MILLIMAN REPORT

Community mitigation and modeling: Rancho Mission Viejo

Commissioned by Rancho Mission Viejo, LLC

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Nancy Watkins, FCAS, MAAA
Garrett Bradford, GISP
Taylor Munch, ACAS, MAAA
Chief Dave Winnacker
Chief Frank Frievalt
Dr. Hussam Mahmoud

Milliman

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1 Background and scope

A series of wildfire events occurring in California since 2017 has resulted in significant underwriting losses and reinsurance cost increases for companies writing homeowners insurance in the state. Accordingly, many insurers have responded by increasing rates and decreasing capacity in high-risk areas. In response to a lack of affordable home insurance, many communities and homeowners across the state of California are taking action to reduce their wildfire risk and some communities have been investing heavily in wildfire mitigation efforts. However, in many cases these communities and homeowners have not seen a corresponding reduction in their insurance premiums or an improvement in insurance availability. This is caused in part by the disconnect between current conditions on the ground and the information readily available and usable to insurers.[1]

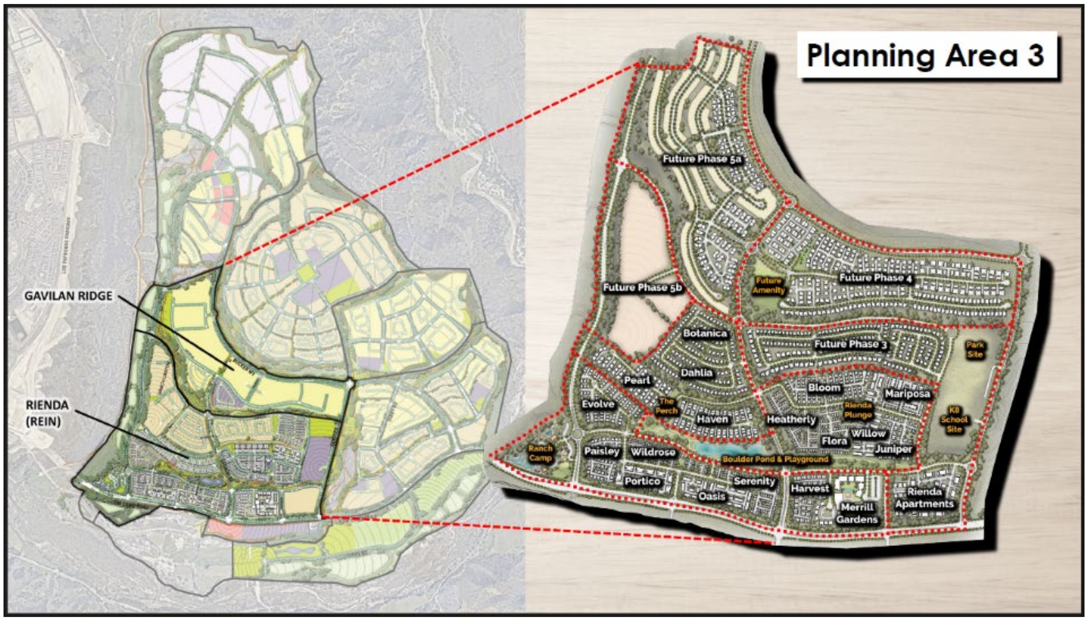
As a planned community that has invested in wildfire resilience, Rancho Mission Viejo (RMV) exemplifies this disconnect between current mitigation actions and insurance availability. RMV is a 23,000-acre active ranch, nature reserve, and master-planned residential community located in the hills of South Orange County in Southern California. Rancho Mission Viejo, LLC is a privately held, family-owned and -operated company responsible for the ranching, farming, planning, development, and fiscal management of RMV. Since 1882, members of the O'Neill/Moiso/Avery family have owned and managed the Ranch, which once exceeded 200,000 acres and now includes the family-developed cities and communities of Ladera Ranch, Las Flores, Mission Viejo, and Rancho Santa Margarita as well as such iconic places as Caspers Wilderness Regional Park, the Starr Ranch Audubon Sanctuary, O'Neill Regional Park, and Marine Corps Base Camp Pendleton.

RMV has undertaken extensive wildfire protection planning and mitigation efforts to reduce wildfire risk in their communities, such as: implementing construction code requirements, modifying fuels to create defensible space, enforcing landscaping restrictions, and improving emergency vehicle access. As they continue development, RMV planners are now in search of ways to continually improve their mitigation efforts as well as ways to enable insurance companies to more accurately account for the risk reduction efforts made when determining eligibility and pricing of insurance. To this end, RMV engaged Milliman Inc. (Milliman) together with XyloPlan, Pyrezo, Cal Poly Wildland-Urban Interface (WUI) Fire Institute, and Colorado State University. Additional information about each of the project team members is provided in Appendix E. This group of collaborators has developed a framework for community mitigation and modeling designed to analyze current mitigation efforts, provide recommendations for mitigation optimization, and use models to create visual and digestible formats of the risk with community mitigation considered. By using this framework, RMV can demonstrate to insurers the impact of the community's risk reduction efforts in a measurable way. This project with RMV serves as the first pilot community to illustrate this framework.

The study region of the project is RMV's proposed planning area 3 (PA3), which is shown in detail in Figure 1 as well as in Appendix D. PA3 is currently under development, with at least a thousand homes already built and occupied. PA3 is only one of the proposed planning areas for RMV's expansion but, for the purposes of this study, PA3 will be analyzed independently, meaning that any current construction or grading immediately adjacent to PA3 is not being considered for the purposes of this study.

[1] It should be noted that another significant contributor to the insurance availability crisis in California is a perceived disconnect between insurers' views of risk and their ability to charge premiums commensurate with that risk under current regulation. The California Insurance Commissioner has proposed a series of regulatory reforms via his Sustainable Insurance Strategy that are generally planned to take effect in 2025. Discussion of these reforms is outside the scope of this report, but additional information can be found at https://www.insurance.ca.gov/01-consumers/180-climate-change/SustainableInsuranceStrategy.cfm.

FIGURE 1: PLANNING AREA 3 (PA3) OF RANCHO MISSION VIEJO (RMV)



Source: Rancho Mission Viejo.

The results of this analysis and framework were demonstrated through a private webinar attended by critical stakeholders (insurers, reinsurers, catastrophe modelers, regulators, and advisory groups) active in wildfire-exposed areas of the United States. The purpose of the webinar was to request feedback from these stakeholders regarding the utility of the framework in measuring and understanding the impact of community mitigation on wildfire risk. To collect the feedback, Milliman conducted interviews with representatives from 11 different insurers and reinsurers.

The first part of this report describes the framework in detail, including the methodologies used and demonstration of the ability to create visual and measurable formats of risk using RMV’s data, considering the community mitigation. The second part of this report describes the subsequent interview process in further detail and includes a summary of findings and next steps based on the feedback given during the interviews.

2 Executive Summary

With respect to RMV and other communities in the wildland-urban interface (WUI), this framework is particularly focused on the potential for urban conflagration, in which fire leaves the natural environment and enters the built environment. The components of the framework discussed in this pilot study were designed collaboratively by Milliman, XyloPlan, Pyrezo, Cal Poly WUI Fire Institute, and Colorado State University. The project team used data provided by RMV and data collected via inspection to create an analysis for each of the components of the framework, as shown in Figure 2.

FIGURE 2: ANALYSIS OF FRAMEWORK COMPONENTS

Fire pathways modeling

- Model the most likely avenues through which fire would enter the community and initiate structure-to-structure spread.

Parcel-level inspections

- Perform on-the-ground wildfire risk inspections for a sample set of buildings.

Vegetation treatment and dynamic community wildfire protection plan

- Provide prioritized mitigation recommendations inclusive of location, prescription, and return interval.
- Develop dynamic Community Wildfire Protection Plan (CWPP) compliant with the Healthy Forests Act of 2003.

Structure-to-structure modeling

- Model structure-to-structure fire spread within the built environment using graph theory in order to provide more nuanced, detailed, and specialized modeling of fire spread than is generally available via the catastrophe models currently available in the wildfire space.

WUI fire protection score

- Provide an objective and digestible rating at the fire battalion level using a system designed to quantify, measure, and classify the ability of a community's fire protection agency to prevent the transition of fire into areas of high structural density.

Data extrapolation and aggregation

- Assess building density, structure separation distance, distance to nearest fire pathway, distance to wildland via geospatial analysis
- Provide maps, graphs, charts, and bivariate analyses to demonstrate findings of all relative variables in formats that might be meaningful to communities and insurers

Our interviews with stakeholders provided the following key findings:

- At the community level, wildfire risk and the ability to measure the impact of risk mitigation actions are not currently well understood.
- The tools and data shown in this framework are novel and in some ways more advanced than tools currently being used to assess community-level mitigation of wildfire risk.
- Fire pathway modeling and the data elements of the framework were of particular interest to insurers.
- There are questions about how the framework could be implemented and shared among all stakeholders, while maintaining competition in the market.
- There is uncertainty as to when and how elements of the framework would be approved by regulators.
- If insurers make pricing changes based on this framework, they would need reinsurers to follow suit.
- Some reinsurers emphasized the need for a portfolio risk view.
- Some reinsurers commented that these tools are better suited for the primary insurers’ use case but noted that they would be happy to see the primary insurers that they work with using them.

At the close of their interviews, several of the interviewees indicated a strong interest in being part of the effort for further industry exploration and adoption.

The following are some key quotes from the interviews about current market problems arising from insufficient wildfire risk assessment, and the perceived value of the proposed framework to address those problems.

Primary insurers:

“I would say there's more valuable information here for a community than a cat model, AAL [average annual loss], or even PML [probable maximum loss].”

“[Fire pathways are] something we just don't have anywhere else in this immensely valuable cause. We only care really about fires on windy days. Everything else fire officials can generally handle. So the fire pathways should be the missing gold nugget.”

“[On targeted mitigation and nonburnable features:] That's worth knowing because we can know these things are there but we can't really evaluate how well done they are…. So if there's actually some science behind [it]… [if it is] enough to slow down the fire arrivals, that would be worth knowing, right?”

“[On targeted mitigation:] If they know for the most minimal amount of effort they're getting the most bang for their buck and it's spoken in that way that seems like super, super valuable to me.”

Reinsurers:

“I can tell you that I was profoundly unsatisfied with the sort of generation of models that considered built-up areas to be unburnable.”

“I think you know, as with most, we struggle most with the building characteristics and the immediate environment around those risks.”

“It becomes really…a complicated exercise to manage a portfolio and to quote business when you have to juggle between these different tools at different resolutions and where there's a lot of uncertainty around each of these, whether they're scores or whether they're cat models, so there’s no single source of truth.”

“I can see the industry saying this is very useful. I really think everyone is struggling. I really don't see that many people would say no, we don't want the extra data.”

“It improves the underwriting and certainly allows for more structures or buildings or homes or businesses to be insurable and identifies which ones might need some sort of defense services or vegetation maintenance plan or mitigation. The pricing is really challenging because there's no standard around pricing.”

“If you were to do it, primarily the community protection efforts, I think that would be a superior risk.”

3 The framework

The following sections describe the methodology for each component of the framework and demonstrate the ability to create measurable formats of risk using RMV's data, considering community mitigation. The components of the framework are as follows:

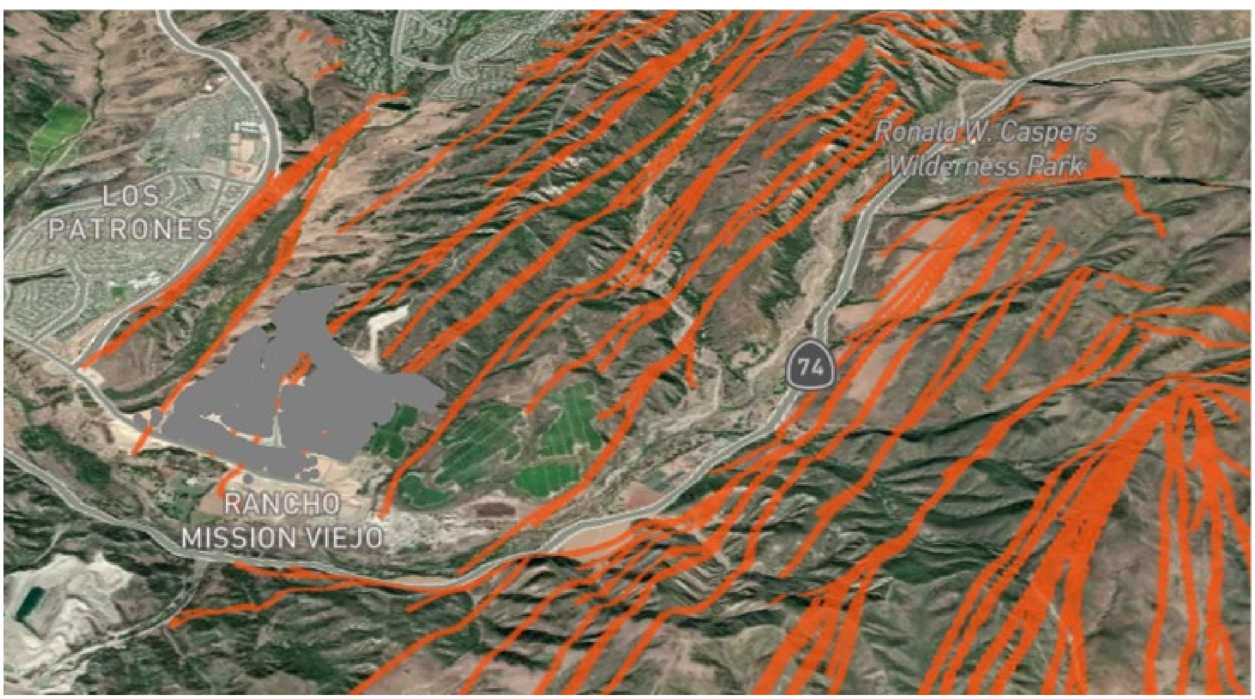
1. Fire pathway modeling
2. Parcel-level inspection
3. Vegetation treatment and dynamic community wildfire protection plan
4. Structure-to-structure modeling
5. WUI fire protection score
6. Data extrapolation and aggregation

3.1 FIRE PATHWAY MODELING

Fire pathways are the routes, modeled by XyloPlan, over which a fast-moving, wind-driven fire event is predicted to spread across the landscape. These pathways are created by the alignment of topography, weather, and fuels and can be understood with computer simulations built on semiempirical mathematical models.

The points of transition where a vegetation fire pathway enters a community are the most vulnerable and, depending on the configuration of the structures in a community, can be catalysts for widespread conflagration due to the network effect of fire spread within the built environment. Measuring structures' proximity to fire pathways and assessing the presence of individual and community-level mitigations, such as the firefighting response, home hardening, and defensible space, can help provide fine-scale differentiation of risk gradients within the same geographic fire-prone landscape.

FIGURE 3: FIRE PATHWAYS



Fire pathways are drawn in orange on this image of RMV's PA3 study area. In this simulated wildfire event, the speed-based fire pathways are modeled during a Santa Ana wind event, with winds from the northeast. Source: XyloPlan. Map Data: ©2024 Mapbox.

3.1.1. Rancho Mission Viejo PA3 Values at Risk

The first step of the fire pathways simulation is to identify the Values at Risk (VaR) for Rancho Mission Viejo (RMV), which are the structures in the third proposed planning area for development (PA3). Because many of these structures have low structure separation distances (SSDs), the intersection of the simulated fire pathways with the VaRs highlights the areas where the vegetation-to-structure fire transition is most likely to start a structure-to-structure conflagration sequence.

3.1.2. Fuel model

The simulation uses the nationwide LANDFIRE wildland fuels dataset. This widely used dataset provides accurate geospatial data on the type, quantity, and location of vegetative fuels. LANDFIRE is updated every other year, incorporating the impact of recent fire disturbances, vegetative fuel treatments, land development, vegetation regrowth, and other changes in the vegetative landscape. Because such conditions are constantly evolving, models that use LANDFIRE and similar datasets often lag in the conditions on the ground. To correct for this, in this study XyloPlan additionally adjusted for nonburnable features, such as vineyards, orchards, and golf courses, that are not properly reflected in the LANDFIRE dataset. This is particularly visible in the orchards east of RMV's proposed PA3 development.

FIGURE 4: RMV PA3 PROPOSED STRUCTURES

XyloPlan evaluates the proposed structures within RMV's proposed PA3 development as VaRs that are capable of structure-to-structure fire spread. The above graphic shows PA3 structures based on a satellite map for visual aid. The underlying fuels dataset used in this study was LANDFIRE 2020. Source: XyloPlan. Map Data: ©2024 Esri.

3.1.3. Wind and weather

A fire weather simulation was developed based on surface observations from local remote automated weather stations to reflect the potential for a hazardous Santa Ana wind event, such as the conditions that were present during the 2020 Silverado Fire. For this project, the Silverado Fire was the chosen event, which occurred in southern Orange County, approximately 20 miles from RMV. The fire burned over 13,000 acres and destroyed 11 structures in the fall of 2020. During the afternoon of October 26, 2020, relative humidity was in the low single-digits and sustained wind speeds from the northeast approached 30 miles per hour, with gusts to 48 miles per hour, which are representative of the Santa Ana wind events common in Southern California.

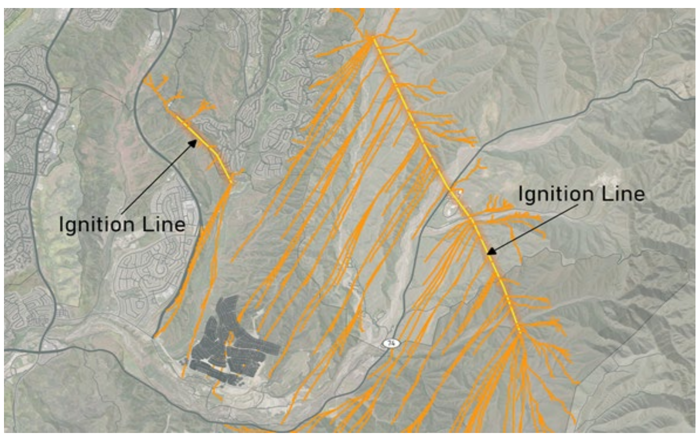
FIGURE 5: SILVERADO FIRE MEASUREMENTS

Wind Speed	35 mph
Wind Direction	29°
Relative Humidity	4%
Scenario Date	10/26/2020

3.1.4. Ignition lines

Wildfire ignition is highly stochastic, predicting ignition locations is challenging, and fire dynamics shortly after ignition may be chaotic. Low-probability fire events can inflict catastrophic damage, so assessing, understanding, and mitigating all potential ignition scenarios is important. While many contemporary modeling efforts use probabilistic modeling to understand the outcomes of many potential ignition scenarios, this study uses an ignition line to represent an already-established fire front upwind of the community, establishing an analysis based on a “worst-case” scenario as opposed to a “probable-case” scenario.

FIGURE 6: IGNITION LINES

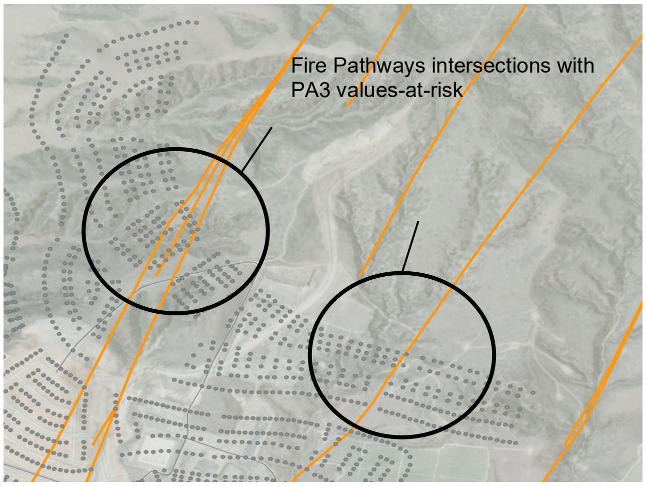


This archetypal ignition line is drawn about five kilometers upwind of RMV’s PA3, and fire pathways are modeled to start along the full length of the ignition line. Source: XyloPlan. Map Data: ©2024 Esri.

3.1.5. Minimum travel time modeling

With the inputs of the ignition line, fuel model, and weather data, the FlamMap wildfire simulation software from the U.S. Forest Service (USFS) Missoula Fire Science Laboratory produces the minimum travel time (MTT) graph for a wildfire under the simulated conditions. These fire pathways routes identify the points of entry into the RMV’s PA3 development area, indicating the locations where fire is most likely to outpace the firefighting response. In these areas, mitigations to interrupt the spread of fire from vegetation to structures should be prioritized. This can take the form of upstream vegetation management, home hardening, defensible space, or the firefighting response.

FIGURE 7: INTERSECTION OF FIRE PATHWAY AND RMV PA3



Source: XyloPlan. Map Data: ©2024 Esri.

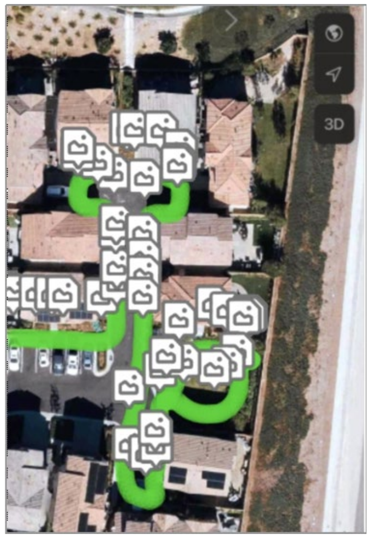
3.2 PARCEL-LEVEL INSPECTIONS

To understand the risk of a vegetation fire transitioning to a structure fire at the points of entry, we must understand the conditions on and around structures. In the case of RMV, all homes are built to Chapter 7A[2] ember-resistant construction standards. This standard includes Class A roof assemblies, non-combustive siding, double-paned windows, and ember-resistant vents, among other elements.

To capture the vegetation around homes, representative parcel-level inspections were conducted by Pyrezo in selected RMV neighborhoods. These inspections were completed with 360-degree cameras and assessed through image capture driven by artificial intelligence (AI), comparing actual conditions against 17 condition codes derived from the California Department of Insurance Safer From Wildfires framework[3] and the Institute for Business & Home Safety (IBHS) Wildfire Prepared Home program.[4]

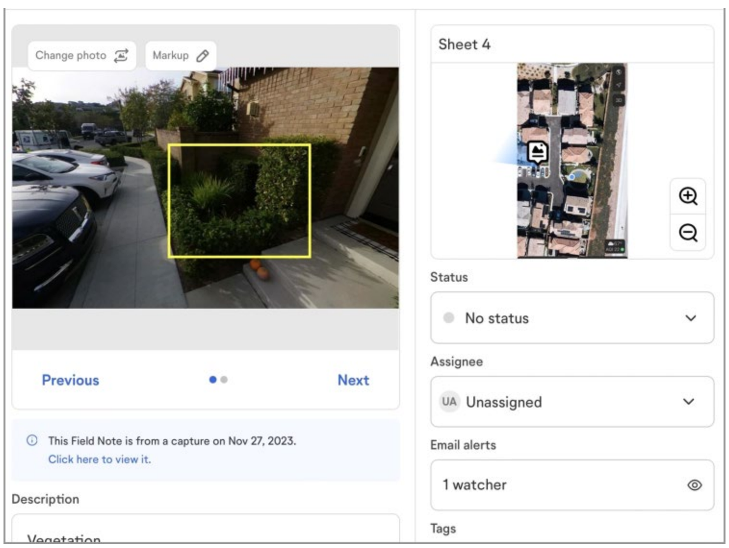
[2] For further detail, please reference the official definition of Chapter 7A, available at https://www.hcd.ca.gov/building-standards/state-housing-law/wildland-urban-interface/docs/2010-part-2-cbc-ch7a.pdf, and the CALFire handbook, available at https://www.marincounty.org/-/media/files/departments/fr/prevention/publications/wui-compliance-products-handbook.pdf.
[3] For further details, please reference Safer from Wildfires, available at https://www.insurance.ca.gov/01-consumers/200-wrr/Safer-from-Wildfires.cfm.
[4] IBHS is an independent, nonprofit scientific research and communications organization supported by property insurers, reinsurers, and affiliated companies. Please see Wildfire Prepared Home, a program of IBHS, available at https://wildfireprepared.org/, for more details.

FIGURE 8: NEIGHBORHOOD INSPECTION ROUTE



Source: Pyrezo.

FIGURE 9: NEIGHBORHOOD INSPECTION REPORT ENTRY, TAGGING AN AREA OF VEGETATION IN ZONE 0



Source: Pyrezo.

Generally, the structures in RMV contained vegetation in zone 0,[5] combustive vegetation in zone 1,[6] and the presence of non-vegetative combustive material such as lawn furniture, wooden fences, and doormats. Each item was tagged for identification and location. Subsequent inspections can be conducted to track changes over time and to verify the presence or absence of mitigations around structures.

[5] Zone 0 is the noncombustible zone of zero to five feet around a building, including the entire footprint of an attached deck. This zone is designed to protect the building from ignition that can result from wind-blown embers that can accumulate at the base of the exterior wall, and from exposure to radiant heat or direct flame contact that would occur due to the ignition of combustible materials located near the building or under an attached deck.

[6] Zone 1 extends 30 feet from the building or to the property line, whichever is closer. More information about the zones can be found on How To Create Defensible Space for Wildfire Safety from CAL FIRE, available at https://readyforwildfire.org/prepare-for-wildfire/defensible-space/#:~:text=About%20defensible%20space%20zones&text=Zone%200%3A%20Zone%200%20extends,varying%20levels%20of%20vegetation%20management.

3.3 WILDFIRE MITIGATIONS AND DYNAMIC COMMUNITY WILDFIRE PROTECTION PLAN

After identifying the fire pathways that encounter VaRs, the analysis was extended to inform planning decisions to mitigate wildfire risk. Slowing a fire's spread outside of the built environment provides additional time for the arrival of local and regional firefighting resources, which, along with home hardening and defensible space, are essential for preventing the spread of fire into the built environment.

3.3.1. Mitigations

The fire pathways analysis informed siting decisions for community amenities, such as sports fields and dog parks, and roadways that also serve as nonburnable community buffers to lower wildfire risk. The wildfire risk reduction value of these features is increased by their placement at the points of transition where vegetative fire will enter the built environment.

In conjunction with pathway fire spread modeling, treatment opportunities were evaluated in the open spaces north of the community as opportunities to slow fire spread. These treatments can be considered in conjunction with the nearby community fuel modification zones, interior slope treatments, fire-resistant construction features, and the available fire suppression response to develop a holistic view of the effect of a layered wildfire mitigation plan.

3.3.2. Dynamic Community Wildfire Protection Program

The vegetative fuel on a landscape is dynamic, with continuous vegetation regrowth and vegetative disturbances, such as planned or unplanned fire, thinning or mechanical fuel treatments, changes to irrigated land, insect or disease infestations, and development. In contrast to a traditional Community Wildfire Preparedness Plan (CWPP), where a community risk assessment is completed at a five-year interval or longer, XyloPlan provides a dynamic CWPP, where fire pathways are modeled annually, taking into account development, fuel regrowth, and disturbances. Each year, cost-effective and beneficial vegetation management activities are evaluated and prioritized for implementation.

A dynamic CWPP includes provisions for a return interval for every vegetation treatment, where there is an expected maintenance period for each type of fuel, and maintenance is planned on a schedule so that communities will continue to receive benefits from any vegetation treatment initially put on the landscape. In addition to predicting when maintenance will be required according to a standard maintenance interval for vegetation type, XyloPlan integrates the most recent LANDFIRE dataset into the simulation, which is corrected with data for nonburnable or modified areas, such as new developments and recent vegetative treatments.

With a dynamic CWPP, which reflects current conditions on the ground, a community can efficiently lower wildfire risk and increase their community wildfire resilience on an ongoing basis, planning and prioritizing the most effective mitigations to allow residents to live in a fire-prone area and reduce vulnerability to catastrophic damage.

3.4 STRUCTURE-TO-STRUCTURE MODELING

3.4.1. AGNI-NAR community fire spread model

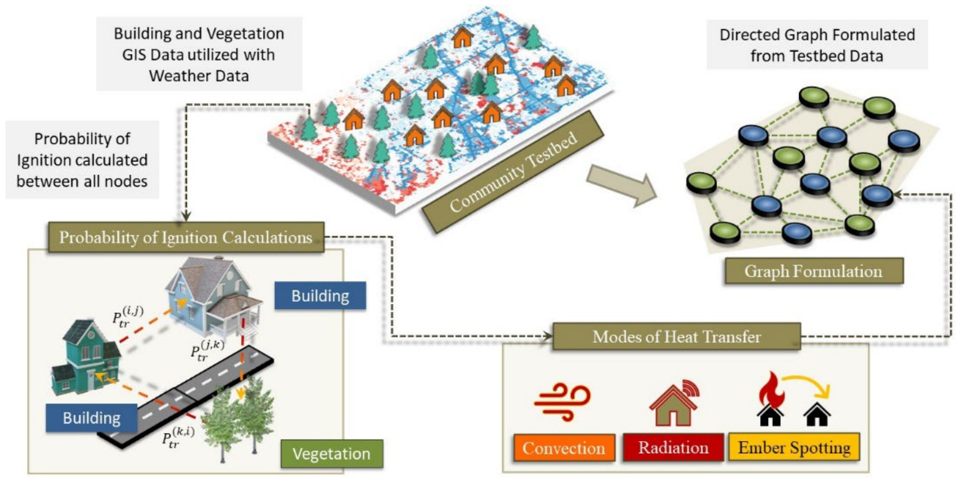
Up until recently, urban conflagration events in which structures became fuel were extremely infrequent. Communities that were previously considered to be low-risk are now experiencing mass destruction from wildfires that ignite structures and spread throughout the community. Given these recent patterns, it is not only important to understand how fire spreads in the wildland, but also how fire spreads from structure to structure and how to mitigate that spread.

In this study, fire spread from structure to structure is modeled using the Asynchronous Graph Nexus Infrastructure for Network Assessment of Wildland-Urban Interface Risk (AGNI-NAR).[7] The model utilizes graph theory to assess fire propagation through intermixed fuel of structures and vegetation. A directed graph comprising nodes and links is developed for the community being analyzed. The nodes represent the location of structures and the primary vegetation fuel. The links (also called edges) represent the fire interaction between the fuel by incorporating different fire propagation modes, including convection, radiation, and ember spotting (embers generated by burning vegetation and homes). The model accounts for relevant community-specific characteristics, including wind conditions,

[7] Mahmoud and Chulahwat, 2018; Chulahwat et al. 2022.

community layout, individual structural features, and the surrounding wildland vegetation. Figure 10 depicts the framework.

FIGURE 10: STRUCTURE-TO-STRUCTURE MODELING FRAMEWORK



Community buildings and vegetation depicted as a network of connected fuel with heat transfer mechanisms are accounted for between all ignitable fuel. Source: Dr. Hussam Mahmoud, Colorado State University.

Appendix C contains additional information regarding the validation of the AGNI-NAR model and related reference materials.

3.4.2. AGNI-NAR model output

Two types of analysis are conducted to determine the fire boundary and the potential damage:

- ***Most probable path (MPP):*** MPPs are the paths with the highest probability for fire propagation from an ignited node to a non-ignited one. A probability value at a given node in the MPP figure indicates the probability of that node being in the path of the fire. The MPP value is calculated for all nodes to calculate the overall fire boundary.
- ***Relative vulnerability (RV):*** RV corresponds to the vulnerability of a node (i.e., structure) in terms of the likelihood of being damaged relative to other nodes or structures in the community. The RV values for each structure are calculated for the fire boundary resulting from the MPP analysis.

With known ignition point(s) or line(s), the fire boundary is determined using the MPP analysis. Once the fire boundary is known, the expected damage within the boundary is determined using the RV analysis.

3.4.2. Scenario-based analysis for Rancho Mission Viejo

Four different hypothetical mitigation scenario analyses are conducted on PA3, as follows:

- ***Low – "minimal mitigation":*** This hypothetical scenario represents an average California community before any form of mitigation is considered. There are no buffer zones and individual structural characteristics were randomized throughout the community, based on Paradise's pre-Camp Fire structural characteristic distribution. Ember spread is considered given that structures are not all ember-resistant.
- ***Medium – "current state":*** This hypothetical scenario represents a community with no buffer zones and individual structural characteristics that are based on the Pyrezo ground inspections of existing Rancho Mission Viejo developments. All structures meet Chapter 7A building requirements, but there is vegetation in zone 0. Ember spread is considered and generated in the wildland. The naming convention "current state" is used to imply what RMV's PA3 *would be* without the implementation of the targeted mitigation proposed below.

- ***High – “highly mitigated”:*** This hypothetical scenario represents a community with no buffer zones from the targeted mitigation proposal but that is otherwise highly mitigated, with all structures meeting Chapter 7A building requirements and no vegetation in zone 0. Because these mitigations are in place, embers catching vegetation in zone 0 would not be considered a threat in this scenario.

- ***Planned – “targeted mitigation”:*** This hypothetical scenario was generated based on the results of the first three scenarios and is meant to represent a community starting with the current state (all structures meeting Chapter 7A building requirements, with vegetation in zone 0), with targeted community mitigation requirements established. There is a perimeter road around the entire community. Structures in the entryway of the fire pathways are removed and replaced with nonburnable amenities such as a soccer field, parking lot, and dog park. The presence of these buffer zones prevents fire from entering the community on the ground. However, due to the presence of vegetation in zone 0, ember spread is still considered and generated in the wildland. Based on the recommendations in this study, this is the scenario RMV planners intend to implement in PA3.

Various building characteristics that are known to impact fire ignition are included in the analysis. The variation in every feature is considered depending on the analysis type. For example, for the High scenario, it is assumed that all buildings are Chapter 7A-compliant, including features such as non-combustible fences, class A roofs, enclosed eaves, mesh vents with no more than 1/8-inch openings, multi-pane windows, etc. For the Low scenario, building characteristics are randomly distributed throughout PA3 to represent an average California community that has not considered implementing any mitigation requirements. Buildings in this scenario may have features such as non-combustible fences, combustible fences, enclosed eaves, unenclosed eaves, mesh vents, unenclosed vents, multi-pane windows, or single-pane windows, etc. The building features were incorporated into the graph model by altering the fire propagation values in the graph links based on feature importance. The importance of each feature was specified based on the odds ratio published by the California Department of Forestry and Fire Protection (CAL FIRE) following the 2018 Camp Fire,[8] as shown in the table in Figure 11.

[8] Porter et al. 2021.

FIGURE 11: TABLE OF ODDS RATIOS IMPLIED BY CAL FIRE'S OBSERVATIONS FROM THE 2018 CAMP FIRE

i	Feature	Condition	Compliant	Ri
0	Elevated deck or porch	Composite	FALSE	0.5
		Masonry or concrete	TRUE	0.3
		None	TRUE	0.5
		Wood	FALSE	2.5
1	Deck or porch on grade	Composite	FALSE	0.3
		Masonry or concrete	TRUE	0.3
		None	TRUE	2.0
		Wood	FALSE	2.7
2	Defensible space	Compliant	TRUE	0.2
		Noncompliant	FALSE	5.0
3	Eaves	Enclosed	TRUE	0.8
		None	TRUE	2.0
		Unenclosed	FALSE	1.0
4	Exterior cladding	Combustible	FALSE	1.5
		Ignition-resistant	TRUE	0.6
5	Fence	Combustible	FALSE	1.8
		None	TRUE	0.7
		Non-combustible	TRUE	1.1
6	Patio/carport cover	Combustible	FALSE	1.5
		None	TRUE	0.7
		Non-combustible	TRUE	1.1
7	Roof	Asphalt	TRUE	0.9
		Concrete	TRUE	1.2
		Metal	TRUE	1.2
		Tile	TRUE	0.4
		Wood	FALSE	6.0
8	Vent screen	Mesh <= 4 mm	TRUE	0.7
		Mesh > 4 mm	FALSE	1.2
		No vents	TRUE	1.1
		No screen	FALSE	1.5
9	Windows	Multi-pane	TRUE	0.4
		Single-pane	FALSE	3.0

Source: CAL FIRE.

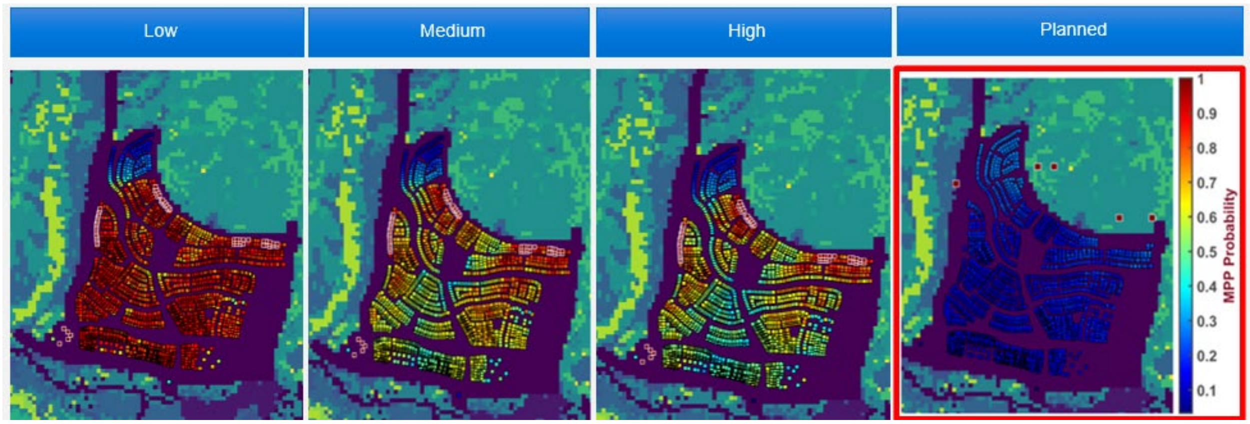
3.4.3. Analysis results

Based on the minimum travel time (MTT) analysis provided by XyloPlan, wildfire entry points were identified for the community. Entry points are considered as initial ignition points to determine the extent of the fire perimeter using an MPP analysis.

Figure 12 shows the fire boundary for the MPP analysis for each scenario. An MPP probability value of 1 implies that the structure is highly likely to be in the path of the fire. For example, the Low scenario, with random distribution of building features in the community representative of pre-Camp Fire conditions, shows almost all building nodes exhibiting a value near 1, implying most of those buildings will be in the path of the fire.

Given the calculated fire boundaries for each case, the likelihood of damage (or survival) for each building is determined as highlighted in Figure 12. The figure shows the expected probability of damage to structures relative to each other, based on the RV analysis for each scenario. An RV probability value of 1 implies that the structure is highly likely to be damaged, whereas a value of 0 implies a higher likelihood of survival.

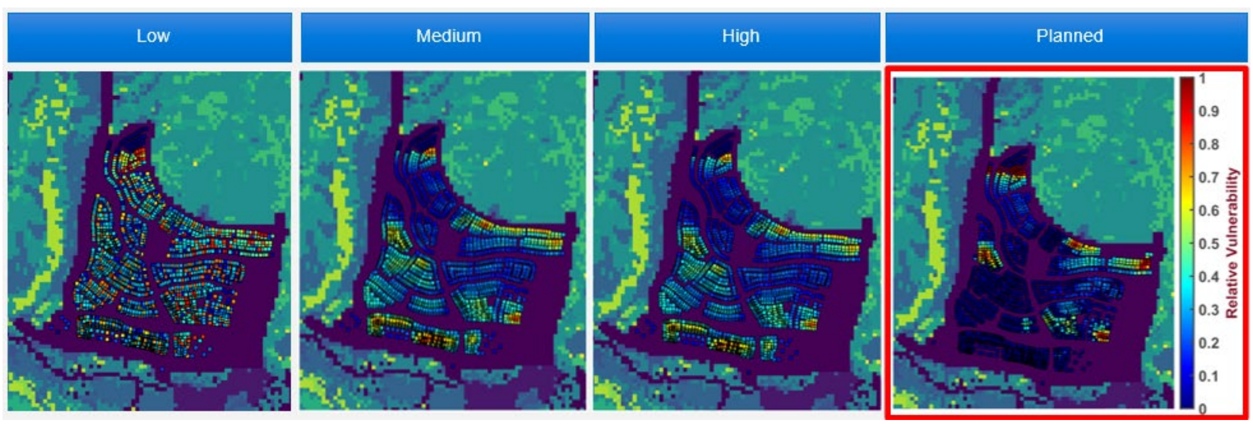
FIGURE 12: FIRE BOUNDARY BASED ON THE MPP ANALYSIS FOR EACH SCENARIO



Source: Dr. Hussam Mahmoud, Colorado State University.

An MPP probability value of 1 implies that the structure is highly likely to be in the path of the fire.

FIGURE 13: EXPECTED PROBABILITY OF DAMAGE TO STRUCTURE RELATIVE TO OTHER STRUCTURES BASED ON THE RV ANALYSIS FOR EACH SCENARIO



Source: Dr. Hussam Mahmoud, Colorado State University.

As shown for the Planned scenario in Figure 12, the fire boundary indicated by the MPP is significantly reduced, with virtually no structures expected to be in the path of the modeled fire. This occurs because the nonburnable features create a buffer that prevents wildfire from entering the community on the ground. Figure 13 also shows a decrease in relative vulnerability values in the Planned scenario for most of the structures. However, there are still structures with relative vulnerabilities greater than 0. These values are present because the RV analysis is calculated under the assumption that a fire does occur and does enter the community. As shown by the MPP analysis, that is extremely unlikely for this scenario. However, there is a potential threat of embers, because there is still vegetation within the community. Thus, the takeaway from the RV analysis is that some structures may be more vulnerable relative to their surrounding structures due to the threat of embers, if a fire occurs and enters the community.

Based on the results of this analysis, RMV community planners are focused on ensuring that their future developments, including the remainder of PA3, reflect the considerations addressed in the Planned scenario. Plans include nonburnable features on the edges of the community, such as sports fields, dog parks, and a perimeter road. This scenario was chosen by RMV as the most cost-beneficial and aesthetically pleasing plan that will still protect the community from wildfire entering on the ground. Note that the results displayed in Figures 12 and 13 are based on a modeled view of PA3 absent any future developments and may not be representative of the true risk once other surrounding developments are graded and built.

3.5 WILDLAND-URBAN INTERFACE (WUI) FIRE PROTECTION SCORE

Unlike an urban fire, wildland fuels create very different fire scenarios in which personnel must focus on fuel management in addition to infrastructure and may have limited access to roads and water supplies. At the same time, wildland fires occur in a highly uncontrolled environment where weather is rapidly changing, hundreds to thousands of structures may be at risk at any given time, and the firefighting response to these events requires a high level of resource coordination within and across firefighting agencies at the local, county, state, and federal levels.

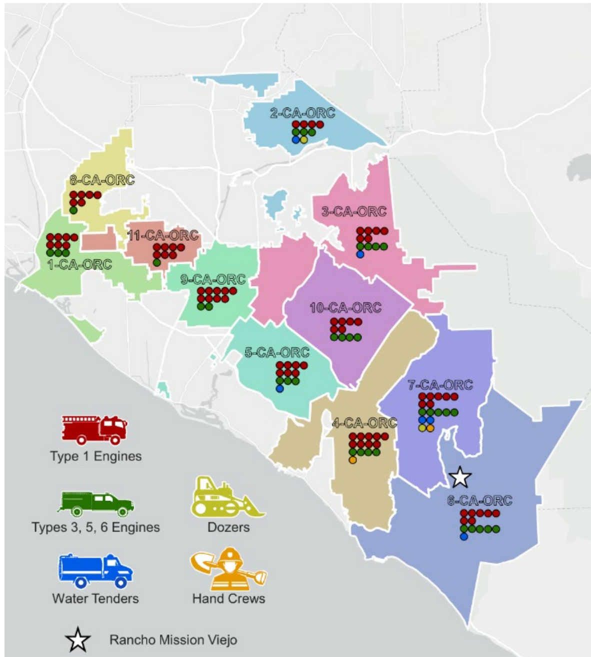
While fire battalions that protect WUI communities can vary widely in their level of fire protection capabilities, there is currently no process to systematically classify and track WUI fire suppression services in a meaningful way that is recognized by communities, insurance companies, and wildfire modelers. Insurance companies have long relied on standard scores and measures of local fire suppression capabilities, but these scores are specific to structure fire response.

The WUI Fire Protection Score is a joint effort between Milliman and the Western Fire Chiefs Association[9] to identify and describe fire protection coverage for communities in the wildland-urban interface. The WUI Fire Protection Score is an objective and digestible scale to provide comprehensive interagency measurements that classify the ability and capacity of a community's fire protection agency to respond to WUI wildfire events and prevent urban conflagrations. It is based on data collected directly from firefighting agencies and their battalions regarding equipment, personnel, training, risk reduction activities, interagency agreements, and geographic proximity. Based on this data, Milliman has created normalized scores for each battalion measuring the ability and capacity to respond to three different types of fire spread: vegetation-to-vegetation, vegetation-to-structure, and structure-to-structure. These scores are then augmented using geographic metrics and base scores for all other battalions that have existing interagency agreements, allowing us to report on the ability and capacity of all resources and personnel responding to wildland fire events in any given battalion's service area.

For the RMV pilot, data was collected to support the base component score for all battalions within the Orange County Fire Authority (OCFA). Along with the score calculation, a drive time analysis was done to show how many of OCFA's resources can reach RMV in a specified amount of time. Figure 14 shows a map of OCFA's equipment and resource availability. The table in Figure 15 shows the number of resources able to reach RMV at different time thresholds. For example, it shows that, in the event of a fire in RMV, OCFA would be able to deploy 62 Type 1 fire engines (used for structure fire response), 33 Type 3, 5, and 6 fire engines (used for vegetation fire response), two dozers, six water tenders, and two hand crews within 45 minutes.

[9] The Western Fire Chiefs Association is a non-profit organization that serves career and volunteer leaders of fire related emergency service organizations.

FIGURE 14: MAP OF OCFA'S EQUIPMENT



The map shows the available resources of each fire battalion that is within the Orange County Fire Authority. Source: Milliman. Service Layer Credits: City of Irvine, City of Newport Beach, County of Los Angeles, California State Parks, Esri, Tom Tom, Garmin, SafeGraph, FAO, METI/NASA, USGS, Bureau of Land Management, EPA, NPS, USFWS.

FIGURE 15: NUMBER OF RESOURCES TO REACH RMV BY TIME THRESHOLD

Resources within minutes					
Drive Time	Type 1 Fire Engine	Type 3, 5, 6 Fire Engines	Dozers	Water Tenders	Hand Crews
<=15 min	7	5	0	1	0
<=30 min	23	14	1	3	2
<=45 min	62	33	2	6	2
<=60 min	75	35	2	6	2

The table shows the drive time to RMV calculated for the various types of resources. This is the type of data that is collected and used within the calculation of the WUI Fire Protection Score. Source: Milliman.

The different equipment named here all serve different purposes but should be considered in risk analysis. For example, bulldozers, water tenders, and hand crews may be optimal choices for fighting a fire moving through a vegetative landscape. However, if the fire transitions to a structural environment, their utility becomes limited. Furthermore, understanding the equipment availability using a time-weighted approach is extremely important because fire is dynamic, and firefighting resources need to arrive within the optimal timeframe to be able to fight it. The WUI Fire Protection Score and the component datasets can provide communities like PA3, as well as insurers and modelers, with a much more detailed, nuanced, and comprehensive approach to quantifying the impact of fire suppression resources.

3.6 DATA EXTRAPOLATION AND AGGREGATION

3.6.1. GIS Layers

Geographic information systems (GIS) layers can be used to map and visualize data, such as areas of wildland vegetation, fuel types, topography, or structure locations. GIS can also be used to calculate geographic metrics that can be used to assess the relative risk of wildfire in communities like RMV. Some metrics, like distance to wildland areas, might be used to assess the risk of a vegetation fire entering a community. Other metrics, like structure separation distance, might be used to assess the risk of fire-spread between adjacent structures within a community.

With the introduction of time-based fire pathways, described in Section 3.1 above, metrics such as distance to fire pathways, distance to ember threat zones, or the number of fire pathway entry points within a critical distance to structures in a community can also be calculated. These geographic metrics can then be used by insurers to measure the relative wildfire risk of a structure in a meaningful and measurable way. Because these layers are dependent on development plans, mitigation, and fuel treatment methods, the metrics need to be dynamic so that changes on the ground can be captured, measured, and acted upon.

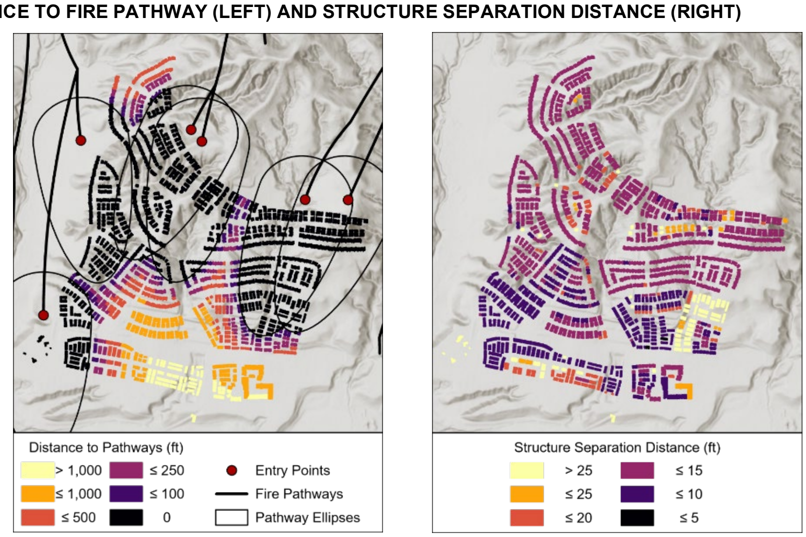
Risk metrics like these can also be used to measure and assess entire communities. As shown in Section 3.4 above, the relative risk of a structure is based on the surrounding nodes in a community, so insurers will not only want to know these metrics for their current or potential policyholders, but they will also want a broader picture that allows them to understand the relative risk of entire communities when deciding where they want to write new business. With dynamic GIS layers, it is possible to assess the potential impact of development plans, mitigations, and fuel treatments on the overall insurability of a community like RMV.

The GIS layers and metrics produced and utilized in our analysis, either as input data for structure-to-structure modeling or as standalone variables, are as follows:

- ***Wildland:*** Area representing the wildland directly surrounding the community of interest.
- ***Fire pathway entry point:*** The point of intersection between the community and the fire pathways provided by Xlyoplan.
- ***Building footprints:*** Footprints representing each structure and roads considered within the community.
- ***Building attributes:*** Various building attributes that contribute to fire mitigation are assigned to building footprints, with varying distributions representing the four different mitigation scenarios.
- ***Distance to fire pathway ellipse:*** Calculated distance from the selected structure to the fire pathway entry point ellipse, illustrated by Xyloplan. The fire pathway entry point ellipse extends 750 meters from the fire pathway entry point and are 250 meters at their widest point.
- ***Structure separation distance (SSD):*** Calculated distance from the selected structure to the next nearest structure.

Figure 16 displays examples of the values of these variables for RMV.

FIGURE 16: DISTANCE TO FIRE PATHWAY (LEFT) AND STRUCTURE SEPARATION DISTANCE (RIGHT)



Source: Milliman. Service Layer Credits: Esri, NASA, NGA, USGS, FEMA.

3.6.2. Insurance metrics

To demonstrate the utility of the new variables, data points, and tools described in previous sections, Milliman synthesized the data calculated in the RMV analysis. Visualizing the data in summaries, graphs, and charts as displayed in the figures below demonstrates different ways stakeholders can use the data collected here.

The new variables introduced in the structure-to-structure analysis section are most probable path (MPP) and relative vulnerability (RV). The table in Figure 17 shows the average value across all structures for each variable by mitigation scenario. From Figure 17, one can conclude that, as mitigation improves, both RV and MPP generally decrease. This is logical; as structures are more mitigated, vulnerability decreases, and the mitigated homes are less likely to be in the path of fire.

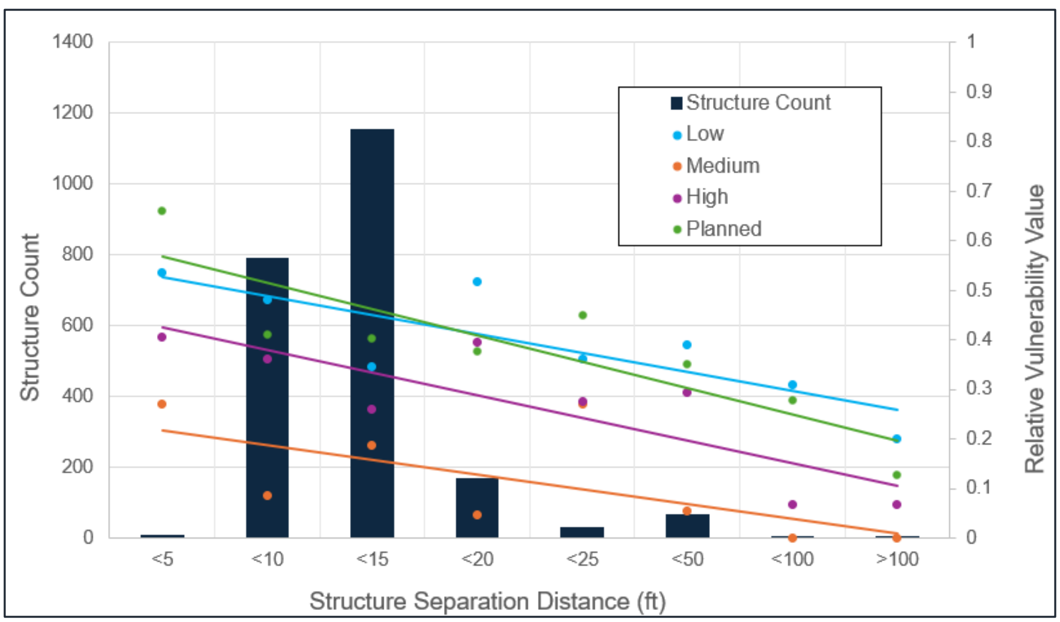
FIGURE 17: RELATIVE VULNERABILITY (RV) AND MOST PROBABLE PATH (MPP) BY SCENARIO

Scenario	Relative Vulnerability (RV)	Most Probable Path (MPP)
Low	0.40	0.85
Medium	0.41	0.63
High	0.31	0.56
Planned	0.14	0.15

Source: Milliman.

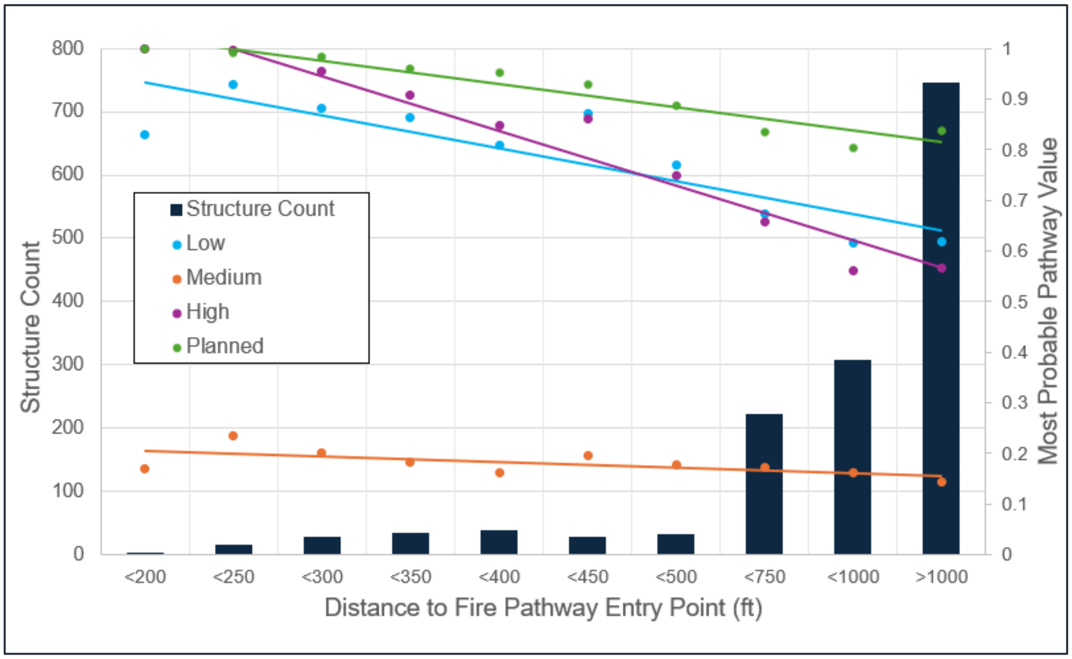
Bivariate analysis encompassing these structure-to-structure modeling variables, as well as the GIS variables introduced in Section 3.6.1 above, can enable one to understand the relationships between them and explain the data. For example, Figure 18 displays a graph of RV by SSD. There is a slightly stronger relationship (depicted with a steeper slope) between RV and SSD in the Low scenario when compared to the other scenarios. This relationship could indicate that RV is more dependent on SSD when structures are less mitigated. Figure 19 displays a graph of MPP and distance to the fire pathway entry point. The strongest relationship between MPP and distance to the fire pathway entry point is in the High scenario when compared to other scenarios. A strong relationship between MPP and distance to the fire pathway entry point in the High scenario may indicate that more mitigation allows us to better predict the path of fire. Thus, with mitigation, fire will travel in a more predictable manner, allowing the firefighting response to be more successful.

FIGURE 18: STRUCTURE COUNT AND RELATIVE VULNERABILITY (RV) VALUE BY STRUCTURE SEPARATION DISTANCE BIN



Source: Milliman.

FIGURE 19: STRUCTURE COUNT AND MOST PROBABLE PATH (MPP) VALUE BY DISTANCE TO FIRE PATHWAY ENTRY POINT BIN



Source: Milliman.

Another way these variables can be useful for understanding risk is to calculate their statistics by categorical groupings. For example, the tables in Figures 20 and 21 display statistics from the Low scenario, calculated across five mitigation categories. Summarizing the data in this fashion allows one to understand the quantity and relative locations of structures grouped by the mitigation criteria they meet. Figure 20 shows that in the hypothetical Low scenario at least half of the community is barely mitigated and only 2% actually meet all Chapter 7A building code requirements. Figure 20 also shows the structure count within a fire pathway ellipse and the average distance to the fire pathway entry point. These relative location variables are important to analyze alongside the mitigation category because the extent to which structural mitigation defines a risk is dependent on the structure's surroundings. For example, a stakeholder may not give as much weight to the mitigation benefits of meeting Chapter 7A building codes to homes far away from fire pathways compared to those that are closer.

FIGURE 20: STATISTICS BY MITIGATION CATEGORY FOR LOW SCENARIO

Mitigation Category	Structure Count	Percent of Total Structures	Structure Count within a Fire Pathway Ellipse	Percent of Structures within a Fire Pathway Ellipse	Average Distance to Fire Pathway Entry Point (feet)
No Mitigations	19	1%	15	1%	1,298
Other Partial Mitigation	1,007	47%	527	46%	1,539
Siding, Fence Mitigated	711	33%	404	35%	1,540
Vents, Propane, Fence Mitigated	371	17%	182	16%	1,567
Meets Chapter 7A Building Code	39	2%	21	2%	1,576
Total	2,147	100%	1,149	100%	n/a

Source: Milliman.

Figure 21 offers a different view of fire pathways by summarizing how many different pathways may impact a structure. In this case, 46% of structures are not within a fire pathway ellipse and 19% are within two fire pathway ellipses. Being in two fire pathway ellipses means there are two possible directions fire may come from and reach that structure.

FIGURE 21: NUMBER OF ELLIPSES OVERLAPPING STRUCTURE BY MITIGATION CATEGORY FOR LOW SCENARIO

	Number of Ellipses Overlapping Structure		
Mitigation Category	**0**	**1**	**2**
No Mitigations	4	8	7
Other Partial Mitigation	480	336	191
Siding, Fence Mitigated	307	271	133
Vents, Propane, Fence Mitigated	189	121	61
Meets Chapter 7A Building Code	18	15	6
Total	**998**	**751**	**398**
Total % of Community	**46%**	**35%**	**19%**

Source: Milliman.

These tables are just a few examples of how the data collected in this framework can be used to generate a more detailed view of wildfire risk. This framework leverages community-level and structure-level mitigation criteria, relative structure locations, the likelihood of where fire may occur, and what direction it may travel to enable builders, homeowners, modelers, and risk takers to have a more complete picture of the risk, which enables objective and quantitative decision-making.

3.7 ADJACENT STUDY: THE WUI DATA COMMONS

It is important to note that the ability to analyze and aggregate many of the statistics mentioned above is contingent on access to accurate, detailed, current information about parcel-level and community-level mitigation features. Aerial imagery can be used to capture some features, such as roof composition. However, it may not reliably capture features not visible from an aerial view, such as enclosed eaves, or attributes that change frequently, like understory vegetation growth. An onsite inspection by a trained professional can capture these elements, but it is costly and time-consuming.

For insurance industry users (i.e., an insurer providing coverage throughout a state or a modeler covering the entire U.S. West), this data is needed at a large scale, so these aforementioned methods of collecting data are not feasible. Even within a community, the ability for fire management agencies to monitor mitigation progress and prioritize future actions is hindered by data limitations; the cost and expertise needed to build up and maintain reliable data can be out of reach. To the extent that communities do have data on their mitigation actions, it may not be captured at the level of detail and/or be sufficiently reliable.

To overcome these challenges, Milliman is working with numerous public and private stakeholders to facilitate the establishment of a proposed WUI Data Commons. Under this proposal, wildfire data from multiple sources would be collected and shared by a variety of stakeholders such as insurers, risk modelers, communities, homeowners, fire management personnel, and government entities. This effort would require data and processes to be sufficiently standardized to ensure that the data collected is sufficiently accurate, unbiased, credible, and recent for the various use cases envisioned. A shared data commons will help various stakeholders engaged in risk measurement and/or risk reduction—both public and private—to incorporate and utilize these data within an adaptive framework. This way, a continuous cycle of improvement and reevaluation can be used to track progress, drive prioritization and implementation, and refine the value of mitigations.

For example, one potentially valuable use case could be the designation of individual neighborhoods by the Institute for Business and Home Safety (IBHS)[10] as Wildfire Prepared Neighborhoods, a means to encourage collective action to understand and undertake the necessary mitigation actions to reduce vulnerability to wildfire. The Wildfire Prepared Neighborhood effort and the need for a data commons are discussed in a strategic plan published by IBHS:[11]

"Understanding and then mitigating the complex set of variables related to community resilience to wildfire is difficult because of the multiplicity of variables that contribute to – or reduce – it…Data related to these variables are neither consolidated nor consistent…IBHS is developing a neighborhood-scale designation for at-risk communities. This endeavor requires additional research centered around the influence of connective fuels between structures and how much fuel management is needed, as well as a neighborhood-scale risk analysis tool, rooted in an open-source data framework, that can meet the scalability needs for such a designation program. Alongside this research, a vast scale of data must be consolidated into an open-source platform that is publicly available and usable."

In 2023 IBHS engaged Milliman to gather input from catastrophe modelers, insurers, reinsurers, and regulators regarding a WUI Data Commons, and to create a sample data specification for parcel-level data collection. The final report and a webinar presenting the results are published to the Milliman website and available through these respective links: WUI Data Commons Phase 1: Stakeholder Interview Summary, at https://www.milliman.com/en/insight/wui-data-commons-phase-1-stakeholder-interview, and The WUI Data Commons: Driving Wildfire Resilience Through Data Transparency, at https://www.milliman.com/en/video/wui-data-commons-wildfire-resilience-data-transparency.

In 2024, in conjunction with the California Fire Chiefs Foundation (CalChiefs),[12] Milliman was awarded a grant from the Gordon and Betty Moore Foundation[13] to integrate the perspectives of other key stakeholders inside and outside the insurance industry to address crucial fundamental questions and lay the groundwork for a successful buildout of the WUI Data Commons. This phase of the work is expected to be completed in late 2024.

[10] IBHS was formed by the property and casualty (P&C) insurance industry in 1977 to help coordinate emerging property insurance plans. Today, it designs safety designations that are recognized by the insurance industry. More information at https://ibhs.org/.
[11] IBHS (November 2023). Strategy 2026: Turning Science Into Solutions. Retrieved October 31, 2024, from https://ibhs1.wpenginepowered.com/wp-content/uploads/Strategy26_web.pdf.
[12] CalChiefs is a large and diverse professional association whose vision is to be the voice of the California Fire Service. Its members range from fire chiefs, executive staff officers, administrative support staff, emergency medical services (EMS) personnel to associated colleagues from fire service support organizations and vendors.
[13] The Gordon and Betty Moore Foundation has a mission of scientific discovery and environmental conservation. Its objective is to tackle large, important issues at a scale where it believes it can make significant and measurable impacts. Its ability to take risks and make long-term and relatively large commitments allows it to undertake challenges not accessible to many other organizations.

4 Interview process

To introduce the framework described in Section 3 above, Milliman presented a private webinar to critical stakeholders, then set up one-on-one interviews with a subset of the viewers to obtain their feedback. The interview process was conducted as follows:

- Milliman identified a list of contacts at primary insurers, reinsurers, catastrophe modelers, regulatory groups, and advisory groups who are significantly involved in the wildfire-exposed homeowners insurance markets in the United States, especially in California.
- Milliman created a presentation, included with this report as Appendix A, to illustrate the community mitigation and modeling framework pilot with RMV.
- Milliman invited the list of contacts to attend a webinar presentation, where attendees would be educated on the community mitigation and modeling framework and invited to ask questions to the project team.
- After the webinar, Milliman reached out to insurance industry viewers to request one-on-one interviews to obtain feedback on the presentation. Milliman created a question list (included with this report as Appendix B) and set up one-on-one interviews to go over the questions. The questions were tailored to gather information regarding current understanding of wildfire risk, interpretations of the framework, and interest in engaging in the future.
- Milliman conducted individual 30-minute interviews with representatives from 11 different entities: six primary insurers, four reinsurers, and one advisory organization. Collectively, the six primary insurers that were interviewed represented 38% of the homeowners market share in California and 33% countrywide.[14]

4.1 INTERVIEW SUMMARY: THE FRAMEWORK FROM THE INSURERS' LENS

The questions asked during the interviews focused on insurers' current understanding of wildfire risk, interpretations of the framework, and willingness to engage in the future. These questions were used as a springboard to drive further discussion. The feedback given by the insurers shared common themes:

- The majority of the insurers began their interviews with a comment on the novelty of the framework and expressed their excitement to be a part of this effort.
- All the insurers agreed that their current tools have flaws or are not as in-depth as those shown in the framework presented.
- Some insurers commented that they are comfortable with their current tools for understanding the characteristics of a risk at *parcel level* as it pertains to wildfire risk: they understand the vegetation in zone 0, the slope, and the individual mitigation measures of the structure. However, many commented that they are not currently viewing risk at all from a *community level*. They understand the importance of it, but don't have the data or tools to analyze it.
- At least one insurer commented that, if there are nonburnable features on a community's edge that could prevent the entry of ground fire, it cannot evaluate how well they are done, so it is not pricing with that in mind.
- Along with the community level view, several insurers are not analyzing firefighting response time on a large enough scale. Some insurers commented that they currently use variables such as distance to hydrant and distance to fire station in rating. It is understood that these local fire responses will be helpful in some situations but, in wind-driven wildfires, more than local resources are needed.

After discussing their satisfaction with current tools, we began to discuss how the framework may fill in the gaps. We asked the insurers and reinsurers how likely they would be to use each of the components of the framework, if it were available to them. The results are shown in the table in Figure 22.

[14] Based on 2023 data from S&P Global Market Intelligence, Insurance Statutory Market Share.

FIGURE 22: INSURER AND REINSURER UTILITY

COMPONENT	PRIMARY INSURER LIKELIHOOD OF USE	REINSURER LIKELIHOOD OF USE
Fire pathway modeling	▪ 4 respondents very likely ▪ 1 respondent not likely	▪ 3 respondents very likely ▪ 1 respondent somewhat likely
Parcel-level inspections	▪ 4 respondents very likely ▪ 1 respondent somewhat likely	▪ 3 respondents very likely ▪ 1 respondent somewhat likely
Vegetation treatment and dynamic community wildfire protection plan	▪ 2 respondents very likely ▪ 3 respondents somewhat likely	▪ 1 respondent very likely ▪ 3 respondents somewhat likely
Structure-to-structure modeling	▪ 2 respondents very likely ▪ 3 respondents somewhat likely	▪ 3 respondents very likely ▪ 1 respondent somewhat likely
WUI fire protection score	▪ 3 respondents very likely ▪ 2 respondents somewhat likely	▪ 3 respondents very likely ▪ 1 respondent somewhat likely
GIS layers and data variables	▪ 4 respondents very likely ▪ 1 respondent somewhat likely	▪ 3 respondents very likely ▪ 1 respondent somewhat likely

Figure 22 provides the perceived utility (usefulness) of the proposed framework, summarized by type of entity interviewed and provided thorough response. Source: Milliman.

Across the interviews, insurers seemed impressed and eager to use fire pathway modeling. They highlighted that this type of modeling allows them to further understand the fires that matter the most to them: the fast-moving, wind-driven wildfires that can potentially burn down an entire town. Being able to predict where a fire may enter a community allows insurers to know where to focus their inspection of mitigation measures and nonburnable community features. An insurer did express that fire pathway modeling may be competitive with catastrophe (CAT) modeling though, so there may be reluctancy to move away from the tool it already knows and uses. However, it did note its understanding that wildfire CAT models are not mature, implying they are not perfect tools. One insurer did mention that it believes that RMV is safer than what its models would suggest.

The other favorite components were parcel-level inspections, WUI Fire Protection Score, and GIS layers. There is a likely common reason why these components were favorites among insurers: they all provide thorough data that is easy to incorporate into their risk analyses.

We then discussed data concerns regarding scale and maintenance of data. As for scale, insurers commented that the focus should be on WUI communities. A few insurers expressed hope that there would be another similar pilot, but for an entire county. The concern with maintaining the data was especially directed at fire pathways, which are dependent on vegetation growth in the WUI that is ever-changing. Overall, there was general support from insurers for the concept, if it results in data being available at the community level, as long as it is accurate, unbiased, and up to date.

Lastly, we theorized about industry adoption of the framework. To the extent that regulators require filing of tools used in pricing, segmentation, or underwriting, all the insurers expressed concern as to whether these tools would be approved by regulators in a timely fashion. Moreover, insurers were concerned about the implementation of the framework. To avoid overconcentration in any one area, it is difficult for any one insurer to partner with a community and commit to offering significant coverage, even if all the right actions are taken. To achieve widespread gains in availability, a critical mass of insurers as well as reinsurers need to be involved. Several insurers said they are willing to be an industry leader and beta-test the tools, but worried that, if the industry does not follow, then they may end up with high concentration risk or unaligned reinsurance costs. In contrast, others expressed “they do not want to be left behind.”

Overall, the insurers were very intrigued by the pilot and began to ask; “where do we go from here?” From these comments, it appears that the insurers may be willing and wanting to make changes, but need the support of other stakeholders, too. Everyone needs to be on board—insurers, reinsurers, regulators, communities, and consumers. If all parties have a better understanding of wildfire risk, whether it be through the tools proposed here, continual discovery in fire science, or common data, then the actions of communities and insurers can be better aligned. If the communities better mitigate against fire, there will be reduced destruction of life and property, translating to reduced losses. If the industry can more accurately price the risk, then consumers will better understand their risk and be incentivized to reduce it. However, reaching that point is not a simple task and will take time. The property insurance market in California and other wildfire-exposed areas is facing a crisis, and all parties need to put in effort for it to recover.

4.2 INTERVIEW SUMMARY: COMMENTS FROM REINSURERS

Reinsurers were asked the same questions. The way they saw their businesses fitting into the picture varied. Some felt the tools were directly useful for risk analysis, others emphasized the need for a portfolio risk view, and others commented that these tools are better suited for the primary insurers' use cases, but reinsurers would be happy to see their ceding insurers use them.

The reinsurers had a variety of current ways to analyze wildfire risk: vendor CAT models, internal maps, hazard scores, studies of land use, and vulnerability reports. Each reinsurer mentioned at least one need for improvement in their current tools, either due to a gap in knowledge or unsatisfactory results.

The reinsurers in general seemed more skeptical of how this framework would be implemented and scaled. Several stressed the importance of the primary insurers using it first. One mentioned that providing reinsurance for high wildfire risks is not only about its appetite, but also that there is an expectation that insurers invest in analytics, more sophisticated underwriting, and build more trust with reinsurers. One commented that it sees so many different types of models and wildfire risk analysis from its primary insurers that are supposedly new and improved; so it would not be interested in this until proven well. As far as using the framework themselves, it was suggested that it would need to be at least at the homeowner association (HOA) level or state level. One reinsurer questioned, if it were to use the data, is it enough to change what it does?

Overall, the reinsurers seemed intrigued and willing to continue to be a part of the conversation, but not as eager as the insurers. These discussions reinforced that all entities need to be on the same page. The reinsurers are relying on the insurers to bring concepts of this proposed framework to industry adoption.

5 Conclusion and next steps

This pilot study and the interviews conducted show a new potential for tools, resources, and opportunities for collaboration to begin rectifying the current crisis in the insurance industry. The pilot study directly introduces new models, new ways to collect parcel data, a fire response scoring system, and visualizations of GIS data. By encompassing these tools into a framework, it demonstrates how various wildfire risk analysis tools can work together to enhance literacy surrounding wildfire risk.

For RMV, this study provides understanding of its current risk through the on-the-ground parcel inspections, recommendations for vegetation treatment, and introduction of the concept of targeted mitigation (the Planned scenario). RMV has already invested in wildfire resilience, and it now has more tools to not only assess its wildfire risk as it expands its community, but it also illustrates to insurers how their planning decisions will impact their risk going forward. RMV is proposing to continue building PA3 as described in the Planned scenario, with nonburnable amenities on the communities' edge, a perimeter road, and all structures meeting Chapter 7A requirements.

We learned through the interviews and conversations with partners that our goals and efforts of this pilot align with those of several other entities, including insurers, reinsurers, modelers, communities, fire specialists, and regulatory bodies. To move forward in achieving our common goals, we must continue to focus on collaboration; sharing our ideas, discovering how all the tools and efforts being made can contribute to each other, and creating literacy around the risk. Some notable other working efforts in this space are the WUI Data Commons (mentioned in Section 3.7 above), the IBHS Wildfire Prepared Neighborhood designation, and the California Department of Insurance's Sustainable Insurance Strategy. We hope to use this pilot study as a springboard for future, larger-scale pilot studies with the goal of increased collaboration and alignment with all stakeholders.

6 Limitations

6.1 USE OF REPORT

The data and exhibits in this report are provided to support the findings contained herein, limited to the scope of work specified by RMV, and may not be suitable for other purposes. Milliman is available to answer any questions regarding this report or any other aspect of our review.

6.2 DATA RELIANCE

In preparing this report, we relied upon the data provided by Rancho Mission Viejo, data provided by the CAL FIRE Damage Inspection (DINS) database, the inspection data collected by XyloPlan, the information provided by the interviewees, and other sources. We did not audit, verify, or review the data and other information for sampling bias, reasonableness, and consistency. Such a review is beyond the scope of our assignment. If the underlying data or information is inaccurate or incomplete, the results of our analysis may likewise be inaccurate or incomplete. In that event, the results of our analysis may not be suitable for the intended purpose.

6.3 MODEL RELIANCES

This analysis is based on the modeling performed by XyloPlan and the modeling performed by Colorado State University. To the extent that the models used are biased, the resulting analysis may be biased.

6.4 UNCERTAINTY

Differences between our projections and actual amounts depend on the extent to which future experience conforms to the assumptions made for the analyses. It is certain that actual experience will not conform exactly to the assumptions used in these analyses. Actual amounts will differ from projected amounts to the extent that actual experience is better or worse than expected.

6.5 VARIABILITY OF RESULTS

While our analysis is based on sound actuarial principles, it is important to note that variation from the projected result is not only possible, but, in fact, probable. While the degree of such variation cannot be quantified, it could be in either direction from the projections. Such uncertainty is inherent in any set of actuarial projections.

6.6 DISTRIBUTION

Milliman's work is prepared solely for the benefit of Rancho Mission Viejo (RMV). Milliman does not intend to benefit any third-party recipient of its work product and Milliman may include a legend on its reports so stating. Except as set forth below, Milliman's work may not be provided to third parties without Milliman's prior written consent. Milliman does not intend to legally benefit any third-party recipient of its work product, even if Milliman consents to the release of its work product to a third party. Rancho Mission Viejo may distribute or submit for publication the final, non-draft version of this report (the Report) that, by mutual written agreement herein, is intended for general public distribution. Rancho Mission Viejo shall not edit, modify, summarize, abstract, or otherwise change the content of the final Report and any distribution must include the entire Report. Notwithstanding the foregoing, no Milliman report shall be used by Rancho Mission Viejo in connection with any offering, prospectus, securities filing, or solicitation of investment. Press releases mentioning the Report may be issued by Milliman or Rancho Mission Viejo upon mutual agreement of Rancho Mission Viejo and Milliman as to their content. Mentions of Milliman work will provide citations that will allow the reader to obtain the full report.

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Any reader of this report agrees that they shall not use Milliman's name, trademarks, or service marks, or refer to Milliman directly or indirectly in any third-party communication without Milliman's prior written consent for each such use or release, which consent shall be given in Milliman's sole discretion.

Attachments:

- Appendix A: Webinar Presentation Recording
- Appendix B: Interview Questions
- Appendix C: Validation of AGNI-NAR Fire Spread Model, and structure-to-structure modeling references
- Appendix D: Planning Area 3 (PA3) Within Rancho Mission Viejo
- Appendix E: Project Team

Appendix A: Webinar Presentation Recording

Link to presentation: https://www.milliman.com/en/insight/community-mitigation-rancho-mission-viejo.

Appendix B: Interview Questions

1. *Do you have any overall comments or questions on the webinar you watched?*

2. *How satisfied are you with your current data, tools, and resources for evaluating wildfire risk?*

3. *If available to you, how likely would you be to use: (very likely, somewhat likely, not likely, n/a, don't know)*

    a. Fire Pathway Modeling

    b. Parcel Level Inspections

    c. Vegetation Treatment & Dynamic CWPPs

    d. Structure-to-Structure Modeling

    e. WUI Fire Protection Scoring/Drive Time Analysis

    f. GIS Layers and Data Variables

4. *What scale of coverage (number of structures, number of communities, geography, etc) is sufficient for you to be able to use this?*

5. *What would you change, if anything? What barriers do you envision towards industry adoption?*

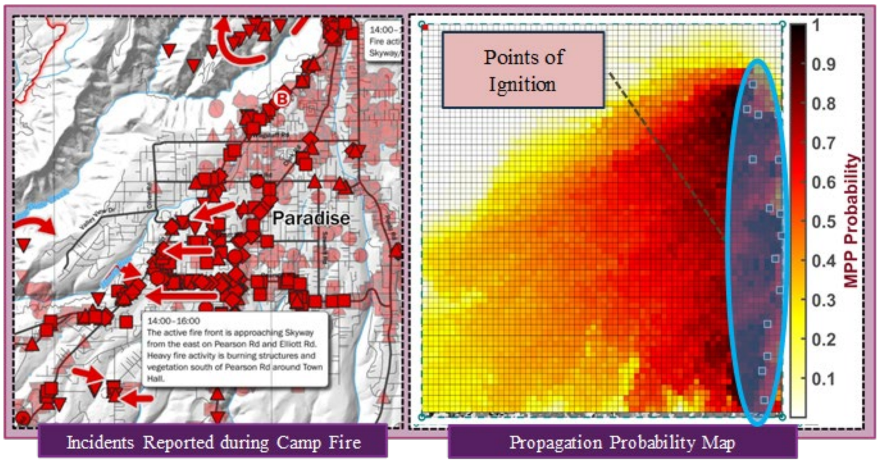
6. *If you had access to this information, what impact do you think it would have on your ability to underwrite and price wildfire risk? What is still missing?*

7. *Would you be interested in having a follow up discussion about any aspect of the framework?*

Appendix C: AGNI-NAR Fire Spread Model Validation and References

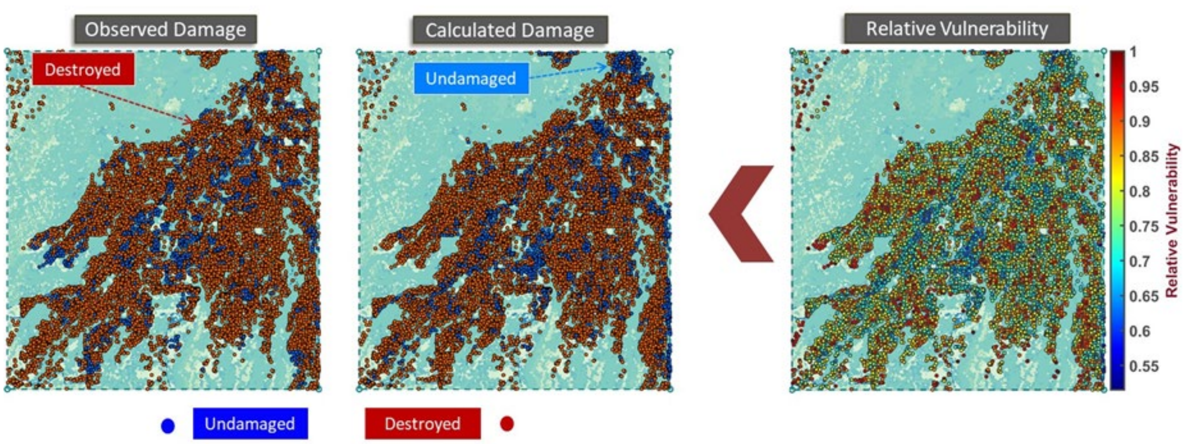
Both the fire boundary (MPP analysis) and the expected damage (RV analysis) have been validated for various communities including the Camp Fire, the Glass Fire,[15] and the Marhsall Fire.[16] Figure 23 shows a comparison between the actual and predicted fire boundary for the 2018 Camp Fire. Figure 24 shows a comparison between the actual and predicted damage states for the 2018 Camp Fire.

FIGURE 23: Comparison of the Fire Boundary Calculated Using the MPP Analysis (right) and Indicated in the Incident Reports Published by the National Institute of Standards and Technology (NIST)



Source: Maranghides 2021.

FIGURE 24: ACTUAL AND PREDICTED DAMAGE STATE FOR THE 2018 CAMP FIRE



Note: The left image shows observed damage states: blue represents undamaged or minimally damaged and red represents significantly damaged structures. The right image shows the vulnerability of buildings relative to each other. The middle image shows the calculated damage states by converting the vulnerability plot into discrete damage states using a cutoff vulnerability value to mark damage versus undamaged states: blue represents undamaged or minimally damaged and red represents significantly damaged structures.[17]

[15] Chulahwat et al., 2022.
[16] Chulahwat and Mahmoud, 2024.
[17] Chulahwat et al., 2022; Mahmoud, July 16, 2024.

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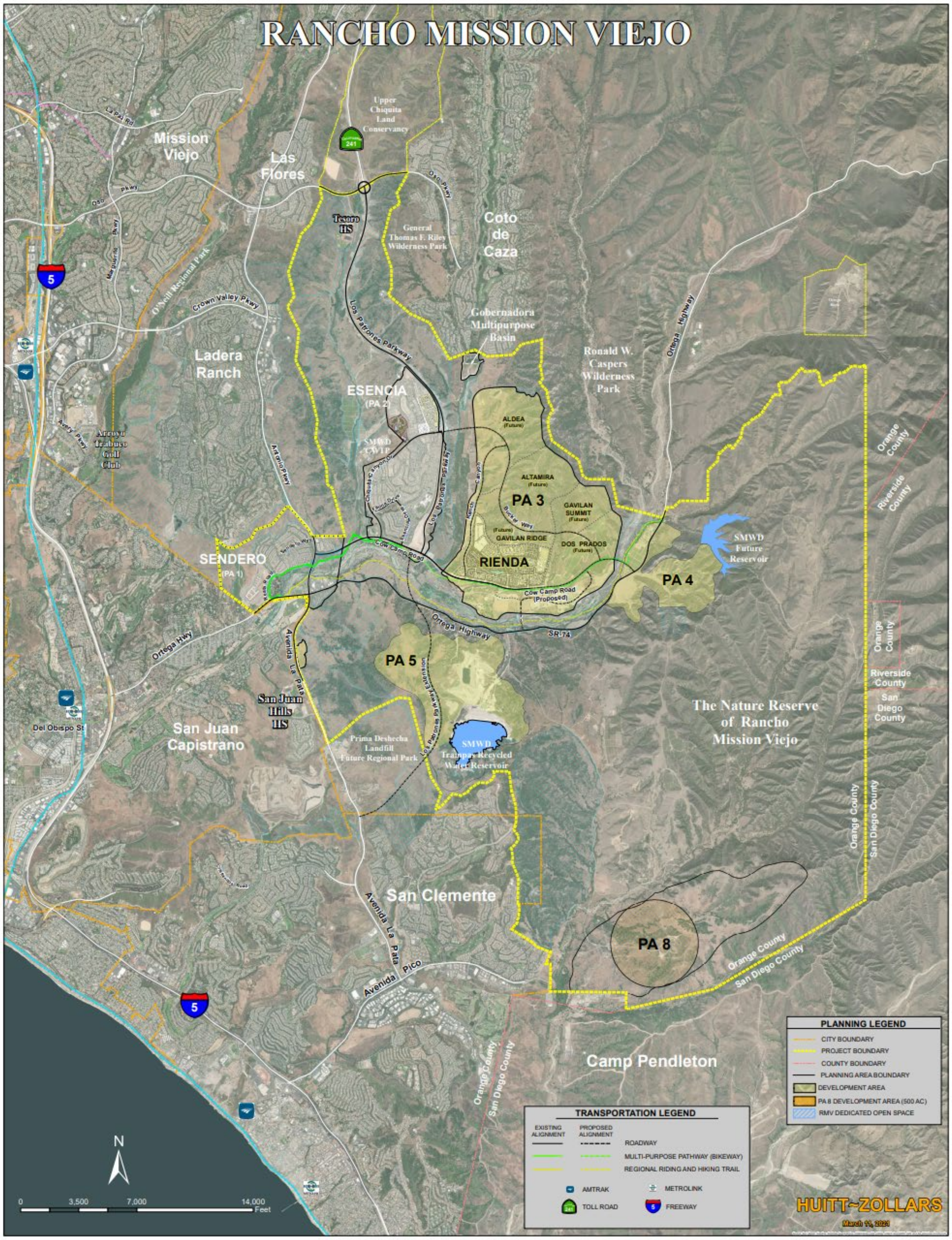
Appendix D: Planning Area 3 (PA3) Within Rancho Mission Viejo



Appendix E: Project Team

Milliman is among the world's largest providers of actuarial, risk management, and related technology and data solutions. Milliman's San Francisco Property & Casualty practice has expertise in all aspects of the insurance industry, including California homeowners ratemaking, wildfire and catastrophic risk modeling, design of premium discount structures for hazard mitigation, and thought leadership regarding climate change.

XyloPlan creates a data-driven, shared view of wildfire risk, with actionable solutions that enable fire-adapted communities.

Pyrezo has created an application consisting of AI-powered wildfire risk assessment to analyze images of property and recommend the most accessible and impactful wildfire mitigations.

Dr. Hussam Mahmoud of Colorado State University has created an innovative model of structure-to-structure fire spread using graph theory.

The Cal Poly Wildland-Urban Interface (WUI) Fire Institute is a mission-driven organization that seeks solutions to the Wildland-Urban Interface fire problem through innovative research, training, and education to create safer and more fire-resilient communities in California and the West.

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milliman.com

CONTACT

Nancy Watkins
nancy.watkins@milliman.com

Garrett Bradford
garrett.bradford@milliman.com

Taylor Munch
taylor.munch@milliman.com