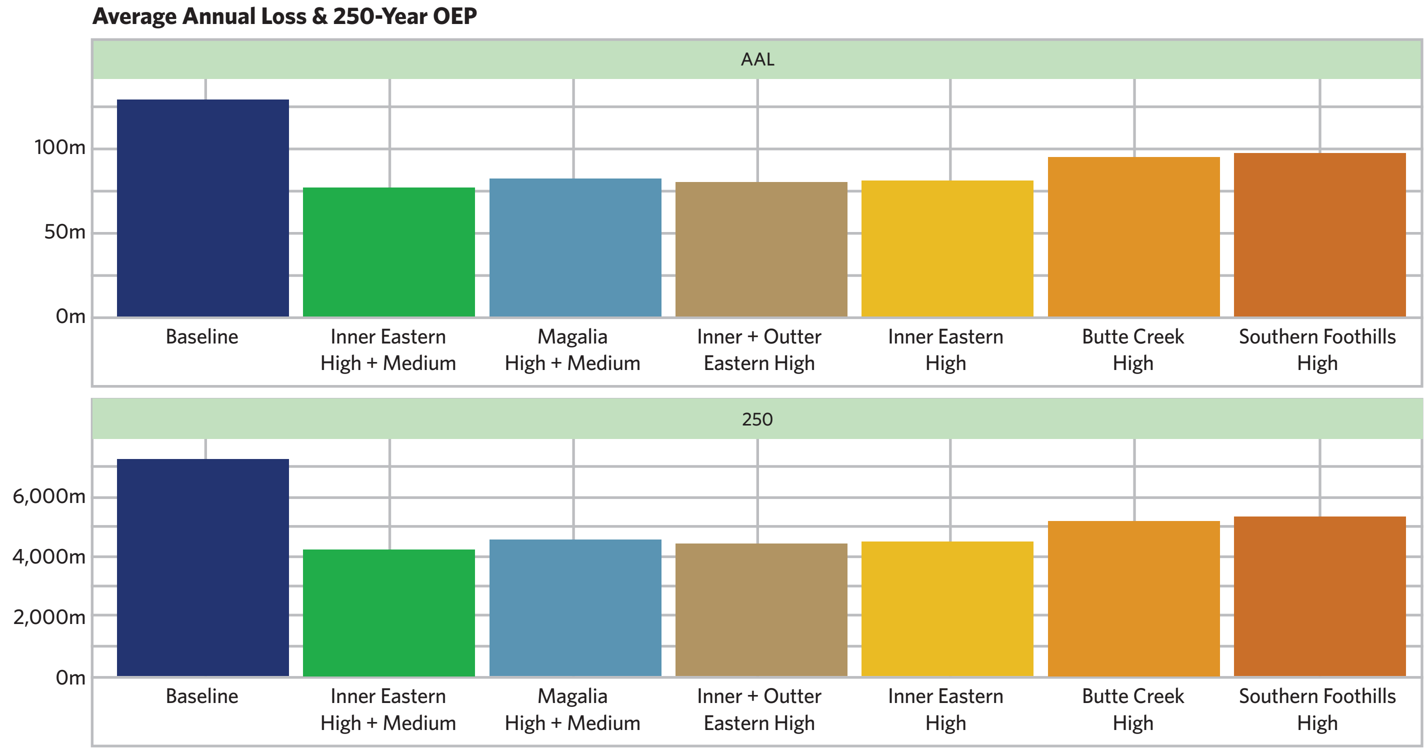


Source: Guy Carpenter *AIR Wildfire Model – TS7.3*

Figure 4 illustrates the benefit of each WRRB under a partial rebuild outlook. As compared to the baseline, both the average annual losses and 250-year losses are reduced by 75%–80%, largely driven by reduction in exposure (the number of structures exposed decreased from 15,600 to 4,600 in the scenario where only 1,000 of the destroyed properties were rebuilt).

As a way to isolate the direct benefits of each WRRB scenario from the short-term decrease in exposures due to the reduction in building stock, the baseline exposures were compared against the full rebuild outlook. This helps to isolate the effect of the planned risk reduction measures and demonstrate the size of the potential benefit to Paradise had these resilience investments been adopted prior to the Camp Fire. Additionally, the impact of compliance with updated building codes and the removal of properties in buffer zones is also assessed, to demonstrate how, implemented together, these measures could drastically reduce risks to people living in the WUI. *See Figure 5.*

FIGURE 5: **WRRB SCENARIO LOSS IMPACT (FULL REBUILD)**



Source: Guy Carpenter *AIR Wildfire Model – TS7.3*

Under a full rebuild scenario, AAL's decrease by 25%–42% based on the WRRB buffer strategy implemented. Tail losses decrease by a similar proportion (27%–42%).

The model estimates for the town of Paradise with the building stock that existed prior to the 2018 Camp Fire averaged USD 125 million per year with 1-in-50-year event of approximately USD 7.2 billion. While the probability estimates for a given loss level are difficult to assess for a small geographic area such as the Town of Paradise within a continent-scale model, the observed shift in the probability estimates is relevant. In the case of the Inner Eastern High + Medium scenario, a 1 in 100-year loss level would now be a much rarer 1 in 350-year loss level.

The most effective of the six different buffering scenarios with respect to risk mitigation—"Inner Eastern – High + Medium"—would have resulted in an average annual loss reduction of USD 27 million (a 21% reduction against the pre-Camp Fire baseline). Taking the additional step of updating all structures in Paradise to align with more modern building codes, losses would have further reduced by an average of an additional USD 25 million (20%) resulting in an overall reduction of USD 52 million (42%). For an event more extreme than a 250-year event at the tail of the exceedance curve, the risk reduction values would be much larger: USD 1.4 billion (19%) and USD 1.6 billion (23%) for buffering and code updates respectively.

Figures 6 and 7 compare the loss probabilities prior to the Camp Fire (dark blue) to the post-fire scenario assuming the Inner Eastern (High + Medium) buffer zone was achieved (light blue). Figure 6 assumes 1,000 properties rebuilt and Figure 7models with every destroyed property outside of the buffer zones rebuilt. *See Figures 6 and 7.*

FIGURE 6: INNER EASTERN—HIGH + MEDIUM WRRB SCENARIO LOSS IMPACT (PARTIAL REBUILD)

Source: Guy Carpenter

FIGURE 7: INNER EASTERN—HIGH + MEDIUM WRRB SCENARIO LOSS IMPACT (FULL REBUILD)

Source: Guy Carpenter

Implementing the WRRB with the least risk benefit would lead to only a USD 7 million (5%) reduction in average annual losses attributable to the buffer versus USD 26 million (20%) attributable to code updates.

THESE RESULTS UNDERSCORE THREE KEY FINDINGS:

1

Implementing buffer area strategies significantly reduces loss impact. Implementing the Inner Eastern – High + Medium WRRB scenario measure alone would reduce average annual losses by an estimated 27%.

2

Not all buffering scenarios are created equal. The placement and extent of buffer zones impact their loss-reduction potential. The range of outcomes across the scenarios in Paradise is wide, with the highest annual average loss reduction benefit of 27% and the lowest of 5%. Different buffering scenarios also cover different acreages and will have different cost levels depending on land and property value in the specific area. A benefit-cost analysis comparing various options would help prioritize parcel protection efforts.

3

Well-designed buffers have the potential to be more beneficial than home hardening measures, but when combined with home hardening measures yield even greater benefits. The data do not suggest an either or approach for buffering or home hardening. Rather, the data suggest that combining these methods is likely to yield the best results in terms of reducing risk. Updating and enforcing modern building codes is universally effective at mitigating wildfire risk. Prior research by the Insurance Institute for Building and Home Safety (IBHS) has underscored the importance of code adoption and enforcement in relation to hurricanes. For example, IBHS found that losses from Hurricane Andrew could have been halved for residential properties had they been built in accordance with Florida's 2004 statewide building code. Further research by the National Institute of Building Sciences (NIBS) indicates that typical Benefit-Cost Ratios (BCR) for current code adoption in relation to riverine flood, wind and earthquake are 6:1, 10:1 and 12:1 respectively. Specific to wildfires NIBS estimates (Porter, 2019) that wholesale adoption of the 2015 International Wildland Urban Interface Code (IWUIC), currently adopted by state or local jurisdictions in 20 U.S. states to date (International Code Council, 2020), would result in a BCR of 4:1. In dollar terms the national benefit of 2015 IWUIC code adoption for one year would be USD 3 billion accruing primarily in the form of property damage reduction (70%) and insurance premium cost reduction (20%). Evaluating the relative effects across the six scenarios, the combined effects of a buffer zone and strong building codes provides 25%–42% reduction in losses. See Table 3. Evaluating the relative effects across three of the six scenarios, the buffer zone provides greater relief than the improved building code enforcement.

In summary, the modeling results demonstrate that buffer areas can provide comparable wildfire risk reduction impact relative to code adoption. However, the effectiveness of these strategies varies according to the configuration and location of the buffer area.

The results also indicate that the greatest risk reduction impact for Paradise is to both enforce modern codes and implement the Inner Eastern High + Medium buffer area strategy. Together these efforts deliver a combined reduction in AAL of an estimated 42%. It is important to note that the combined risk reduction figures consider wildfire risk reduction buffers, the hardening of structures through improvements in reconstruction between the original exposures, and the rebuild assumptions after the Camp Fire (including roof covering (asphalt shingles), wall siding (brick), glass type (tempered)), as well as Paradise qualifying as a FireWise Community. These findings underscore the importance of comprehensive risk management strategies that include buffer areas, modern code enforcement, structure hardening, and other safety and preparedness measures.

TABLE 3: REDUCTION IN AAL FOR VARIOUS RISK MITIGATION STRATEGIES ON PRE-CAMP FIRE RESULTS

SCENARIO	NAME	BUILDING CODE	BUFFER ZONE	COMBINED
1	**Inner Easter**—High + Medium	-20%	-27%	-42%
2	**Magalia**—High + Medium	-20%	-20%	-36%
3	**Inner + Outer Eastern**—High	-20%	-24%	-40%
4	**Inner Eastern**—High	-20%	-23%	-38%
5	**Butte Creek**—High	-20%	-6%	-25%
6	**Southern Foothill**—High	-20%	-7%	-26%

Source: Guy Carpenter

VII Estimated Impact On Wildfire Insurance

The aforementioned wildfire risk reduction measures have the potential to create a win-win-win situation for insurers, policyholders and communities, as adoption could result in both increased availability of insurance and lower premiums.

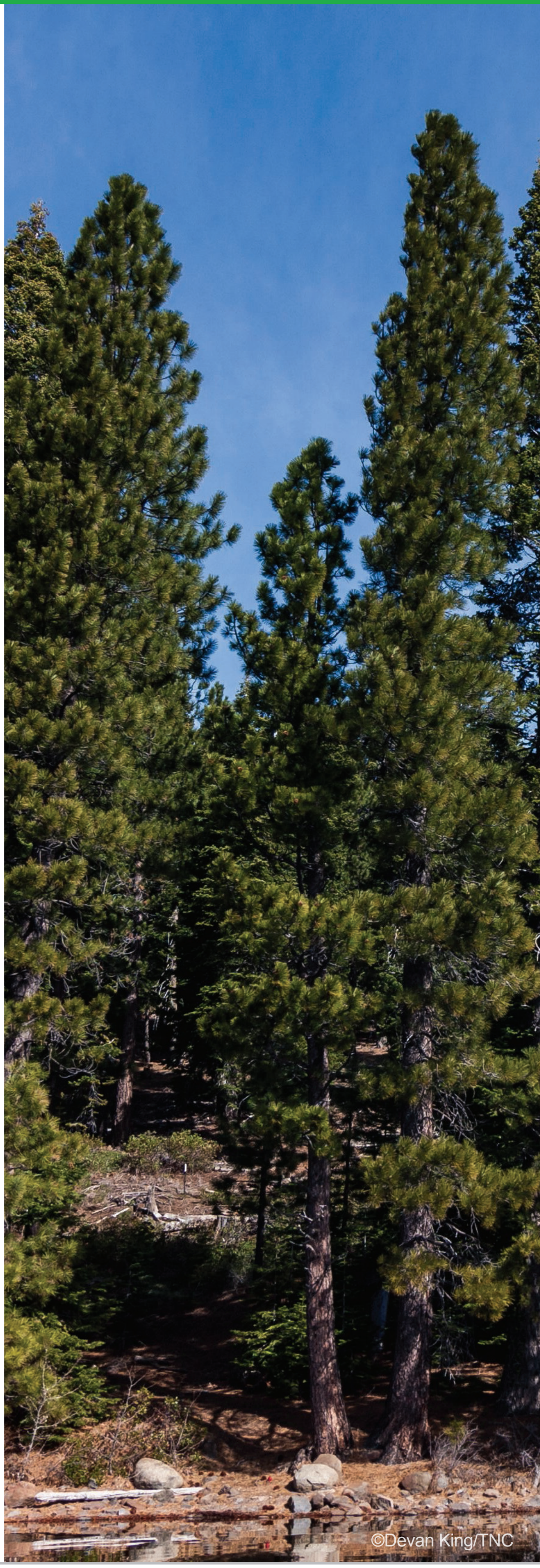
Insurers withdraw from markets where the risks are not well understood. Insurers also manage capacity in markets where risks are correlated; that is, where multiple policies can file claims out of the same underlying cause, and thereby, affect insurer earnings. After the Camp Fire, these conditions are apparent in Paradise. However, the analyses presented in this paper offer a pathway to both a better understanding of wildfire risk and a significant reduction in the size of insured loss from a severe wildfire.

Many insurers are concluding that current market pricing does not reflect the present risk presented by wildfires in many areas. Some carriers are also concluding that certain homes in the WUI face such substantial wildfire risk that they are declining to insure them. This is reflected in the trending non-renewals of private home insurance in the WUI and the increase in homeowners having to obtain home insurance from California's public fire insurer of last resort, California Fair Access to Insurance Requirements (FAIR) plan. The number of California homeowner policies that insurers declined to renew rose 31% to 235,250 in 2019, which was up from 179,458 in 2018. The number of policies issued through the FAIR plan also rose to 190,196 from 140,138, according to a report by the California Department of Insurance (California Department of Insurance, 2020).

The application of community or regional scale wildfire buffers, and resilience measures, as outlined in this report, should not only reduce risk of loss, but also importantly increase the capacity of insurers to write insurance for homes in the WUI. Reduction in wildfire risk should lead to a consistent adjustment of pricing.

Specifically, the combined impacts from applying the Inner Eastern High + Medium WRRB scenario and the use of modern fire-resilient building materials would have the potential to reduce the 2018 Camp Fire loss by 42%, from over USD 10 billion to roughly USD 6 billion with a full rebuild. While total insured values are the same, this is a 42% reduction in insurance capacity needed as insurers think about allocated capital, and by extension, risk loading. From a practical perspective, if the same housing stock has significantly smaller loss, the amount of required capital held by insurers to pay claims or manage the risk (loss cost) drops significantly. This translates into a smaller "risk load" required for each policy.[8]

Presently, the rate filing process in California allows for experience to be used, not catastrophe model loss costs, though catastrophe models can be used for territorial relativities. Regardless of the relationship between historical experience and catastrophe models, resilience measures that reduce loss costs can be viewed either as a way to restate historical experience at a



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lower loss level, or a lowering of a target rate needed to achieve a sustainable market equilibrium. From a segmentation standpoint, resilience measures will tend to increase (loss cost or price) distance between "best" and "worst" risks to insure. Increased need for underwriting may increase segmentation between private insurers and the California FAIR Plan.

Reducing the risk with the wildfire resilience measures outlined in this report will re-attract insurance capacity and significantly improve the financial resilience of the whole community in Paradise. The 42% risk reduction predicted by the modeling will then help insurers calculate pricing and have a significant impact on premiums. Applications of this strategy may be applied to additional wildfire-exposed areas in fire-dependent forest ecosystems. The win-win-win is that policyholders can find insurance again, communities can again sustain themselves and insurers understand reduced risk in a way that encourages long-term availability at stable pricing.

BOX 3: **COMMUNITY-BASED CATASTROPHE INSURANCE**

One possible way to capture the financial realization of these novel wildfire resilience efforts in insurance pricing is a new approach called, Community Based Catastrophe Insurance (CBCI). CBCI is an innovative framework where the Town of Paradise, or another community-scale entity, like a special purpose district, facilitate the purchase of or purchase insurance protection on behalf of its residents through partnership with insurers, reinsurers or other capacity providers (Bernhardt et al 2021). CBCI presents an opportunity for private risk carriers and local leaders, or other entities, to form long-term partnerships by actively managing risks and working to improve or sustain community insurance coverage together.

Importantly, monetizing the estimated risk reduction benefits provided from these resilience measures can demonstrate the potential return for Paradise and its residents in the form of reduced premium in addition to the benefits of future losses avoided should the buffer area scenarios be implemented. Implementing wildfire risk reduction measures at community-scale can be made more achievable through a CBCI program and represents the most effective means to improve the financial and physical resilience of the community.

VIII Implications And Recommendations

The tragedy experienced by Paradise residents demonstrates one of the worst-case scenarios associated with living in the WUI. But the research presented here also demonstrates that through coordinated community action and investment in safer development practices, those risks can be greatly mitigated and reduced to a level that is both livable and insurable.

Through calculated, strategically placed WRRB areas, both wildfire ignition rates and fire severity can be reduced. Curtailing risks improves survivability for people and homes. Additionally, by lessening the risk of property damage, strategic buffer areas also improve insurance affordability, which is necessary for post-loss recovery.

A case study on the town of Paradise illustrates how strategic WRRBs provide significant reductions in potential wildfire losses. Implementing the Inner Eastern – High + Medium WRRB scenario measure alone would reduce average annual losses by an estimated 27%. Furthermore, compliance with updated building codes is shown to universally reduce loss by 20%. Fire ignition and fire severity reductions, combined with building code changes are important to survivability, and insurance is important to disaster recovery.

Currently, many carriers are shying away from wildfire exposures, thinking they are too costly to insure. However, this study outlines how updated and enforced building codes, along with efforts to manage physical wildfire risk through buffers could meaningfully reduce the incidence of multi-billion dollar fires, which are the events of most worry and cost to insurers. A reduction in size of extreme events, coupled with the decrease in loss costs, can bolster insurance availability and will translate into lower wildfire rates and premiums. Without a functioning insurance market, communities and their residents in wildfire-prone areas are left vulnerable to financial ruin, in addition to the risk to lives and property. The residual exposure, which in turn relies on Federal disaster aid, which is supported by the U.S. taxpayer, will also be reduced.

Ignition-reduction plans work best when implemented across an entire community, but funding community initiatives can be difficult, especially in places such as Paradise, where the population has plummeted. In some cases, the funding has to come before the tax base recovers. Federal and state resources must be brought in to support communities in recovery like Paradise, but also to support communities proactively seeking to implement CBCI programs or other innovative partnerships to reduce their wildfire risk.

The approach explored here, if adopted, could also facilitate the replacement of sprawl as the predominant community design trend with denser, fire-resilient cluster development. With fewer homes dispersed in wildlands, other key risk-reduction strategies such as controlled burning could be reintroduced to fire-dependent ecosystems, such as the Northern Sierra—helping to restore habitats while further reducing wildfire risks.

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And, if applied more broadly to communities across the WUI, this approach would have a further multiplying effect on improving insurers view of risk on a regional scale. This would also help insurers improve management of aggregate risk, helping to maintain a sustainable property insurance market. Further implementation of local and regional wildfire resilience strategies, like those outlined in this report, will greatly improve financial resilience across the market and foundationally improve the future viability for communities and western states going forward.

TOGETHER, THE NATURE CONSERVANCY, AND MARSH MCLENNAN, RECOMMEND THE FOLLOWING ACTIONS:

1

Local governments in the Wildland Urban Interface should evaluate whether wildfire buffers would reduce the risk of wildfire losses for their community. Where local governments find that wildfire buffers are an effective way to decrease wildfire risk, they should plan for and implement wildfire buffers.

2

Each state and the Federal Government should provide funding to local governments to evaluate whether wildfire risk buffers would mitigate their wildfire risk. Furthermore, where such buffers could in fact reduce risk, funding to plan for and implement wildfire risk buffers should be provided to local authorities.

3

Insurers and insurance modelers should consider the results of this study and seek to incorporate the risk reduction benefits of wildfire buffers in their wildfire risk modeling.

4

Insurers and/or reinsurers should consider proactively partnering with community (or regional entities) to offer products which account for the risk reduction benefit of wildfire buffers as these measures are implemented. This includes participating in innovative CBCI programs, which can assist with and further incentivize implementation of such wildfire resilience strategies.

Where such authority is needed, state legislation can be enacted to explicitly authorize local governments and districts to fund, establish, and maintain wildfire buffer strategies along with CBCI programs.

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ENDNOTES

PAGE 8

1 Recent studies have indicated that maximum spotting distances for western tree species are 1.4 miles under extreme wind conditions, although travel distances are more typically under a mile for moderate to high wind scenarios (Page and Blunck, 2019).

2 The scientific literature contains few empirical or modeling studies that quantify ignition-reduction for green land uses such as orchards and parks. We found only one study offering empirical support that the greenness, spatial arrangement, and proximity of trees and shrubs to houses relative to wind direction can be manipulated to reduce the risk of house losses during wildfires (Gibbons et al., 2018).

3 As a caveat, there are also anecdotes of orchards providing a direct path for a fire to move from wildlands to human communities due to the presence of unmanaged undergrowth and weedy grasses that spread the fire. For these types of buffers to work, as mentioned above, vegetation and other management for low-flammability is essential. When drought is also occurring, some of the management strategies needed for these lands to act as buffers–such as irrigation–may present their own challenges.

PAGE 9

4 This time period is used to produce the California Basin Characterization (BCM) model, which provides historical and projected climate and hydrology data relevant for watershed-scale evaluation and planning.

5 In this model, two CMIP-5 climate scenarios were employed with the RCP 8.5 emission scenario – designed to be relevant for California. Resulting datasets from both climate models were each reclassified into three categories, ranging from one (lowest fire probability) to three (highest fire probability) before being added to obtain a single Wildland Fire Probability index.

6 Inputs for the fire probability model are described in Syphard et al. (2018).

PAGE 13

7 Appendix 2 includes some of the key inputs for portfolio analysis within a catastrophe model.

PAGE 21

8 A deeper explanation of these mechanics is contained in Appendix 2.

X Appendices

APPENDIX 1: KEY INPUTS FOR PORTFOLIO ANALYSIS WITHIN A CATASTROPHE MODEL

$M OF LOSSES	AVERAGE ANNUAL LOSS (AAL)								
COLUMN #:	A	B	B/A-1	C	C/B-1	D	D/C-1	D/B-1	D/A-1
SCENARIO NAME	**Pre-Camp Fire**	**Update in Exposures**	**% Difference**	**Buffer Exposures Removed**	**% Difference**	**WRRB Scenario**	**% Difference**	**% Difference**	**Total % Difference**
Inner Easter—High + Medium	126	101	-20%	97	-4%	74	-24%	-27%	-42%
Magalia—High + Medium	125	99	-20%	98	-1%	80	-19%	-20%	-36%
Inner + Outer Eastern—High	127	101	-20%	96	-5%	77	-20%	-24%	-40%
Inner Eastern—High	126	101	-20%	97	-4%	78	-19%	-23%	-38%
Butte Creek—High	124	99	-20%	96	-2%	92	-4%	-6%	-25%
Southern Foothill—High	128	102	-20%	95	-7%	95	0%	-7%	-26%

$M OF LOSSES	ANNUAL STANDARD DEVIATION (ASD)								
COLUMN #:	A	B	B/A-1	C	C/B-1	D	D/C-1	D/B-1	D/A-1
SCENARIO NAME	**Pre-Camp Fire**	**Update in Exposures**	**% Difference**	**Buffer Exposures Removed**	**% Difference**	**WRRB Scenario**	**% Difference**	**% Difference**	**Total % Difference**
Inner Easter—High + Medium	2,208	1,736	-21%	1,707	-2%	1,318	-23%	-24%	-40%
Magalia—High + Medium	2,181	1,717	-21%	1,725	0%	1,396	-19%	-19%	-36%
Inner + Outer Eastern—High	2,139	1,682	-21%	1,725	3%	1,382	-20%	-18%	-35%
Inner Eastern—High	2,208	1,736	-21%	1,707	-2%	1,381	-19%	-20%	-37%
Butte Creek—High	2,203	1,733	-21%	1,701	-2%	1,631	-4%	-6%	-26%
Southern Foothill—High	2,153	1,698	-21%	1,692	0%	1,701	1%	0%	-21%

$M OF LOSSES	250 YEAR OCCURRENCE EXCEEDANCE PROBABILITY (OEP)								
COLUMN #:	A	B	B/A-1	C	C/B-1	D	D/C-1	D/B-1	D/A-1
SCENARIO NAME	**Pre-Camp Fire**	**Update in Exposures**	**% Difference**	**Buffer Exposures Removed**	**% Difference**	**WRRB Scenario**	**% Difference**	**% Difference**	**Total % Difference**
Inner Easter—High + Medium	7,213	5,570	-23%	5,479	-2%	4,199	-23%	-25%	-42%
Magalia—High + Medium	7,139	5,554	-22%	5,521	-1%	4,500	-18%	-19%	-37%
Inner + Outer Eastern—High	7,213	5,591	-22%	5,479	-2%	4,401	-20%	-21%	-39%
Inner Eastern—High	7,213	5,570	-23%	5,479	-2%	4,457	-19%	-20%	-38%
Butte Creek—High	7,142	5,528	-23%	5,391	-2%	5,193	-4%	-6%	-27%
Southern Foothill—High	7,380	5,790	-22%	5,271	-9%	5,302	1%	-8%	-28%

APPENDIX 2: EXAMPLE PRICING MODEL & MECHANICS

Insurance pricing can be reduced to AAL + Risk Load + Expenses. As expenses are thought of as a percentage of premium, the formula is (AAL + Risk Load)/(1-expense ratio). The one unknown is calculation of risk load. While risk load can look like a percentage of premium, the truer calculation is to look at potential capital need and apply a tranched rate (https://www.variancejournal.org/issues/07-01/72.pdf) to that need, or to apply leverage factors to the capital need and apply a fixed rate to the post-leverage factor allocated capital.

In the without resilience measures scenario, with a $125m AAL and a $7.2b 1 in 250 year loss, insurers would need to have $7.075b of capital available in case of this $7.2b loss. We now have a price of:

(125m + 7,075m*WACC)/(1-Expense Ratio)

Where WACC is weighted average cost of capital.

In the rebuild with resilience measures scenario, for the same houses, the price becomes:

(73m + 4,127m*WACC)/(1-Expense Ratio)

The mathematical cost savings is then:

(52m + 2,948m*WACC)/(1-Expense Ratio)

Overall, this is a 42% reduction in price, before considering the effect the economics of a shift in the supply curve bringing down price. The math of this 42% price reduction is roughly the same if one allows for leverage, allocates less than full capital and demands a 15% rate of return on risk-adjusted capital. In one instance we have a calculation of risk-adjusted return on capital, in the other we have a calculation of return on risk-adjusted capital.

APPENDIX 3: ACREAGE FOR EACH WILDFIRE RISK REDUCTION SCENARIO

WRRB SCENARIO	SQUARE METERS	ACRES
Inner Easter	16,308,457	4,030
Magalia	15,509,728	3,832
Outer Eastern	54,999,658	13,590
Butte Creek	9,946,743	2,458
South Flats	43,306,309	10,701

BOX A1: THESE ARE SOME OF THE INPUTS TYPICALLY USED BY THE INSURANCE INDUSTRY TO ASSESS RISK EXPOSURE

- Location Information:
  - Street address
  - ZIP code
  - City
  - State
- Insured limits information (policy/site)
- Coverages A - D
- Deductible information (policy/site)
- Location building characteristics (strongly recommended):
  - Occupancy
  - Construction
  - Year built
  - Square footage
  - Number of stories
- Premium (portfolio management, limits profiles)
- Optional characteristics (optional but improve the accuracy of the results):
  - Cladding type
  - Roof age
  - Roof covering
  - Roof geometry
  - Shutter type