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July 9, 2021

To Whom It May Concern:

In late 2019, the Safety and Enforcement Division of the California Public Utilities Commission's engaged a consultant, Technosylva Inc., to analyze the capabilities of certain new advanced wildfire risk analysis modeling. Pursuant to the engagement Technosylva has prepared a report regarding the new wildfire modeling software capabilities. This report is attached.

The Safety and Enforcement Division did not independently validate the findings of this report by Technosylva. The issuance of this report by the Safety and Enforcement Division should not be interpreted as an endorsement by the Commission of any aspect of this report.

If you have any questions regarding the report, please contact Anthony Noll at (916) 928-3315 or at Anthony.Noll@cpuc.ca.gov.

California Public Utilities Commission

2019 PSPS Event –Wildfire Analysis Report

Event Date: **October 26 - 29, 2019**

IOU: **Pacific Gas & Electric**

Prepared by:

Technosylva Inc. (La Jolla, CA)

technosylva

California Public Utilities Commission

2019 PSPS Event Wildfire Risk Analysis Report

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Public Safety Power Shutoffs (PSPS) Event Wildfire Risk Analysis Summary Report

October 26-29th, 2019

Pacific Gas & Electric

PREFACE

In the wake of the unprecedented 2017 and 2018 wildfire seasons in California, and amid the increasing frequency of extreme weather events resulting from climate change, the practice of electric utilities preemptively de-energizing powerlines in response to weather and environmental conditions commensurate with rapid fire spread and related destruction has grown in use and prevalence. This practice is commonly referred to as "public safety power shutoffs" or "PSPS" by California's investor-owned electric utilities.

From a policy perspective, while subject to consideration by the California Public Utilities Commission (CPUC) since 2008, PSPS policy is still nascent. PSPS as a wildfire risk mitigation measure wasn't first utilized until October 2013, and even then, it was only implemented by San Diego Gas & Electric, occurred seldomly, and had relatively limited customer impacts. Since that time, as the utilization of PSPS as a wildfire risk mitigation measure has grown in practice and prevalence, thus occurring more frequently and impacting more Californians, the need for evolution and refinement in the CPUC's assessment of this policy and practice has become evident. To this end, the CPUC has engaged Technosylva to conduct this project and present an example of the type of refined analysis that can be conducted and reported, on a per-event basis, to provide a more sophisticated assessment of PSPS events.[1]

While this study propels the CPUC's analytical assessment of electric utility PSPS events, it should be noted that additional analyses are required to obtain a complete picture of the true impacts of such events. The fire spread simulations, based on the location and type of damages sustained to de-energized portions of powerlines during a PSPS event, provide a glimpse into "what may have been" by simulating the potential fire spread from a utility-caused ignition and quantifying the associated impacts on people, buildings, and the landscape. However, this analysis does not assess "what actually was," in terms of the realized impacts on Californians as a result of the PSPS event. Although the instant analysis quantifies the potential wildfire related impacts avoided as a result of proactively de-energizing powerlines, it is evident from the historic execution of these events that power outages can also profoundly disrupt Californian's daily lives, create or exacerbate emergency situations, and strain economic progress. Accordingly, further analysis of these realized impacts must also be conducted and compared to provide a robust and complete assessment of the effectiveness of PSPS implementation as a wildfire risk mitigation measure. The assessment of realized impacts is not within the scope of this report.

[1] The three large investor-owned electric utilities in California (i.e. PG&E, SCE, and SDG&E) all have access to the same Technosylva software used to conduct this analysis.

Moreover, it should be noted that not only does this analysis rely upon the simulation of potential utility-caused ignitions related to utility-reported damage sustained during a PSPS event, but also relies upon utility determination of whether the nature and conditions of the damage would have likely resulted in arcing or emission of sparks. Only damage incidents identified by utilities as resulting in arcing or emission of sparks were simulated as potential utility-caused fire ignitions. However, further study and analysis of the relationship between various damage conditions and the probability of a resultant utility-caused ignition is required, as this probability is also dependent on the fuel type, density, and conditions at the damage location. Having a deeper understanding of the probability that damage sustained during a PSPS event could result in an ignition would enhance the precision and accuracy of these wildfire simulations.

Lastly, considering the nascent, developing, and evolving nature of PSPS as a utility wildfire risk mitigation strategy, it should be noted that refined clarity, standardization, and data are needed to ensure consistency and comparability from event to event. For example, a single “PSPS event” may span several days or even weeks and would likely include the de-energization of various circuits, and some circuits potentially numerous times. As such, cross-utility comparisons at the event-level are of little use, especially if there are consecutive extreme fire weather events resulting in successive PSPS events being initiated.

1. INTRODUCTION

In response to weather driven wind events in October 2019, several Public Safety Power Shutoff (PSPS) events were initiated by the Investor Owned Utilities (IOUs). A wildfire risk analysis has been conducted for each 2019 PSPS event, allowing the CPUC to better understand the severity of the weather conditions and the potential risks averted from wildfires that could have ignited from possible electric utility infrastructure ignition sources based on damages sustained following the power shutoff.

This document presents the wildfire risk analysis results for the PSPS event that occurred in **Pacific Gas and Electric Company's (PG&E)** service territory from **October 26 - 29th, 2019**. The analysis quantifies the potential impacts averted from wildfires that could have been ignited by electric utility infrastructure assets damaged during the PSPS event if they were not de-energized. These damage incident data are compiled from IOU field inspections on asset infrastructure after the 2019 PSPS event occurred.

The analysis identifies the expected spread of fire simulations based on the damage incident locations as potential ignition points, and quantifies the impacts from those potential fires, in terms of buildings, population, critical facilities and acres impacted, under worst-case fire weather conditions that occurred within the PSPS event time boundaries.

This analysis reflects "*what could have been*" had the PSPS not occurred, aiding the CPUC in conducting a richer analysis and evaluation of IOU PSPS decisions by quantifying the potential impacts that could have been avoided and providing a measure to compare against actual sustained impacts.

The analysis does not consider suppression activities during the simulated fire spread and, therefore, the final fire impact could have been less than calculated. Also, note that the fire modeling approach used in this work considers an encroachment function to analyze the fire impact on buildings and population based on fire intensity and the rate of spread near the houses. Finally, this work takes into account input data uncertainty (especially, weather and ignition parameters) to analyze the fire propagation and impacts, an innovative approach to that ensures more reliable results.

The analysis has been conducted using the advanced wildfire behavior and prediction modeling software Wildfire Analyst™ (Technosylva, La Jolla, CA).[2]

[2] More information about Wildfire Analyst can be obtained from https://www.wildfireanalyst.com/.

2. OVERVIEW OF PSPS EVENT

On October 26, 2019 and October 29, 2019, PG&E implemented two Public Safety Power Shutoff (PSPS) events in order to mitigate catastrophic wildfire damage presented by significant offshore wind events combined with low humidity levels and critically dry fuels. The first offshore wind event started on October 26 with weather conditions lasting through October 28. The second offshore wind event started on October 29 with weather conditions lasting through October 30 for the majority of areas in scope for de-energization and ending on October 31 in the remaining areas in scope. Within these offshore wind events, PG&E planned de-energization times specific to different geographic areas based on their unique weather timing to minimize outage durations. Approximately 941,000[1] customers were impacted over the course of both events, with some customers impacted by both events.

Over the course of the combined October 26 and October 29 events, customers were impacted with longer outage durations than other events in 2019. Two factors contributed to extended outages. First, the duration of the offshore winds was longer in comparison to past events. The wind during the October 26 event lasted roughly 36 hours in some areas, and during the October 29 event weather lasted roughly 24 hours. Second, the consecutive and close timing of the two offshore wind events created a scenario where the October 26 event “all clears” occurred roughly 24 hours prior to when the October 29 offshore winds were expected to arrive, and de-energization was to begin in many of the same areas. This overlap of 2 events, one concluding and one beginning, resulted in approximately 12 hours of day-light restoration time available for patrols and restoration for the October 26 event. Customers in scope for both events experienced a cycle of either being de-energized and restored for a short period of time, and then de-energized again, or being de-energized and remaining de-energized over the duration of both events. The average customer outage duration for the combined events was approximately 55 hours. PG&E recognizes that the timely restoration of customers is of the utmost importance and is committed to leveraging all currently available resources while continuing to explore new processes and technologies that reduce restoration times.

The following map shows the areas affected by the PSPS event during this time period. A detailed description of the event, including time periods and locations for de-energization footprints, can be obtained from the CPUC web site at:

https://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/News_Room/NewsUpdates/2019/Nov.%2018%202019%20PGE%20ESRB-8%20Report%20for%20Oct.%2026%2029%202019.pdf

Figure 1. October 26-29, 2019 PG&E PSPS event areas.

3. ANALYSIS OF WEATHER CONDITIONS

3.1 Overview

The overall weather pattern for this PSPS event was characterized by southward propagation of an upper-level trough that advanced directly over California October 27, 2019. [3] Atmospheric conditions were driven by this upper level trough which became elongated with positive tilt. The base of the trough tracked along the California coastline while an upstream ridge over the Pacific amplified. Surface high-pressure in the wake of the trough, comprised of much cooler and drier air, occupied the Great Basin. A strong inverted surface trough located over southern California also developed and induced a strong cross barrier pressure gradient along the Sierra Nevada crest.[4] This strong pressure gradient caused the development of strong surface winds that were channeled across the Sierra Nevada and into the lower elevations. A strong temperature inversion, near crest height, was evident in the atmospheric profiles analyzed that indicated a stable layer. This stable layer was likely capable of mountain wave deflection. Downward deflection of mountain wave energy is a key contribution to the onset of downslope windstorms. Downslope windstorms allow for strong and dry winds to mix to the surface and promote elevated fire weather threat.

The wind event was long lived, more than 24 hours, and surface gusts exceeded 85 knots (>100 mph). Widespread surface observations confirmed strong and gusty winds capable of serious damage to various infrastructure across the northern California region. The atmospheric moisture was spatially and temporally variable at the onset of the event, however moisture quickly decreased as the wind event progressed. The maximum gusts forecasted by the National Weather Service were expected to be around 70 knots (80 mph). This forecast was not only verified but exceeded at numerous surface locations. Additionally, fire was already on the ground with the Kincade Fire being far from containment.[5]

The significance of the event is highlighted by:

- An upper level trough propagated southward directly over California
- A strong cross-barrier surface pressure gradient developed along the Sierra Nevada crest
- Variable moisture levels at event onset were replaced by generally dry conditions as the event progressed, likely enhanced by downslope winds
- Surface observations indicated widespread sustained winds of 25-65 knots and gusts > 85 knots
- Uncontained fire was already on the ground
- A secondary wind event occurred 24 hours later with significantly less intensity, although this caused a disruption to restoration operations.

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[3] A trough is an elongated region of relatively low atmospheric pressure often associated with weather fronts.

[4] An inverted surface trough is an atmospheric trough which is oriented opposite to most troughs of the mid-latitudes.

[5] The Kincade Fire started on 10/23/219 and was contained on 11/06/2019. It burned 77,758 acres in Sonoma County, lasting 13 days.

A detailed review of the weather conditions is described in Appendix A.

3.2 Observed Weather Versus Modeled Conditions

We analyzed and compared observed and modeled weather conditions (especially, wind speed and direction) for all PSPS fire incidents. Both modeled weather prediction data provided by PG&E and weather station observations data were used to conduct the analysis. A comparison between weather data from the nearest weather station to each damage incident and the modeled weather data at both the damage incident ignition point and the weather station location is provided. Appendix B provides summary weather analysis results for each significant damage incident through two different charts. The first chart shows the comparison between the weather station values and the simulation modeled values at ignition point. The second chart shows the comparison between the weather station values and the modeled weather values at the station coordinates.

Both modeled wind direction and speed data is for the most part consistent with weather station at the same geographical point (modeled wind) and ignition point (simulation wind) in almost all damage incident simulations, reflecting that this FireCast input is consistent to model fire behavior and progression. Although we found slight differences between modeled wind speed data, simulation and the nearest weather station with some simulations with higher modeled wind speed than in the nearest weather station (see Appendix B), these differences were significantly lower than other PSPS events such as the October 9th. The modeled values are totally reliable to model the fire progression, especially considering the probabilistic simulations executed for this report dealing with weather uncertainty.

4. SUMMARY OF DAMAGE INCIDENTS

4.1 Data Collection Methods

The analysis relied upon PG&E's assessment of damage incidents for ignition potential. Data on the damages were obtained from patrols conducted by PG&E field personnel subsequent to reenergization. All damage identified from these PG&E field inspections was documented with standard forms including GPS recorded location, photographs and a description of the damage. The documentation was then submitted to a team of PG&E analysts who evaluated the data to determine whether the damage reflected a potential ignition. Quality assurance was then conducted by PG&E Electric Operations personnel who have extensive field experience to make a final determination of whether the damage event would cause a potential ignition. This assessment, provided by PG&E, is the sole information used to identify possible ignitions and is the basis for the analysis provided in this report. The analysis assumes all damage incidents likely to cause arcing would result in an ignition. In general, damage incidents where arcing would likely occur were identified when:

1. Non-insulated conductors were in contact directly or indirectly (e.g. a tree branch laying across two or more conductors).
2. A non-insulated conductor or conductors were in contact with the ground directly or indirectly (e.g. a tree failure where the tree was leaning against the line without causing the line to fall to the ground)

4.2 Description of Damage Incidents

According to the detailed report received from PG&E and their field inspections, a total of 441 damage incidents were reported for the October 26 PSPS event, including location and estimated damage time. Of the 441 possible ignition points, only 422 incidents were located in the PG&E provided PSPS areas. Accordingly, only 422 damage incidents were used as ignition points to conduct fire spread simulations. The following map presents the locations of the damage incidents relative to the PSPS event areas.

A unique identification number is provided for each damage incident. The numbering of the incidents reflects the ranking of impacts on population derived from the fire spread simulations. For example, the number 1 incident contains the most amount of potential impacts while incident 422 contains the least amount of potential impacts. Impacts are measured in terms of buildings impacted, population impacted and acres burned. Please refer to Section 5 for a detailed description of the analysis methods.

Dashed lines highlight areas where a cluster of incidents occur. These are presented in Figures 3 and 4. The PSPS event boundary is shown in **blue**. Note map scale varies for each map. In addition, some incident labels do not appear due to clustering. These are shown in Figure 3 and 4.

Figure 2.Damage incidents relative to PSPS event areas.

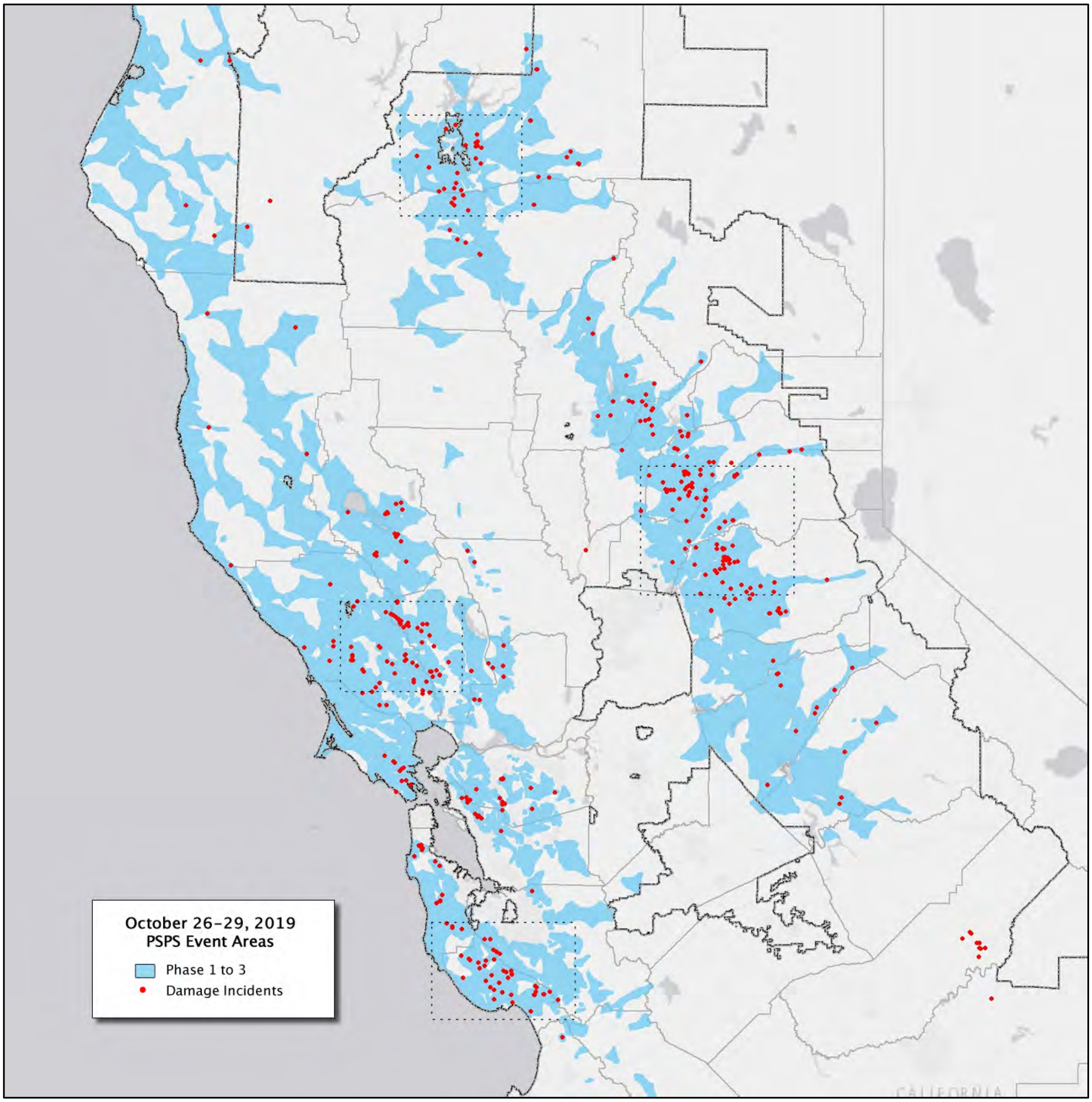
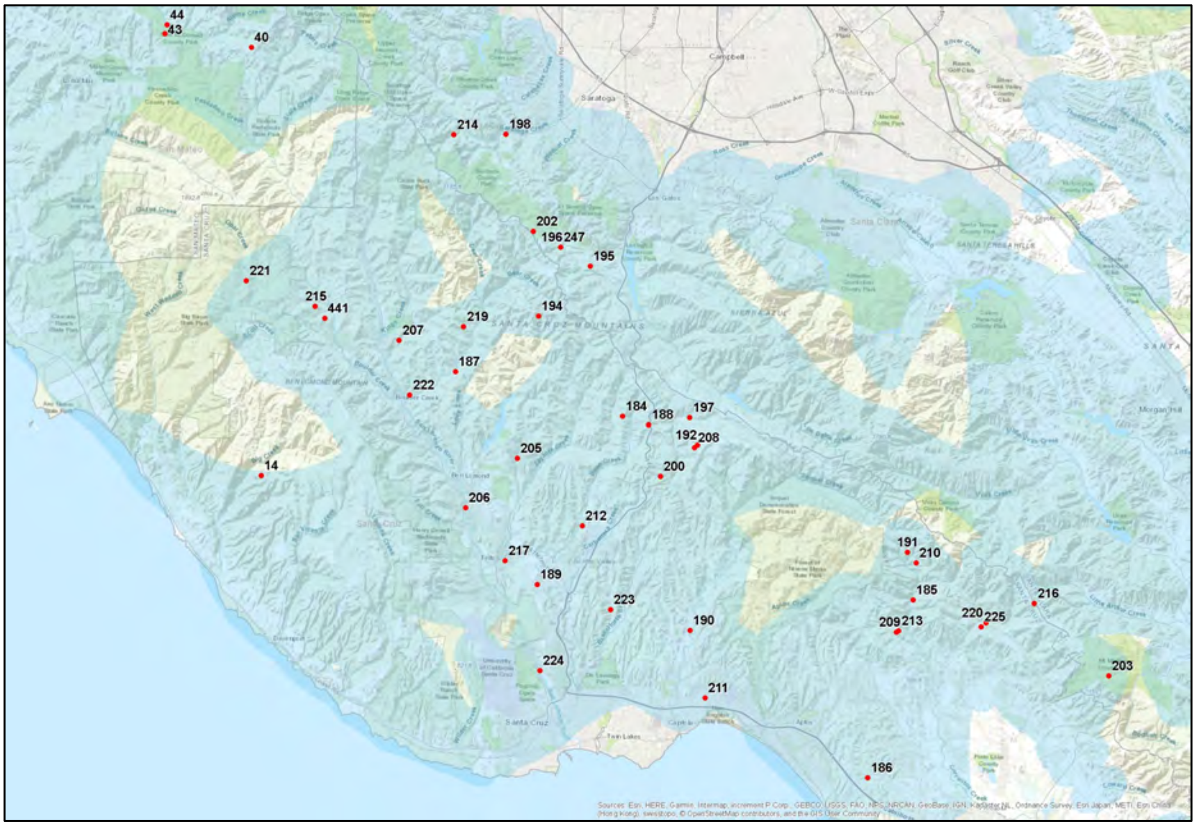
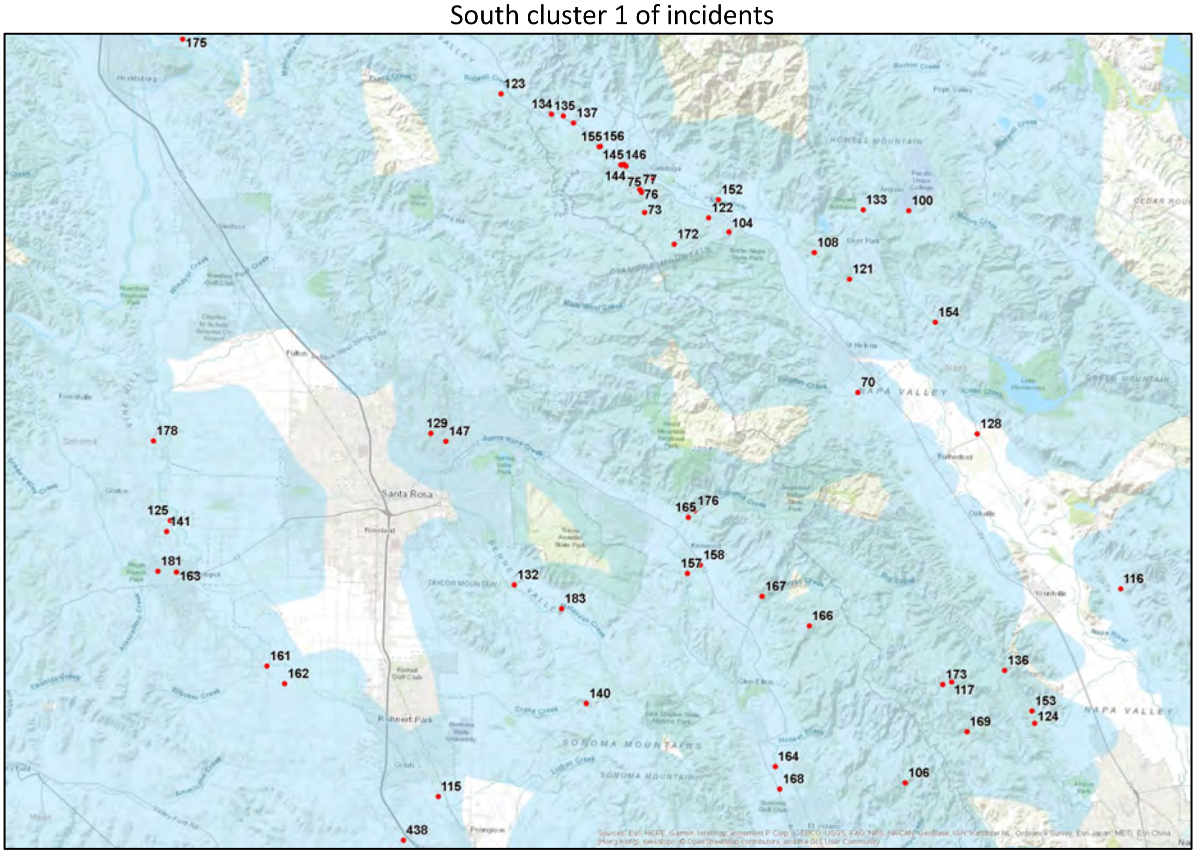


Figure 3. Maps 1 and 2 of cluster incidents.

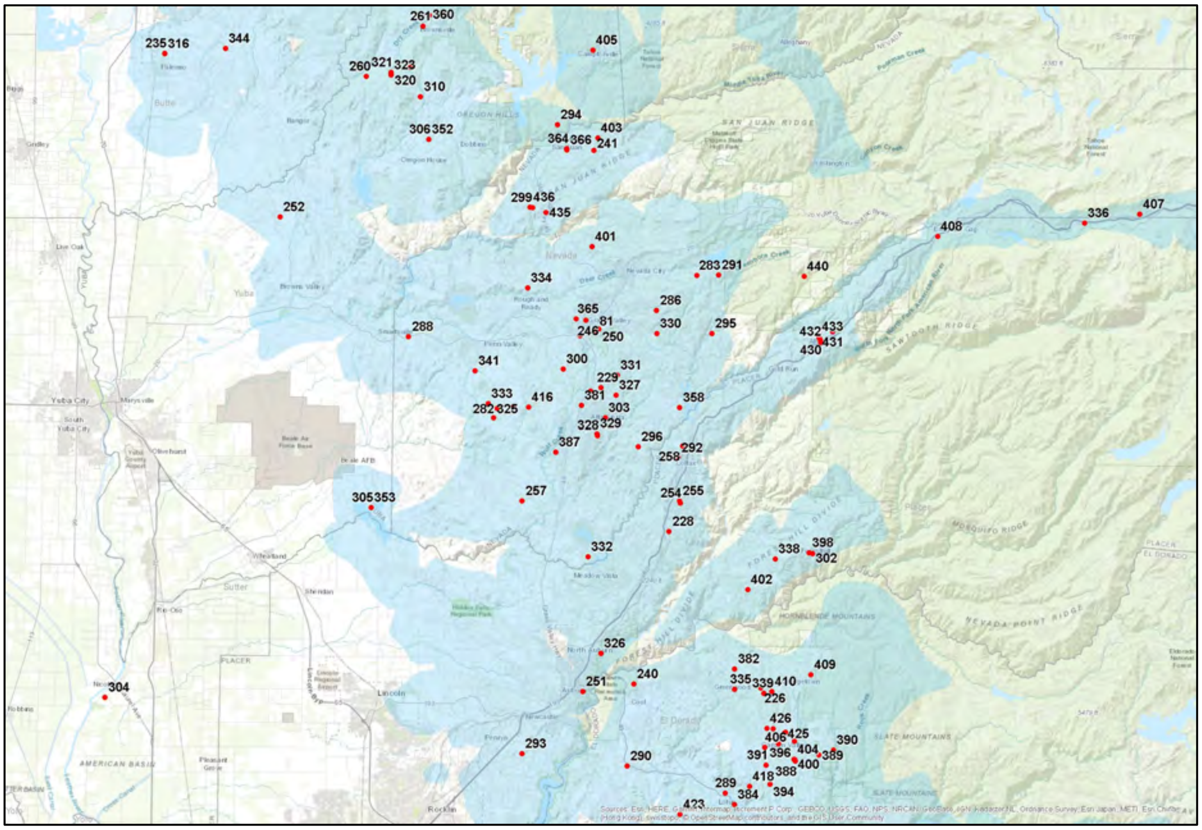


South cluster 1 of incidents

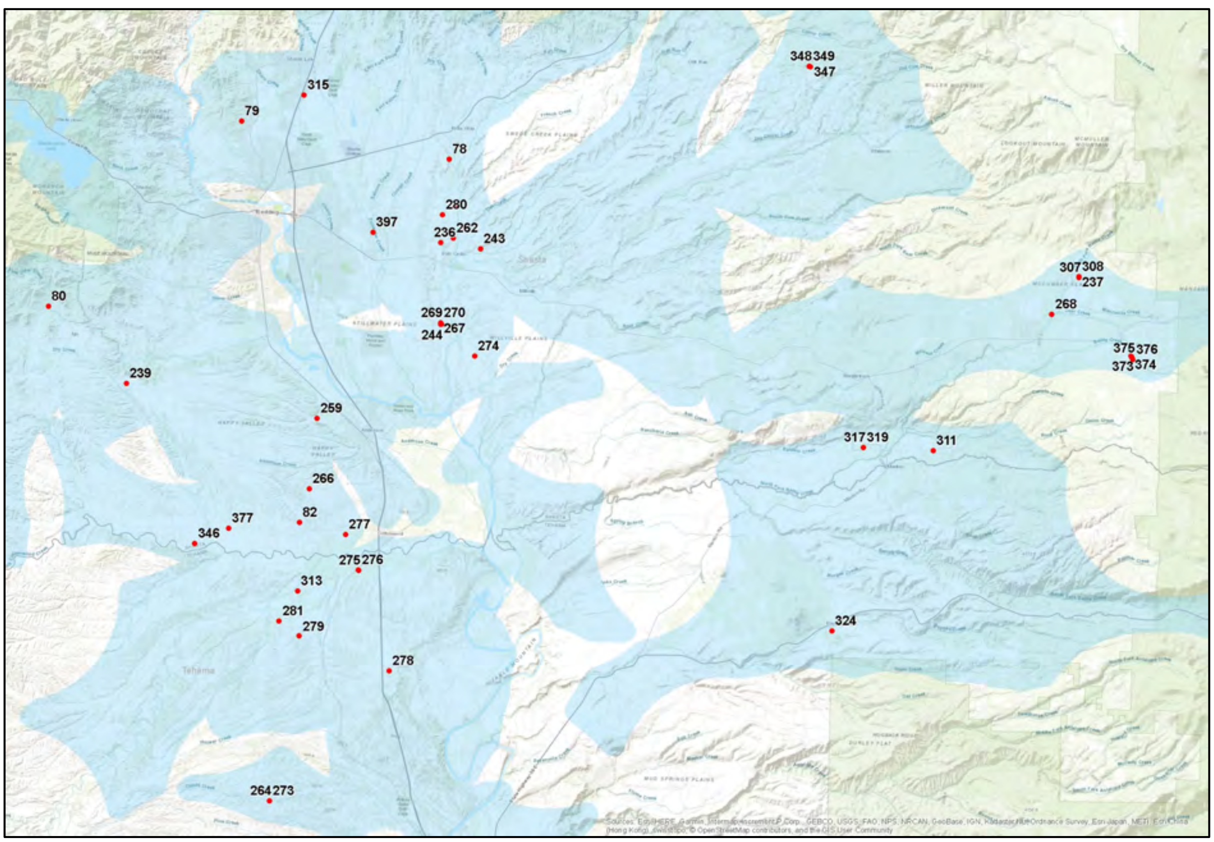


West cluster of incidents

Figure 4. Maps 3 and 4 of incident clusters.



East cluster of incidents



North cluster of incidents

5. SUMMARY OF ANALYSIS RESULTS

Fire spread simulations were undertaken for the 422 damage incidents using the location of the electrical assets involved in the damage incident as the ignition source, and the date/time estimate for the damage occurring as the start time for the fire simulation (see Section 5.3). The simulations were run for a 24-hour duration. Impacts to buildings, population, and acres burned were calculated for each fire simulation.

The analysis also calculated several other metrics to help assess the potential significance of the fire prediction. A key metric is the Initial Attack Assessment (IAA) [6], which quantifies the likelihood of the simulated fire escaping initial attack by suppression resources. This metric helps distinguish fires that may potentially take long to suppress compared to average fires that would typically be extinguished quickly due to spread characteristics under the specific weather conditions at the time of the event.

5.1 Methods Used

The following technical tasks were undertaken to derive the analysis results.

1. Obtain damage incident data and PSPS event data from IOUs
2. Obtain weather forecast data from IOUs
3. Compile weather station observation data
4. Geo-reference the damage locations and PSPS events boundaries
5. Compile weather data and determine best data for each simulation analysis
6. Conduct analysis of weather conditions
7. Determine the most likely ignition time for the damage incidents
8. Conduct deterministic fire spread prediction simulations
9. Calibrate outputs & revise if necessary
10. Generate summary results for all damage incidents
11. Identify the most significant damage incidents based on simulation results
12. Conduct a probabilistic simulation for the most significant damage incidents
13. Generate summary of the most significant simulations
14. Compile a summary of active wildfires during the event period
15. Conduct analysis of historical fire comparison
16. Compile results into PSPS event report

5.1.1 Fire Behavior Modeling

Fire simulations were performed with Technosylva's Wildfire Analyst™ software. Wildfire Analyst is a software that provides real-time analysis of wildfire behavior and simulates the spread of wildfires. Wildfire Analyst employs published and proven algorithms used to simulate fire behavior.[7] Numerous enhancements to the published science have been implemented by

[6] The IAA index provides an estimation of the difficulty of fire control in the initial attack. The index is compound of two subindices based on fire behavior (rate of spread, flame length) and fire growth metrics (fire perimeter for the first hour of fire growth with no intervention of suppression resources; fire area growth between the first and second hour).

[7] Rothermel, R., 1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. Intermt. For. Range Exp. Stn. Res. Pap. INT-115. Ogden, UT.

Technosylva that provides more advanced capabilities for spread modeling and impact analysis. The methods also utilize crown fire model and spotting algorithms. Topographic characteristics (elevation, slope, aspect), weather (temperature, relative humidity and wind fields), surface fuel types and moisture (dead and live), canopy characteristics and foliar moisture content are all used as inputs into the fire behavior modeling.

A key enhancement incorporated into the analysis is the use of a surface fuels dataset that has been updated to reflect vegetation disturbances up to 2018. This also includes an enrichment of urban and non-burnable fuel delineation to facilitate more accurate urban area encroachment and associated impacts to buildings and people.

The duration of all incident fire simulations was 24 hours.

The outputs provided the simulated fire spread and behavior characterized by rate of spread, flame length, fire line intensity and type of fire in each pixel (unburnable, surface, torching or crowning). These are considered standard fire behavior outputs.

5.2 Using Deterministic and Probabilistic Fire Simulations

The primary concern with any fire ignition is the spread of the fire and potential impacts from that fire spread. This is particularly important in adverse weather conditions that lead to PSPS events.

Two methods exist to predict fire spread and analyze potential impacts - deterministic and probabilistic.

Deterministic methods apply well established and proven fire spread models using forecasted and observed weather data to calculate the estimated time of arrival, behavior characteristics, and the consequence of a fire. This method allows for virtual real-time analysis of a fire and can be adjusted based on a fixed set of input data values. This method provides well understood and reliable results if input data is accurate. However, the capability of accurately predicting the fire spread and impact is linked to input data uncertainty, such as the time of ignition, ignition location, forecasted weather conditions, etc., as well as the model's inherent inaccuracy. Results can vary greatly depending on the accuracy of these key input parameters. Deterministic modeling was used to calculate the fire spread and impacts for each of the 422 damage incident locations.

Probabilistic methods apply the same fire spread models with a variation of inputs to determine the probability of occurrence. The probabilistic approach performs approximately 100 fire simulations with varied input data for each damage incident considering advisable thresholds for each input according to scientific literature[8]. The inputs that are varied are dead fuel moisture, wind speed, and wind speed. The model provides probability-based outcomes, estimating the time and probability of a fire reaching a specific point of the landscape and associated impact as a function of that probability. The aim of probabilistic modelling is to provide decision-makers a representative scheme of the possible outcomes of the fire simulations after analyzing the nature

[8] Alexander, M.E., Cruz, M.G., 2013. Are the applications of wildland fire behavior modeling. Environ. Model. Software. 41, 65–71. https://doi.org/10.1016/j.envsoft.2012.11.001

of the uncertainties in the fire incident[9]. This analysis may be helpful in structuring the problems, integrating knowledge, visualizing the results[10] as well as easing the work of decision-makers by supporting consistent and justifiable decisions[11].

Since some of the inputs for the damage incidents could vary, probabilistic methods were used for those most significant fire simulations identified through deterministic methods. This accounts for possible variation in key input data providing an enhanced analysis of possible spread and consequence. Please refer to Sections 5.5, Section 5.6 and Appendix B for a description of this approach.

5.3 Defining Ignition Parameters

5.3.1 Ignition location

The ignition location used for each fire simulation is based on the GPS coordinates (latitude/longitude) for the individual damage incidents provided by PG&E from their field inspections

5.3.2 Time of Ignition

The time of possible ignition for a damage incident is a difficult variable to accurately predict within the PSPS event timeframes given the transient nature of weather conditions influencing damage caused by line slap, pole failure, flying debris and tree falls on electrical assets. Accordingly, an estimated time of ignition was used for the fire simulations based on the following criteria:

1. Estimated time of damage provided by PG&E, ensuring the estimated ignition time occurred within PSPS event boundaries.
2. In any instance in which the estimated ignition time was not within the PSPS event boundaries, we adjusted the time to within the outage start and end times to ensure the simulations were consistent with the intent of the evaluation – assessing potential impacts averted while the power was shutoff.
3. Additionally, in certain cases where the estimated ignition time was within the PSPS event boundaries but coincident with additional weather conditions[12] more likely to result in fire simulations with higher impacts on buildings, population and acres burned, the estimated ignition times were adjusted. In these simulations the worst weather scenario was used through a quantitative analysis of hourly wind speed and fuel moisture content considering a temporal window of ± 12 hours within the shutdown.

These criteria were applied for the deterministic simulations for the 422 damage incidents.

[9] Power, M., McCarty, L.S., 2006. Environmental risk management decision-making in a societal context. Hum. Ecol. Risk Assess. An Int. J. 12, 18–27. https://doi.org/10.1080/10807030500428538.

[10] Kiker, G.A., Bridges, T.S., Varghese, A., Seager, T.P., Linkov, I., 2005. Application of multicriteria decision analysis in environmental decision making. Integr. Environ. Assess. Manag. 1, 95–108. https://doi.org/10.1897/IEAM_2004a-015.1.

[11] Uusitalo, L., Lehikoinen, A., Helle, I., Myrberg, K., 2015. An overview of methods to evaluate uncertainty of deterministic models in decision support. Environ. Model. Softw. 63, 24–31. https://doi.org/10.1016/j.envsoft.2014.09.017.

For the most significant damage incidents, the probabilistic simulations inherently accommodate for input data uncertainty and, indirectly, with the issues related to the time of ignition since the model considers varying input data (especially, fuel moisture content and wind speed).

5.3.3 Probability of Ignition from Damage

Damage to an electrical asset may result in a wildfire depending on the probability of that damaged electrical asset causing an ignition. The probability of ignition for an electrical asset can vary given that multiple factors influence it, including the type and condition of asset, nature of the damage, vegetation near the incident and weather conditions.

Damage incidents and locations are identified by IOU field personnel performing post-PSPS event patrols and reported in post-event reports pursuant to Commission Resolution ESRB-8. The damage incident data provided by PG&E includes supporting documentation comprised of photographs and damage descriptions made by PG&E field personnel for each damage location. The damage documentation is then provided to a PG&E technical analyst who reviews and quality assures each location's documentation in order to provide a preliminary determination of the likelihood of arcing (assuming the system had remained energized). Final determination of the likelihood of arcing is determined by PG&E Electric Operations Director. Each Electric Operations Director involved in the final determination has extensive field or engineering experience. It should be noted that these determinations are binary, and each damage incident is determined to either likely cause arcing or not. In general, locations where arcing would likely occur were identified when:

- Non-insulated conductors were in contact directly or indirectly (e.g. a tree branch laying across two or more conductors).
- A non-insulated conductor or conductors were in contact with the ground directly or indirectly (e.g. a tree failure where the tree was leaning against the line without causing the line to fall to the ground)

5.4 Summary of All Damage Incidents

Table 1 shows the number of buildings affected, population impacted, and acres burned for all 422 fire incident locations, after averaging 100 fire simulations during a 24 hour fire duration for each incident location, totaling 42,200 fire simulations conducted. The fire impacts in terms of burned area, buildings and population are the highest among all 2019 PSPS events that have been analyzed, due to a higher number of damage incidents and average impact by fire. More than 250,000 buildings and 420,000 people may have been affected by fires simulated for the identified damage incidents. Additionally, the fires may have burned approximately 3,000,000 acres.

Additionally, there were several damage incident clusters across the PG&E territory located in the counties of San Mateo, Santa Cruz, Sonoma, Napa, El Dorado, Nevada, Yuba, Tehama and Shasta. This could increase the risk of having many simultaneous fires in the same area exceeding fire suppression capabilities and threatening communities more easily.

Note that the variability in fire impact between damage incidents is reflected as the difference between the mean, maximum values and standard deviation. The fire impact deviation was high among incidents and not all fires in the same day would create the same impact, reflecting the need of analyzing all incidents independently for PG&Es decision to shutoff power. This was the purpose of this analysis.

Table 1. Total expected impact, mean and maximum per fire simulation for all 422 damage incident predictions.

Impact Type	Total	Mean	Maximum	Standard deviation
Population	421,271	998	13,384	1,880
Buildings	257,570	610	6,927	1,131
Acres Burned (ac)	3,056,346	7,242	73,508	10,945

5.5 Criteria for Selecting Significant Incidents

Once the fire spread prediction analysis was completed for all 422 damage incidents, specific criteria was applied to identify the most significant incidents. Worst cases were identified considering the following criteria. This was not specific to thresholds or distributions.

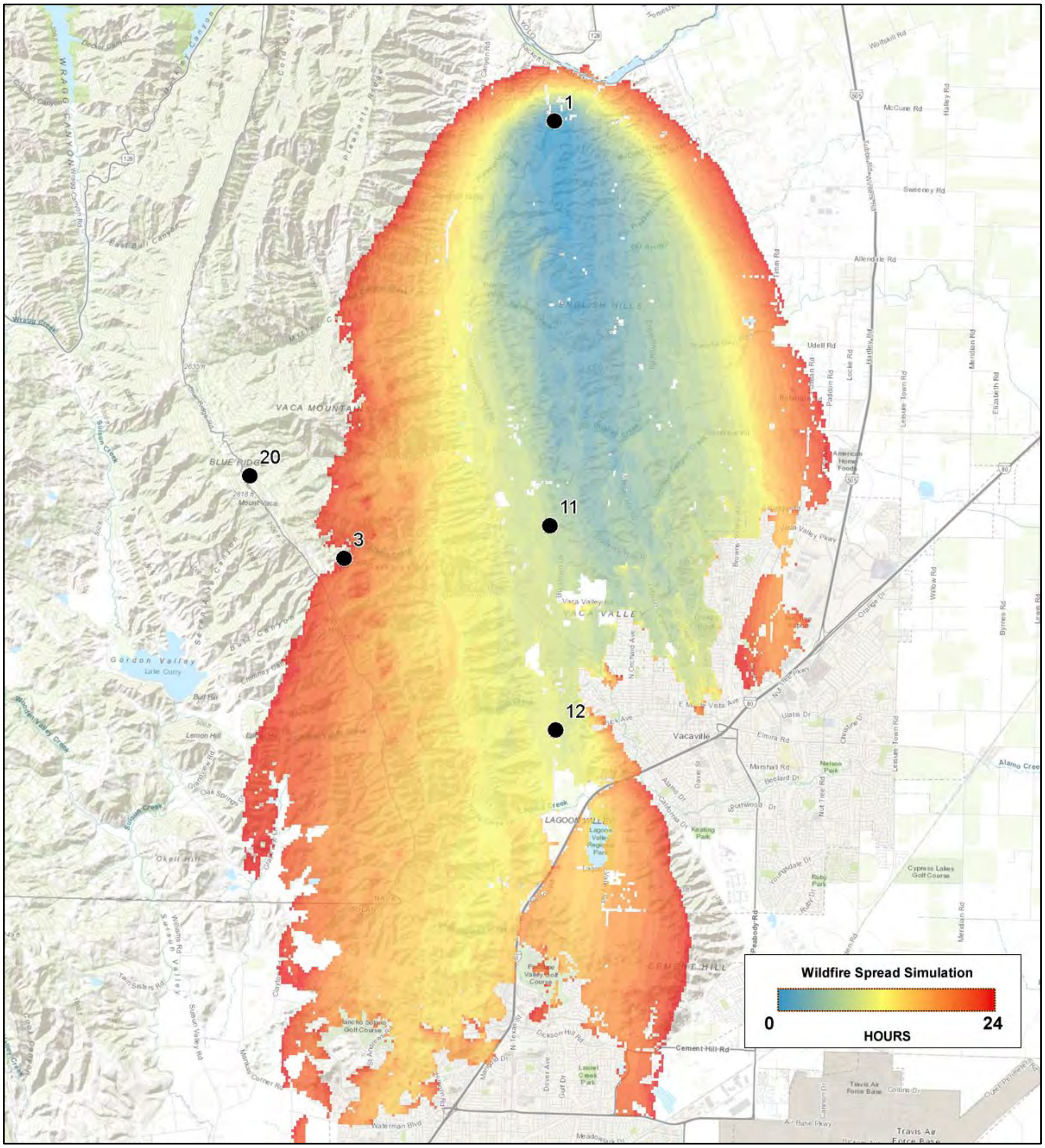
1. Total population impacted, using the LandScan 2016 population count data.[13] This data provides an accurate definition of population count for the USA. It is ideal for identifying population for wildland, Wildland Urban Interface (WUI), and urban areas. LandScan data has become the de facto standard for quantifying impacts to population for wildfire risk assessments conducted across the nation. Data is synchronized with the most recent Census update to accurate reflect population totals for geo-administrative areas.
2. Total buildings impacted. Original source is the Microsoft Buildings dataset 2018.[14]Building footprints enhanced by Technosylva to include missing data areas and misclassification for California.
3. Size of the fire, given that large fires typically result in high costs for suppression and restoration in addition to greater population and building impacts.
4. Initial Attack Assessment index rating – identifies those fires that would likely escape initial attack suppression and would spread quickly.[15]
5. For situations where a cluster of damage incidents exist, a single worst-case damage incident simulation was selected based on population impacted. The following figure shows an example where incidents 11 and 12, which have large impacts themselves, are not included in the final list of significant incidents because they immediately are contained within the simulated spread of damage incident 1. Note incident number 3 is still included as it is not immediately in the simulation extent of incident 1, and has different impacted areas.

[13] LandScan 2016 data was used as the source for population analysis. More information can be found at https://landscan.ornl.gov/.

[14] More information about the US Building Footprints data released by Microsoft can be found at https://github.com/microsoft/USBuildingFootprints.

[15] IAA is a metric developed by Technosylva in concert with experienced fire professionals to define the likelihood of a fire to escape initial attack suppression. It is based solely on fire behavior and fire growth characteristics. It is used to help distinguish fires that are likely to spread quickly and become large fires.

Figure 5. Example of incident clusters.



5.6 Summary of Significant Incidents

Using the criteria described in the previous section, a list of the most significant fire incidents was identified from the 422 damage incidents based on criteria described in the previous section. The following table lists these incidents. Incidents are numbered by a ranking of potential impacts starting at 1 (i.e. most impacts). The IAA is shown as guide for potential to spread rapidly and exceed initial attack.

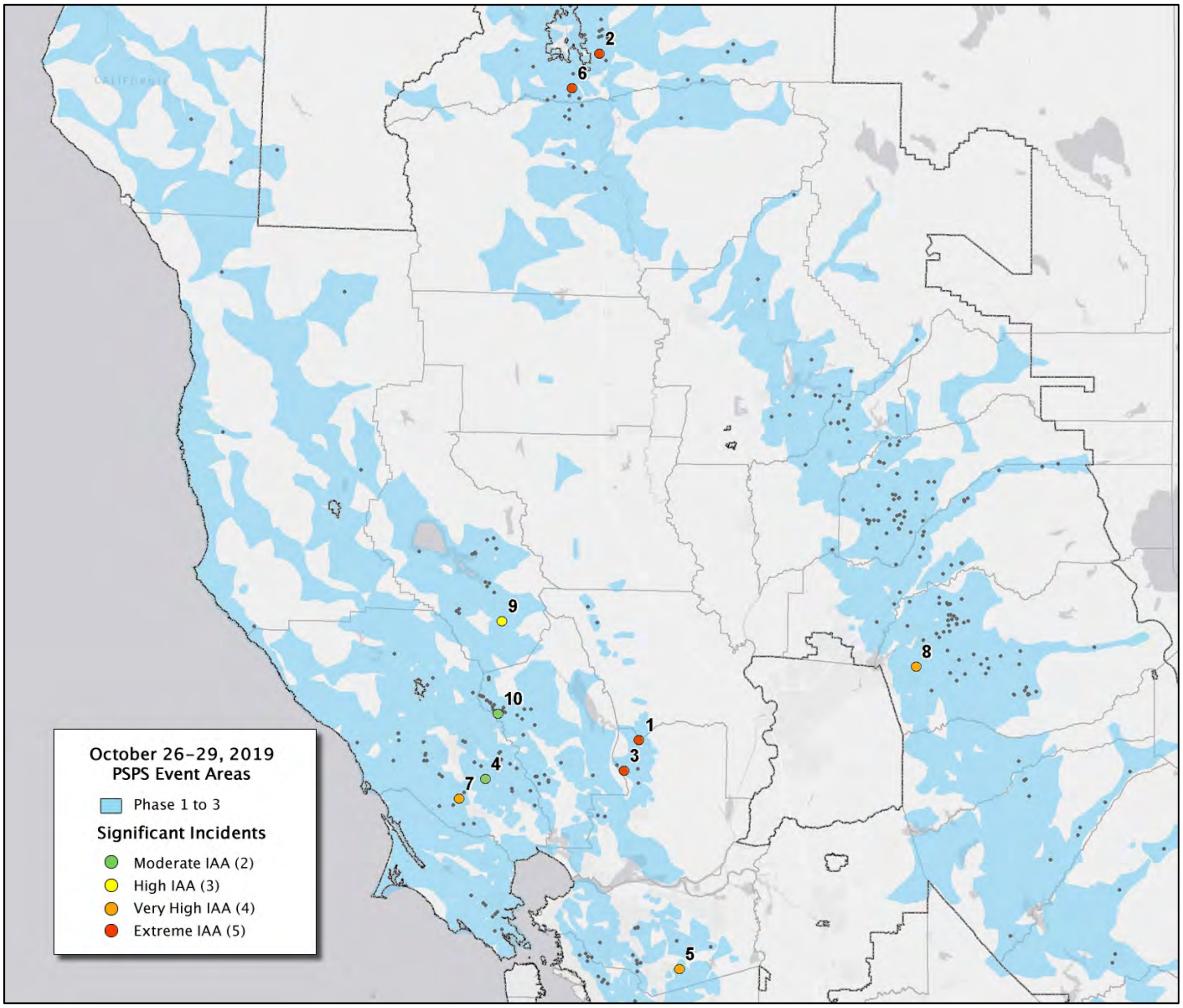
Table 2. List of significant simulated fires for this PSPS event (sorted by population impacted).

Damage Incident	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
1	Solano	13,384	6,927	50,228	**5**
2	Shasta	7,750	4,835	36,981	**5**
3	Solano	7,211	3,169	30,076	**5**
4	Sonoma	6,807	5,344	22,736	**2**
5	Contra Costa	6,425	1,163	15,771	**4**
6	Shasta	4,511	3,094	26,816	**5**
7	Sonoma	4,403	4,086	31,814	**4**
8	El Dorado	4,255	1,587	8,599	**4**
9	Lake	3,738	1,447	4,746	**3**
10	Napa	3,418	1,838	17,709	**2**

Low (1)   Moderate (2)   High (3)   Very High (4)   Extreme (5)

Figure 6 presents a map illustrating the location of the significant incidents identified in Table 2. Other incidents are shown in smaller **grey** points as reference.

Figure 6. Map of the significant damage ignition locations.



Although large fires, in terms of acres burned, usually correlate to higher impacts for buildings and population impacted, the analysis reveals that small fires can also result in large impacts due to their specific location and proximity to buildings and people.

Fire simulations with an intense fire behavior (high flame length and high rate of spread) typically result in an Initial Attack Assessment Index (IAA) value of high (4) or extreme (5), and have the largest burned areas based on a 24-hour fire simulations. Fire behavior is related to fuel types, complex topography and adverse weather conditions (i.e. low fuel moisture and high wind speed). The IAA index is intended to be used to analyze the fire simulation and the initial attack difficulty, not to analyze potential impacts in terms of buildings of population. As such, some fires with low-moderate IAA values also had high impacts. Figure 6 summarizes the population and buildings impacted for the most significant incident simulations.

Figure 7. Summary of population and buildings impacted for the significant incidents.

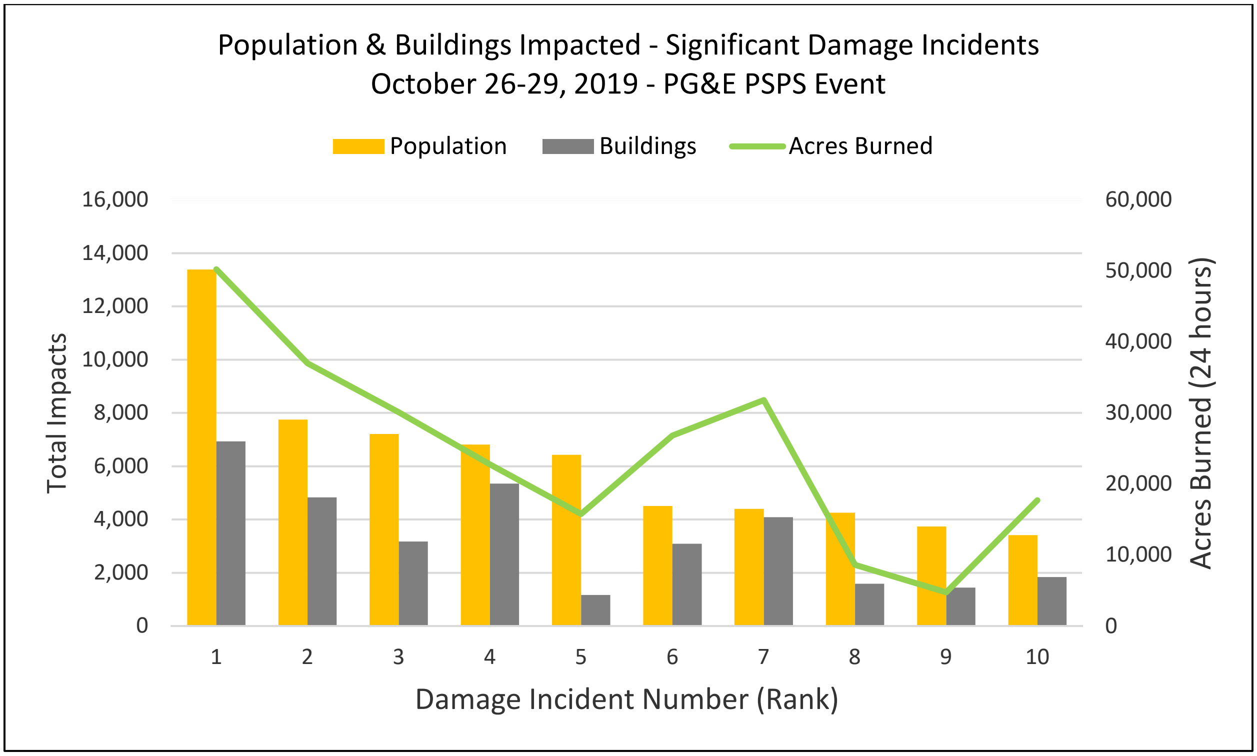
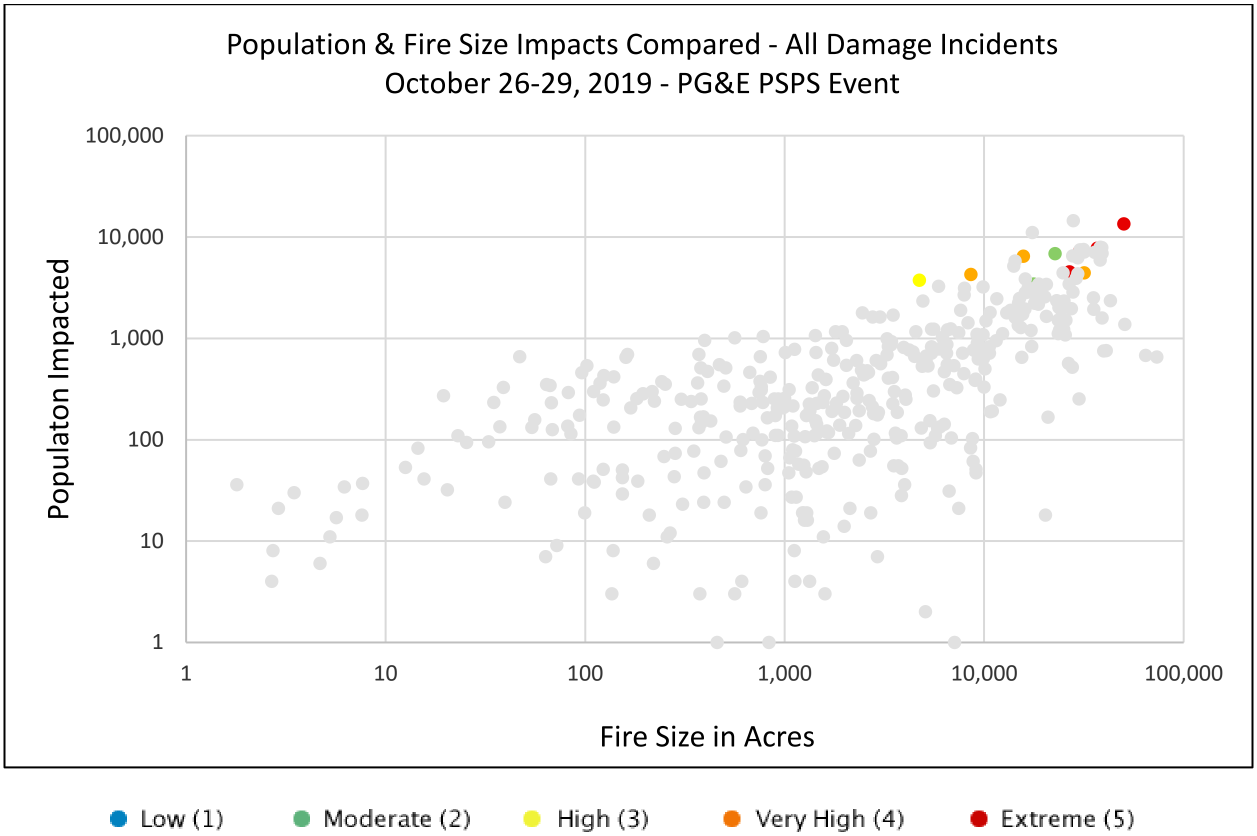


Figure 7 presents the population impacts of each fire simulation as a function of size (acres burned). Fires are color coded by IAA. This chart shows that fire simulations with high IAA index values consistently have large impacts. These fire simulations are significant from the start and are likely to escape initial attack.

Figure 8. Number population impacts as a function of fire size. Colors represents IAA values from low (blue) to extreme (red) for the significant incidents.



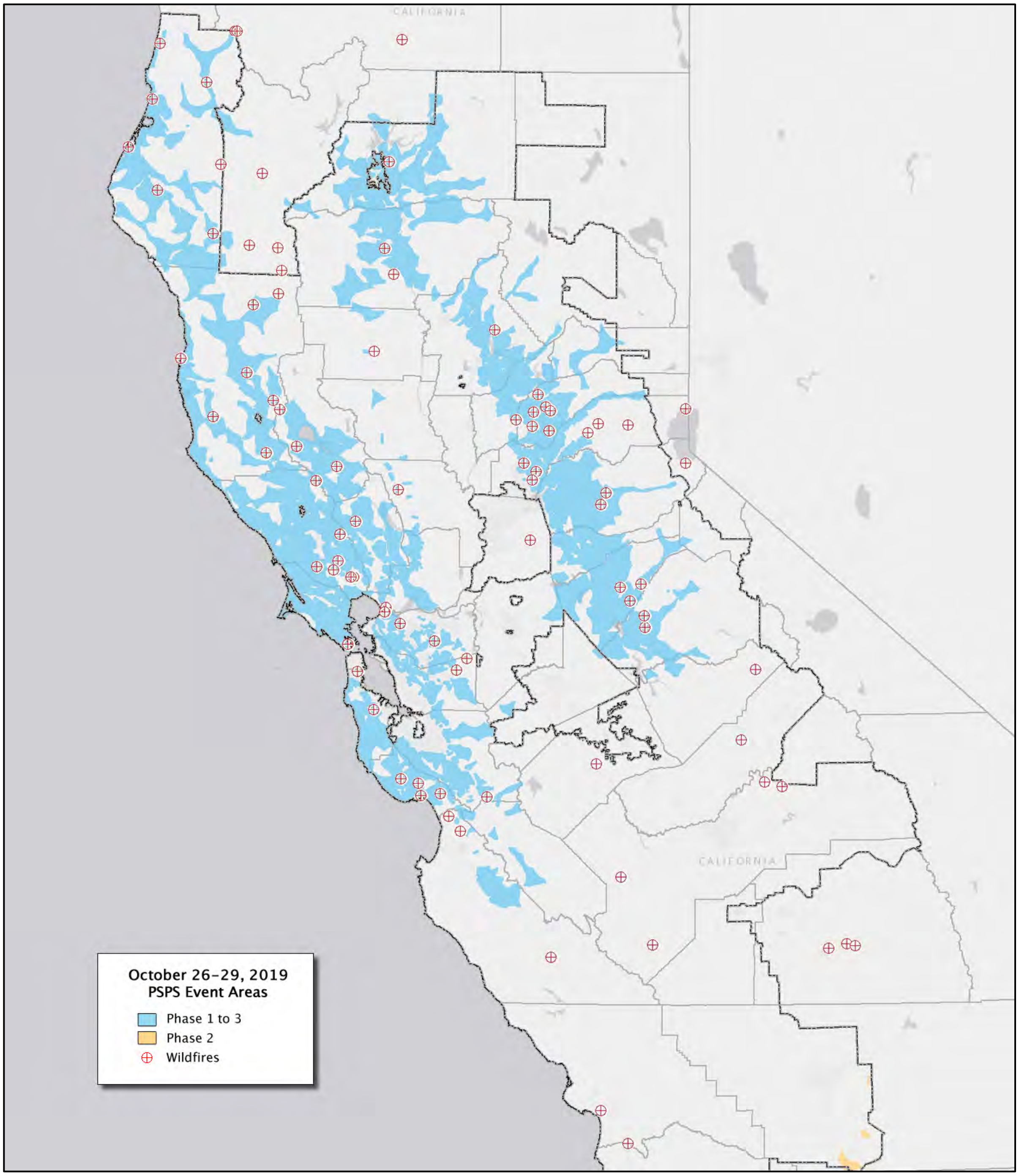
In summary, the following conclusions are reached:

- Generally large fires result in large impacts
- Moderate size fires can also result in large impacts
- Many small fires resulted in large impacts due to proximity of buildings and people in specific situations
- Fires with the highest IAA have large burned areas and usually large impacts. This reflects that fires with high IAA are significant from the start.
- Many locations resulted in low or null impacts to population. These may illustrate circuits or segments thereof, which could be good candidates for sectionalizing to reduce PSPS impact.
- Note that 16 of 422 incidents had no impacts on population. These are not shown in in the chart.

6. SUMMARY OF ACTIVE WILDFIRES DURING THE PSPS EVENT

This section summarizes the active wildfires that occurred during the PSPS event in California. One hundred forty (140) fire incidents were recorded in the Integrated Reporting of Wildland-Fire Information (IRWIN) system from October 26 to 29, 2019.[16] Fifty four (54) of the fires are located inside the PSPS event areas. Figure 8 shows the location of these fires.

Figure 9. Wildfires occurring during the Oct 26-29 PSPS event.



[16] The IRWIN system records wildfires in California through integration with CAL FIRE, all federal agencies and LA County. Wildfires in other local responsibility areas are not recorded in IRWIN or shown on this map.

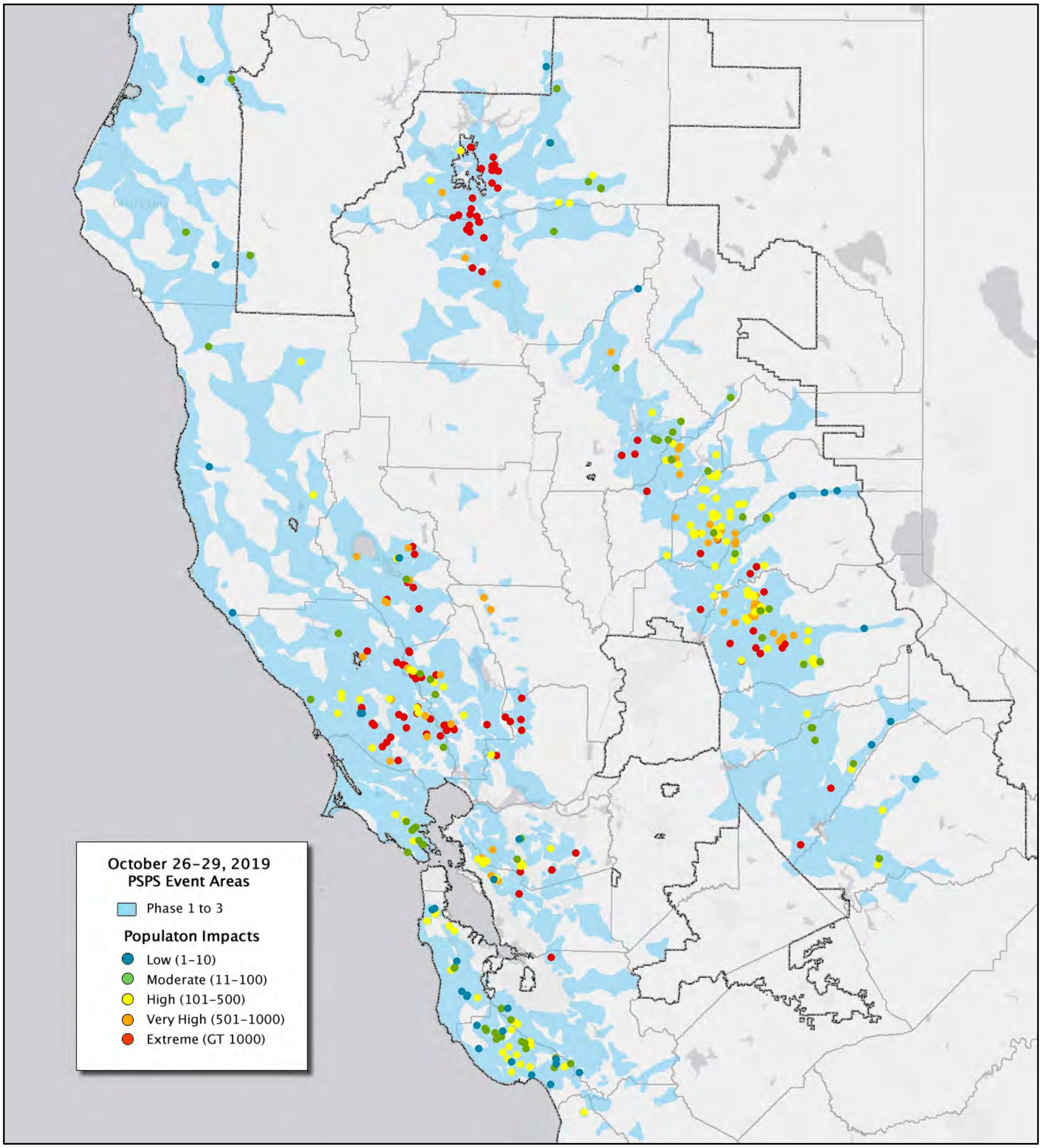
7. CONCLUSIONS

7.1 Findings

- Damages sustained to de-energized PG&E facilities during the October 26-29, 2019 PSPS events would have the highest fire impact in terms of burned area, buildings and population compared to all other 2019 PSPS events, due to a higher number of reported damage incidents (422) and average fire impacts.
- More than 250,000 buildings and 420,000 people may have been affected by simulated fires starting in the identified damage incident locations inside PSPS boundaries. The fires may have burned almost 3,000,000 acres in total. Note the that these results do not consider fire suppression. Additionally, there were several damage incidents clusters across the PG&E territory located in the counties of San Mateo, Santa Cruz, Sonoma, Napa, El Dorado, Nevada, Yuba, Tehama and Shasta. This could increase the risk of having simultaneous fires in the same area exceeding fire suppression capabilities and threatening communities more easily. Based on these data, it seems reasonable the shutdown was executed based on these results.
- 115 of 422 incidents (27%) resulted in impacts to less than 100 people. 35 of 422 incidents (8%) resulted in impacts to less than 10 people. This indicates that some areas may not be worthwhile for shutoff, as wildfires beginning in these areas have relatively limited impacts on the population.. Figure 10 presents a map showing the damage incidents classified by population impacts. PSPS event boundaries are shown in **blue**.
- Note that the variability in fire impacts between damage incidents is very high. The fire impacts of each incident depends on specific environmental conditions (i.e., fuels, weather, topography, etc.) and the exposure of assets (buildings, population). The fire impact deviation was high among incidents and not all fires in the same day would create the same impact.
- Fire could have spread quickly (> 50-100 chains/h) in several damage incidents due to high wind speed, low fuel moisture content and grass-shrub fuel types, exceeding fire suppression capabilities in the initial attach (high IAA) and throughout the fire.[17]
- The fire activity reflected by IRWIN incidents (140 fires during the PSPS event) higher than other PSPS events, together with recorded damage incidents could have increased the number of simultaneous fires, decreasing the availability and effectiveness of suppression resources.
- Although we found slight differences between modeled wind speed data, simulation and the nearest weather station with some simulations with higher modeled wind speed than in the nearest weather station (see Appendix B), these differences were significantly lower than other PSPS events such as the October 9th. The modeled values are totally reliable to model the fire progression, especially considering the probabilistic simulations executed for this report dealing with weather uncertainty.

[17] Chains per hour is the accepted standard for describing wildfire rate of spread within forestry and wildfire management agencies and science. A chain is equivalent to 66 feet.

Figure 10. Population impacts for damage incidents.



- Probabilistic simulations analyze potential fire impacts considering input data uncertainty. In operational settings, its use seems mandatory given the high degree of input data uncertainty, especially in terms of wind speed. Local winds are difficult to predict accurately and weather stations are often too far to be representative of localized conditions. Therefore, it is important to consider probabilistic approaches to estimate the potential impact of fires when evaluating simulations with significant impacts and account for this input data variability.. Probabilistic methods were applied for the most significant fires and are included in Appendix B.
- The custom weather and fuel types of Technosylva's Wildfire Analyst software module allow users to modify input data on the fly based on real observations. This report highlights the importance of these tools to improve the fire simulation outputs based on integrated input data (i.e., cameras, weather station integration, IRWIN, etc).

7.2 Recommendations and Opportunities for Improvement

- This work includes the potential impact of damage incidents on population, buildings, and the landscape if ignitions were to occur from the damage incurred to de-energized utility facilities during a PSPS event. The selected incidents shown in this report need to be analyzed with caution due to the uncertainty of input data found during the analysis. Specifically, in the future, the probability of ignition may be evaluated more granularly than the binary yes/no assessments used for this analysis to facilitate more detailed future analysis for specific events.
- The data and techniques applied in this analysis provide outputs that quantify the potential impact of fires ignited from the damage incidents. This provides a retrospective view of the PSPS decision to de-energize. The results identify where large impacts may have been avoided, as well as other areas where minimal impacts may have occurred.
- Additionally, the fire modelling techniques applied in this analysis, using Technosylva's Wildfire Analyst software, can be used for decision-making before the PSPS event leveraging PG&E's forecasted weather data. With this preemptive data in hand, de-energizing decisions can be evaluated both temporally and spatially in advance.
- Specific standards for damage incident data collection should be employed in future to facilitate this kind of analysis as a standard method to evaluate PSPS decisions. Recommendations will be provided as a result of this analysis. This will afford an objective method that will quantify potential impacts consistently for all IOUs and PSPS events.
- The on-going research of IOUs and Technosylva on wildfire modelling methods and data will increase the opportunities for improvement of future analysis. This includes better data collection and modeling of surface and canopy fuels, live fuel moistures, and enrichment of urban area delineation for encroachment analysis. These methods will enhance the accuracy of impact analysis and consequence modeling consistent with risk management industry approaches.

APPENDIX A: DETAILED WEATHER ANALYSIS

This appendix presents a detailed weather analysis for the PSPS event.

PG&E released a fact sheet that clearly highlighted the northern Sierras, Coastal Ranges, and Santa Cruz Mountains as the principal regions of impact, and these areas were analyzed separately as the Sierra region, Sonoma region, and the Diablo region (Figure 10). Pine Flat Road observed the strongest wind gust and was subsequently used as a proxy for the peak of the event. This site, depicted in Figure 11, is in the Mayacamas Mountains in the northeast of Sonoma County, California. A time series of sustained wind speed and gusts at Pine Flat Road is shown in Figure 11. The sustained winds exceeded 25 knots for more than twenty-four hours. The peak gust was recorded at approximately 1500 UTC October 27, 2019 and will further be referenced as the peak of the event. Event characteristics are analyzed using upper atmosphere analyses, atmospheric soundings, surface analyses, and surface weather station observations.

Figure 11. Surface observation locations are displayed over shaded terrain contours. Marker colors signify the Sierra region (blue), Sonoma region (green), and Diablo region (black). Each region has a site located near crest height (diamonds), in the mid-elevations (squares), and lower elevations (circles). Pine Flat Road is displayed by a ´+´ and is only referenced to identify the peak of the event.

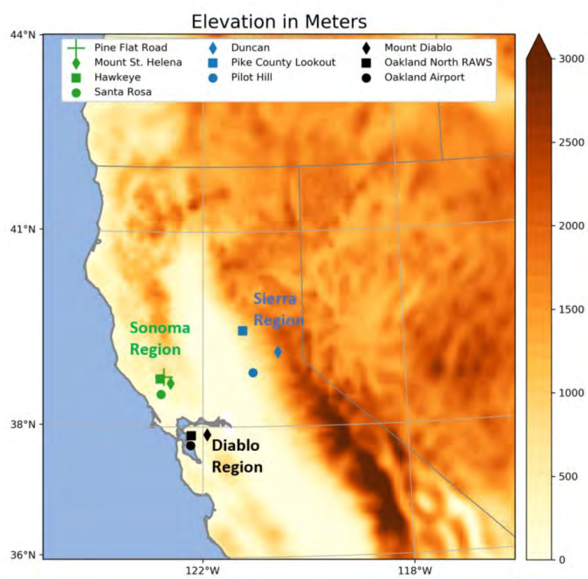
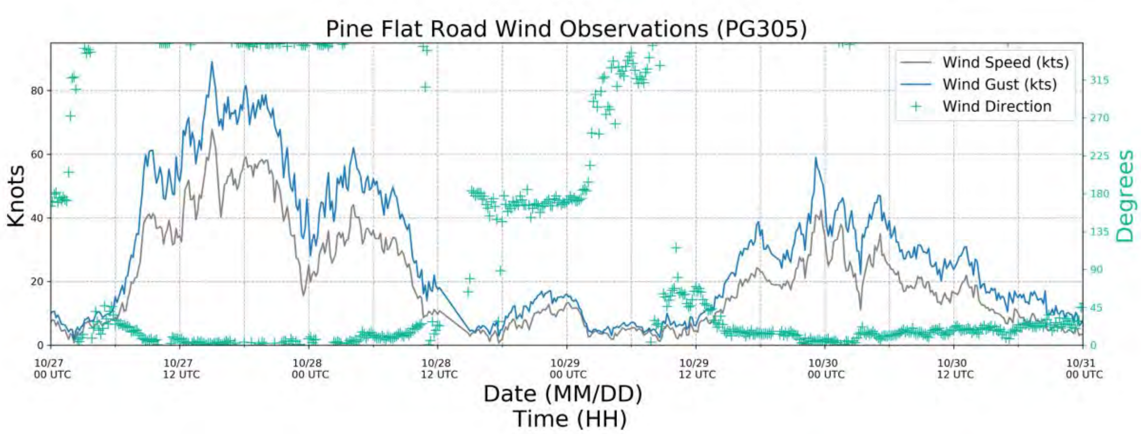


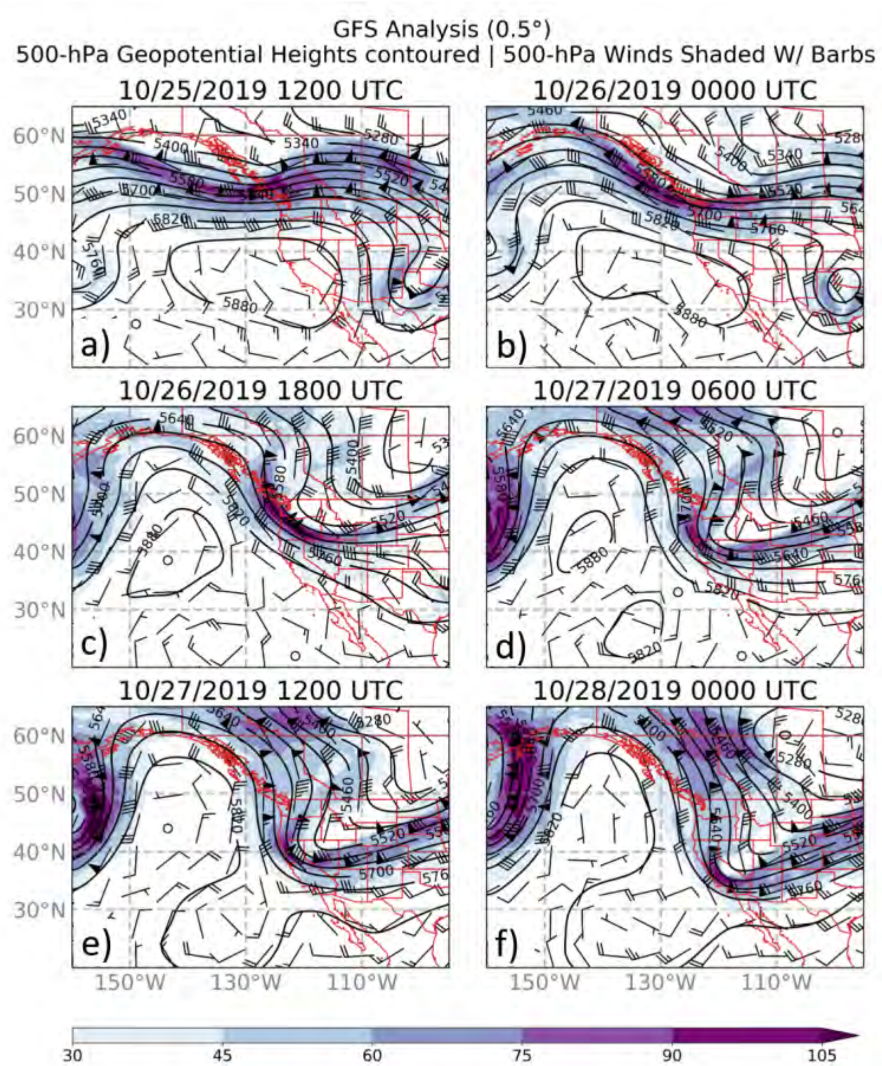
Figure 12. Surface wind observations from Pine Flat Road measured in knots.



Upper Atmosphere Analysis

The global forecast system (GFS) re-analysis dataset with 0.5° horizontal resolution was used to produce synoptic maps and analyses for this event. At 1200 UTC October 25, 2019 a shortwave trough traversed through a long wave ridge of high pressure in the Eastern North Pacific (Figure 12a). At 0000 UTC October 26, 2019, the shortwave trough began its southward propagation. As this trough advanced south, the upstream ridge over the Pacific amplified. At 0600 UTC October 27, a well-developed positive tilt shortwave trough was dropping southward into Northern California, and by 0000 UTC October 28 the shortwave axis had pushed into Southern California. Atmospheric profiles are examined next to determine regions of atmospheric stability during the event.

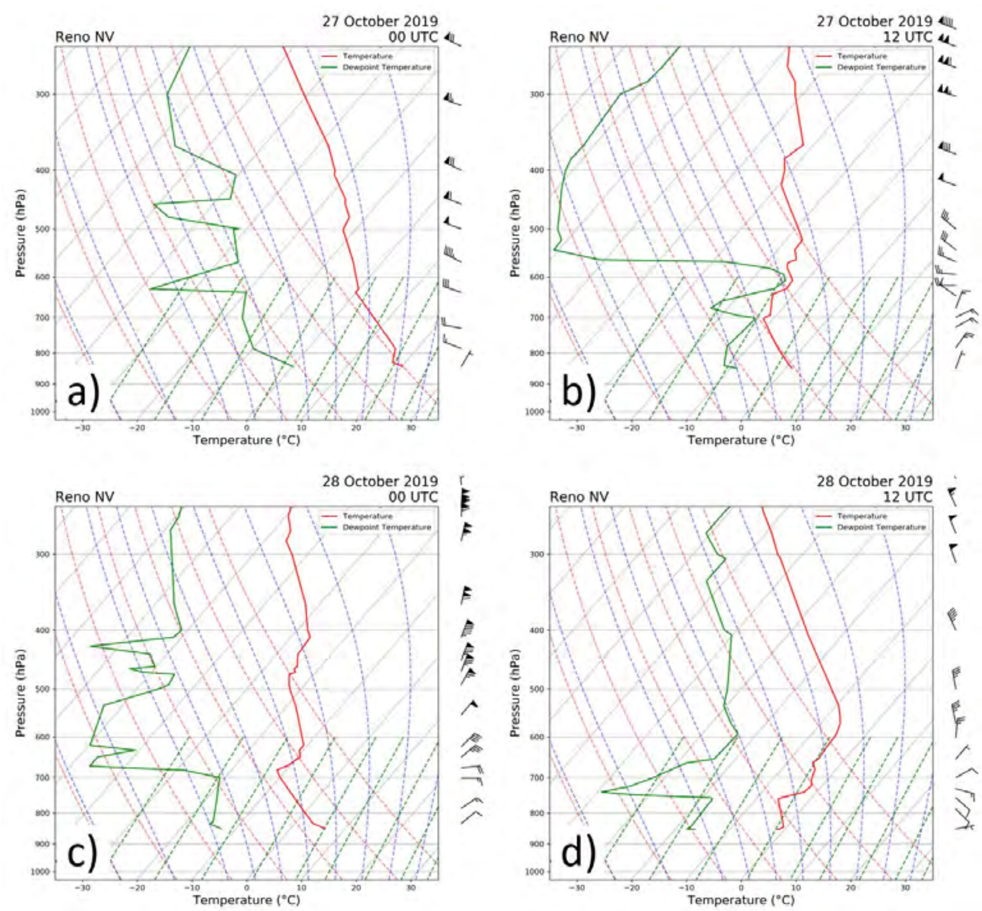
Figure 13 Geopotential heights at 500-hPa are contoured and winds are shaded in knots. Time is labeled in UTC.



Atmospheric Soundings

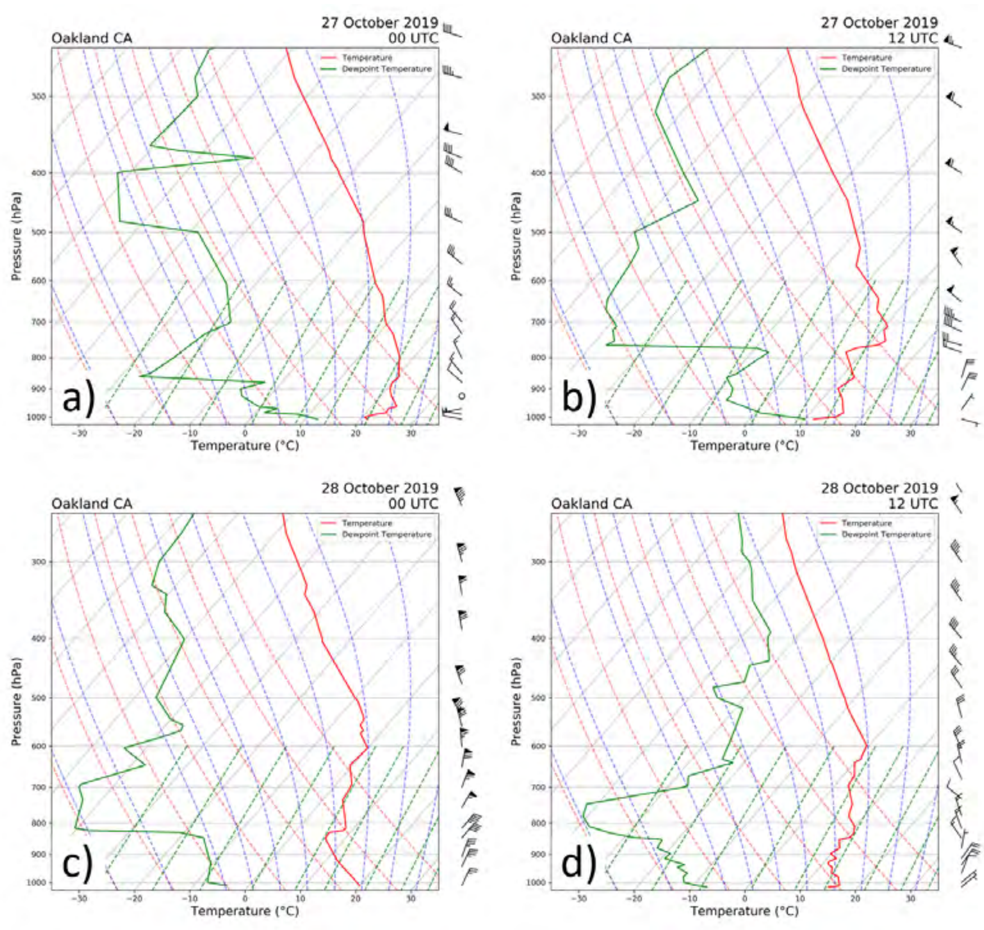
Standard NWS upper-level radiosonde soundings are available every twelve hours at numerous locations in the US. For this event, radiosonde soundings from Reno, Nevada were used to diagnose conditions necessary for downslope windstorms. The higher elevation of the Sierra region are best represented by atmospheric profiles from Reno. Figure 13a-d displays skew-t diagrams of atmospheric profiles during the event in chronological order. A temperature inversion was well developed in Figure 13b. The winds at that time were also backing with height which was indicative of cold air advection (CAA) in the mid to lower atmosphere that contributed to this inversion. This inversion was also associated with mid-level moisture that dried out as the event evolved. The initial inversion was situated near crest height (Figure 13b), then increased in altitude (Figure 13c), and then again descended towards crest height (Figure 13d) positioned at approximately 8,400 feet above mean sea level (~750 hPa). The inversion acted as an upper barrier to compress winds between the topography. The Sierra regional analysis showed a bi-modal wind peak that was separated by weaker winds at 0000 UTC 28 October which aligned with the increase of the inversion height. Reno is situated at 4,970 feet of elevation and the atmospheric profile is therefore only representative of high-elevation locations such as the Sierra region. An analysis was also performed using sounding data from Oakland, California which showed a more representative atmospheric profile for the lower elevation mountain ranges.

Figure 14. Atmospheric profiles recorded every twelve hours from Reno, Nevada (KREV) are chronologically ordered in panels a though d, starting 00 UTC 27 October 2019 and ending 12 UTC 28 October 2019.



The lower elevations, such as the north bay, Diablo, and Santa Cruz regions, are best represented by the atmospheric profiles from Oakland, California. Skew-t diagrams of the atmospheric profiles collected from Oakland are shown in Figure 14. A robust temperature inversion was observed at 1200 UTC 27 October (Figure 14b). Significant CAA in the lower levels contributed to this inversion's strength. The atmosphere at that time was very sheared with low level winds out of the east and backing to westerly flow above the inversion. A familiar pattern is noticed where the inversion lifted briefly at 0000 UTC 28 October and a simultaneous decrease in surface winds was observed. This observation stresses the importance of the height of the stability layer and its proximity to crest height. It is the compression caused by this stable layer that forces downward deflection of mountain waves. Further, the mid-level moisture was much less prominent in the Oakland soundings than Reno. It is likely that Oakland observed drier conditions through the column because the air had undergone adiabatic compression as it crossed the Sierra Nevada and subsided into the lower elevations of coastal California. Surface pressure gradients and moisture are analyzed in the following section.

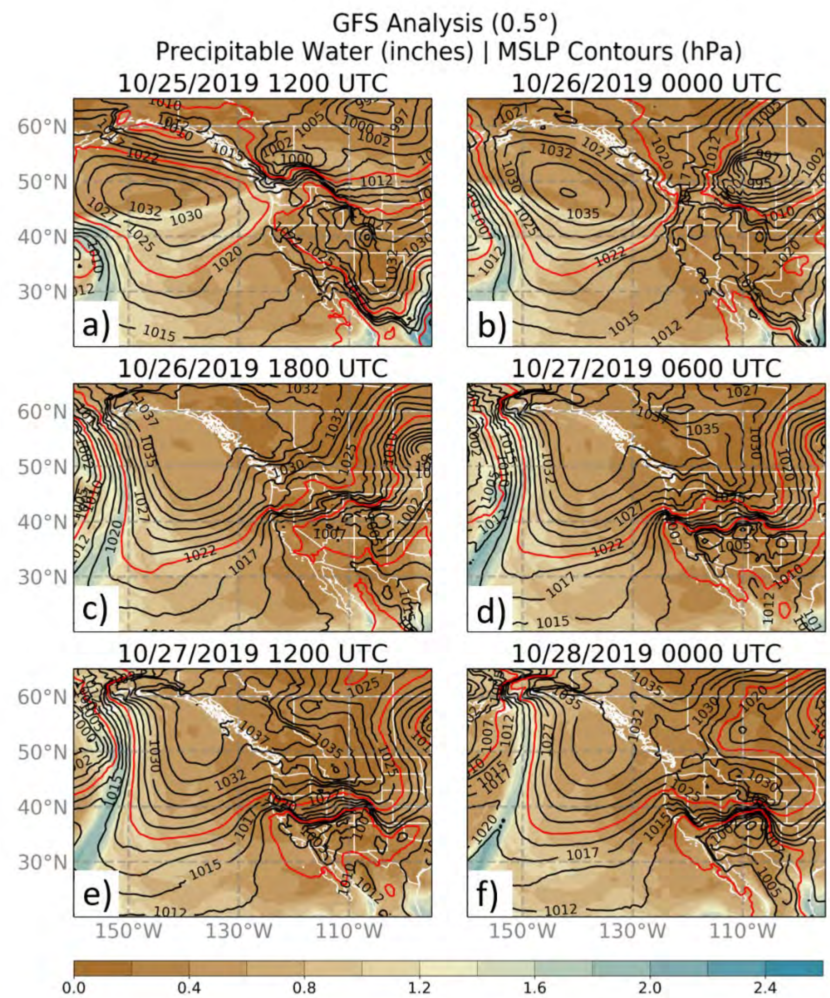
Figure 15. Atmospheric profiles recorded every twelve hours from Oakland, California (KOAK) are chronologically ordered in panels a though d, starting 00 UTC 27 October 2019 and ending 12 UTC 28 October 2019.



Surface Analysis

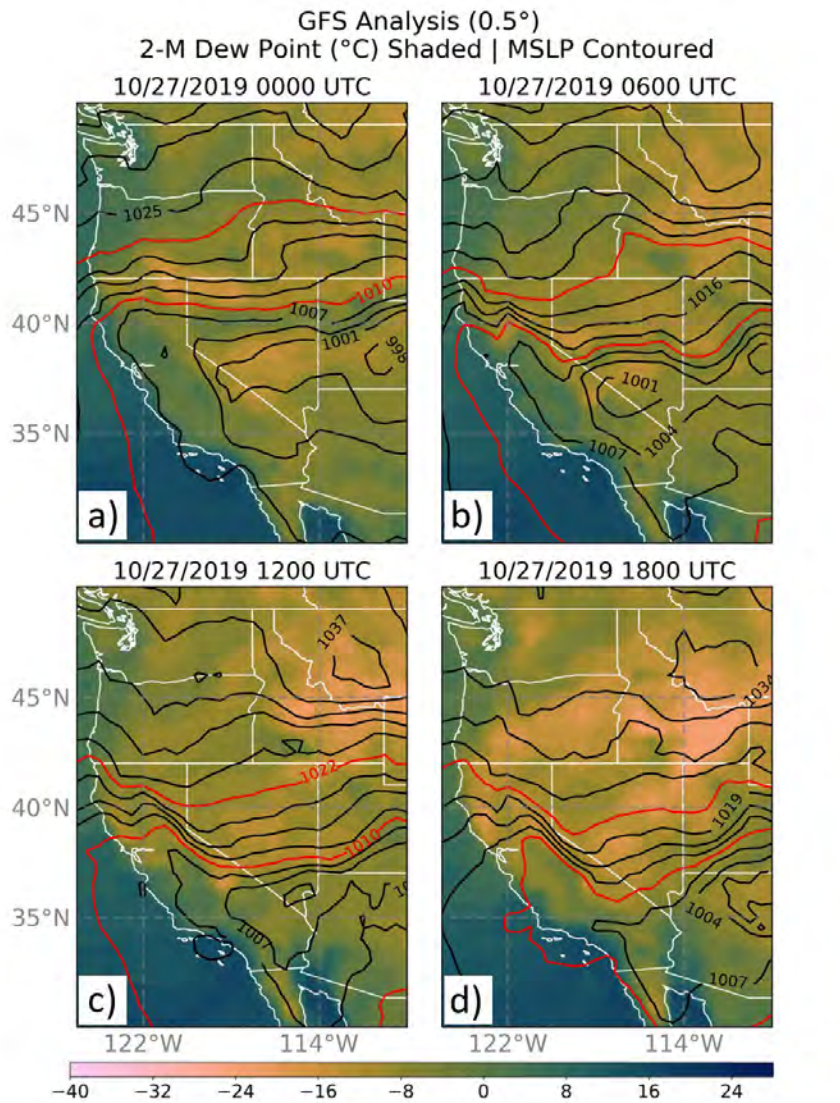
Analyses focused on the surface conditions showed important characteristics associated with this event. First, was the development of a strong surface pressure gradient that set up along the Sierra Nevada crest, and second, a swath of moisture, shown by precipitable water in Figure 6a, stretched from the central Pacific to the Washington coast. A key component of the strong pressure gradient was a high-pressure feature over British Columbia and the Gulf of Alaska that intensified (Figure 15). Twelve hours later, shown in Figure 15d, high-pressure extended into the Great Basin while an inverted surface trough developed over Southern California. The precipitable water indicated limited and scattered moisture associated with a weak low over British Columbia. The moisture variabilities are investigated further using 2-m dewpoint temperatures and surface observations to fully understand how the weather conditions attributed to enhanced fire weather risk.

Figure 16. Precipitable water shaded (inches) with mean sea level pressure (MSLP) contoured in black. Red contours are tracers of MSLP at 1010 and 1022 hPa. Time is labeled in UTC



Finer details of the surface pressure gradient and the 2-m dewpoint temperatures are shown in Figure 16. The residual surface moisture, shown in Figure 16a, extended across central Nevada and California. As the onset of the wind event approached, 0600 UTC 27 October, a majority of California experienced a small increase in 2-m dewpoint temperatures. A dry airmass eventually developed across northern California as the wind event progressed. At 1800 UTC 27 October the wind event was well underway, but the peak gusts at Pine Flat Road had already occurred which was likely due to the erosion of the inverted trough (Figure 16d). Extremely dry air was pronounced over Sonoma County and was yet another indicator that downslope winds likely occurred. Regional analyses, conducted next, search for more distinct evidence regarding the occurrence of downslope winds on the lee of their local topography.

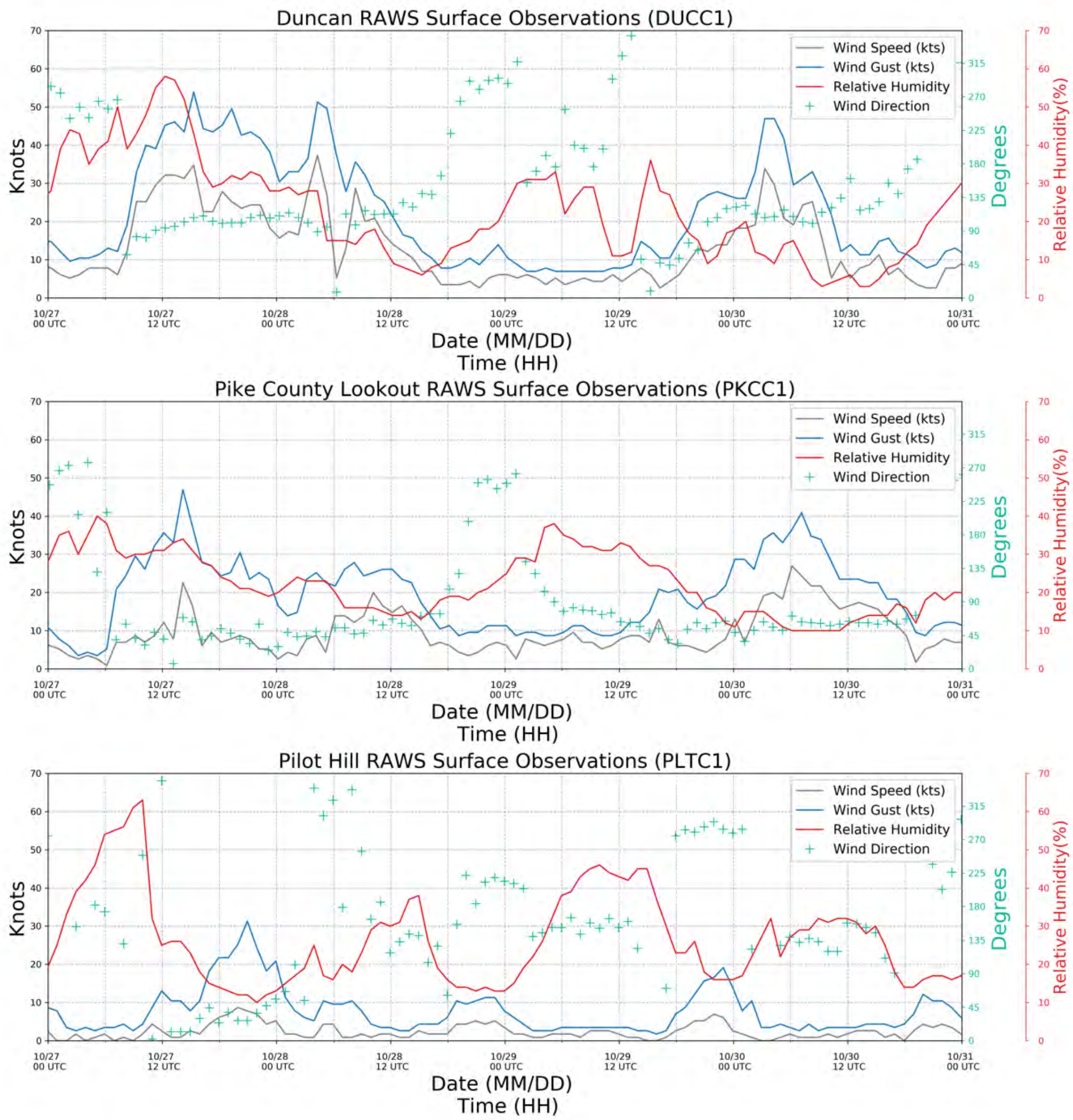
Figure 17. Dewpoint temperatures at two meters (2-m dew point) are shaded (Celsius) whit black contours of MSLP and red tracers at 1010 and 1022 hPa. Time is labeled in UTC.



Regional Analysis

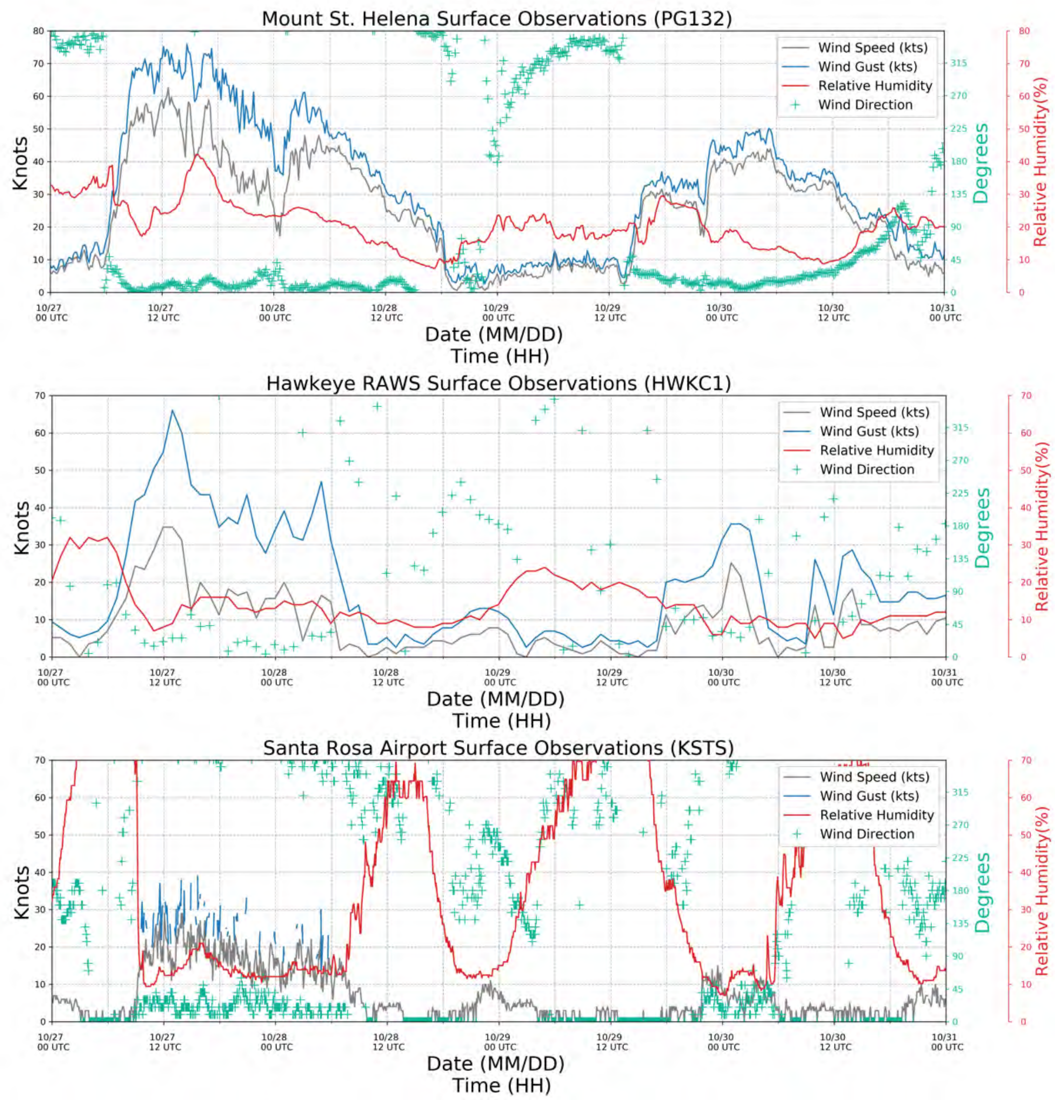
Surface observations are analyzed by region with all stations located on the lee side of the local topography. Each region has one station located near crest height, at a middle elevation, and at the base of the topography. This was chosen in order to better understand the extent of the winds in each region at different altitudes. All stations analyzed in the Sierra region (Figure 17) experienced stronger wind speeds ranging in direction from E to NE. First, the crest height location (Duncan RAWS) observed two wind maxima within the 27-28 October period. It is the vertical evolution of the inversion height, as previously discussed, that likely explains this behavior. Also, the low elevation site (Pilot Hill RAWS) observed the driest air during the wind event. This is evidence of downward mixing of dry air from aloft. Lastly, the winds only reach the base elevation site during the inversion's descent which further suggests that downslope winds occurred in the northern Sierra region. Despite these facts, a maximum in wind speed was not observed in this area. Stations in the Sierra region also observed a spike in relative humidity (RH) during the wind event while the Sonoma and Diablo regions did not see the same trend in RH.

Figure 18 Wind observations (kts) and relative humidity (%) from surface weather stations across the Sierra region The locations are in descending order from highest elevation to lowest starting with Duncan RAWS (top), Pike County Lookout RAWS (middle) and Pilot Hill RAWS(bottom). Each location recorded hourly surface observations.



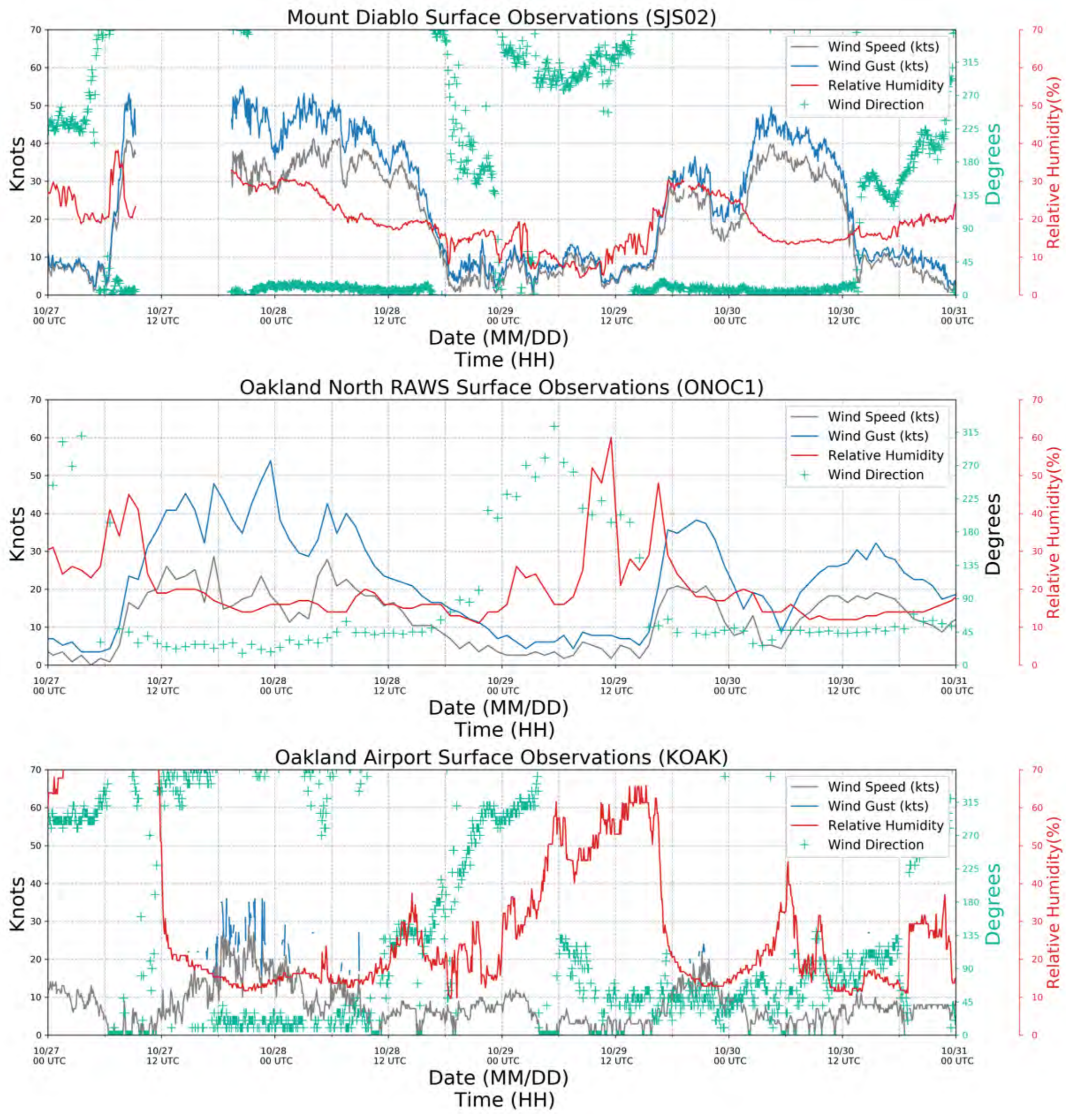
Peak surface winds were observed in the Sonoma region by the stations located near crest height. The Sonoma region had much less moisture except for the low elevation site that had marine moisture influences prior to the event (Figure 18, bottom panel). The onset of the event in this region resulted in NNE winds that gusted over 30 knots at all elevations. This indicates that in this region the winds aloft eventually mixed down to the surface extending all the way to the base of the topography. Also, RH values plummeted with the onset of the winds when the low and mid-level locations observed single-digit RH values. Single digit RH was observed at the Hawkeye RAWS with simultaneous gusts recorded in excess of 50 knots. The significance of these observations is that Red Flag Warning wind thresholds for single digit RH values are 5-10 knots. The combination of wind and very dry air, likely exacerbated by downslope winds, made this event incredibly significant in the Sonoma region.

Figure 19. Wind observations (kts) and relative humidity (%) from surface weather stations across the Sonoma region The locations are in descending order from highest elevation to lowest starting with Mount St. Helena (top), Hawkeye RAWS (middle) and Santa Rosa Airport (bottom). Santa Rosa recorded five minute observations, Mount St. Helena recorded ten minute observations, and Hawkeye RAWS recorded hourly observations.



The Diablo Range similarly exhibited evidence of downslope winds. The onset of the event at the base of the topography, Oakland Airport, is indicated by the vertical red line in Figure 19 which represents the sharp decrease in RH values. From Figure 19, the driest air occurred in the low elevations shortly after the onset of the event. Winds from the NNE were observed at all elevations and again provide evidence of downslope winds in the region. Before the onset of the downslope winds, the presence of the marine layer was observed by higher RH values >70% at Oakland Airport. It should also be noted that Half Moon Bay airport observed downslope winds in the Santa Cruz Mountains (not shown). All three regional analyses have provided evidence of a downslope windstorm in the lee of their local topography. This confirmed that this event was widespread and not localized to higher elevations.

Figure 20. Wind observations (kts) and relative humidity (%) from surface weather stations across the Diablo region The locations are in descending order from highest elevation to lowest starting with Mount Diablo (top), Oakland North RAWS (middle) and Oakland Airport (bottom).Mount Diablo and Oakland Airport recorded five minute observations while Oakland North recorded hourly observations.



Lastly, widespread damage potential for the primary event has been established with downslope winds more than likely in all three regions analyzed. Further, restoration operations only had about twenty-four hours before another wind event unfolded. Sustained winds at Pine Flat Road subsided to below 20 knots at approximately 1200 UTC 28 October. Then 27 hours later, at approximately 1500 UTC 29 October, sustained winds again increased to over 20 knots and persisted for nearly twenty-four hours. This secondary wind event was not the focus of this analysis, but the figures have extended timelines which show details about the secondary event. It should be noted that while this second event had much less damage potential, it was a huge threat to restoration operations in all three regions. This secondary wind event was associated with an additional shortwave that propagated along the already meridionally oriented jet.

Finally, Northern California had significantly less impacts associated with the secondary event, but the Santa Ana Winds were extremely active in Southern California. Again, improved spatial and temporal atmospheric vertical profile observations are needed to better understand and forecast when and where the winds will mix to the surface and cause significant impacts to utility infrastructure.

APPENDIX B: ANALYSIS OUTPUTS FOR SIGNIFICANT DAMAGE INCIDENTS

This appendix provides a description of the fire spread prediction and impact analysis outputs for the most significant damage incidents matching those summarized in Section 5. Maps are provided for both the deterministic and probabilistic simulations. Building footprints are shown in both maps as reference. In addition, the deterministic boundary is also shown in each probabilistic map as reference. Map scale varies across the maps as they are sized to match simulation extent. Each simulation represents a 24 hour duration.

For each incident, critical input data such as wind speed and direction are analyzed, including fire behavior and impact metrics shown through tables and figures.

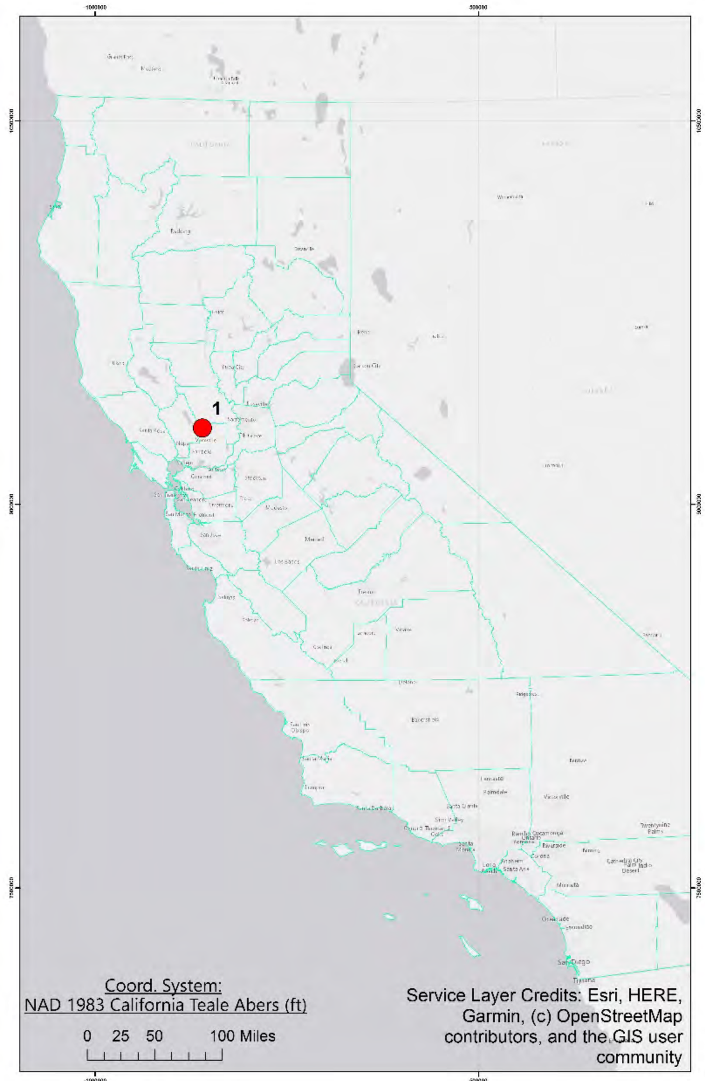
Two weather charts are included for each fire simulation, representing hourly wind direction and speed throughout the incident (i.e. 24 hours) for the nearest weather station and modeled winds for the weather station location point and the ignition location of the incident. In this sense, wind data uncertainty is shown both spatially and temporally.

Two charts on fire behavior are included in each simulation to show the rate of spread and flame length (i.e. fire intensity) throughout the fire duration with well-known variable thresholds established in fire science.

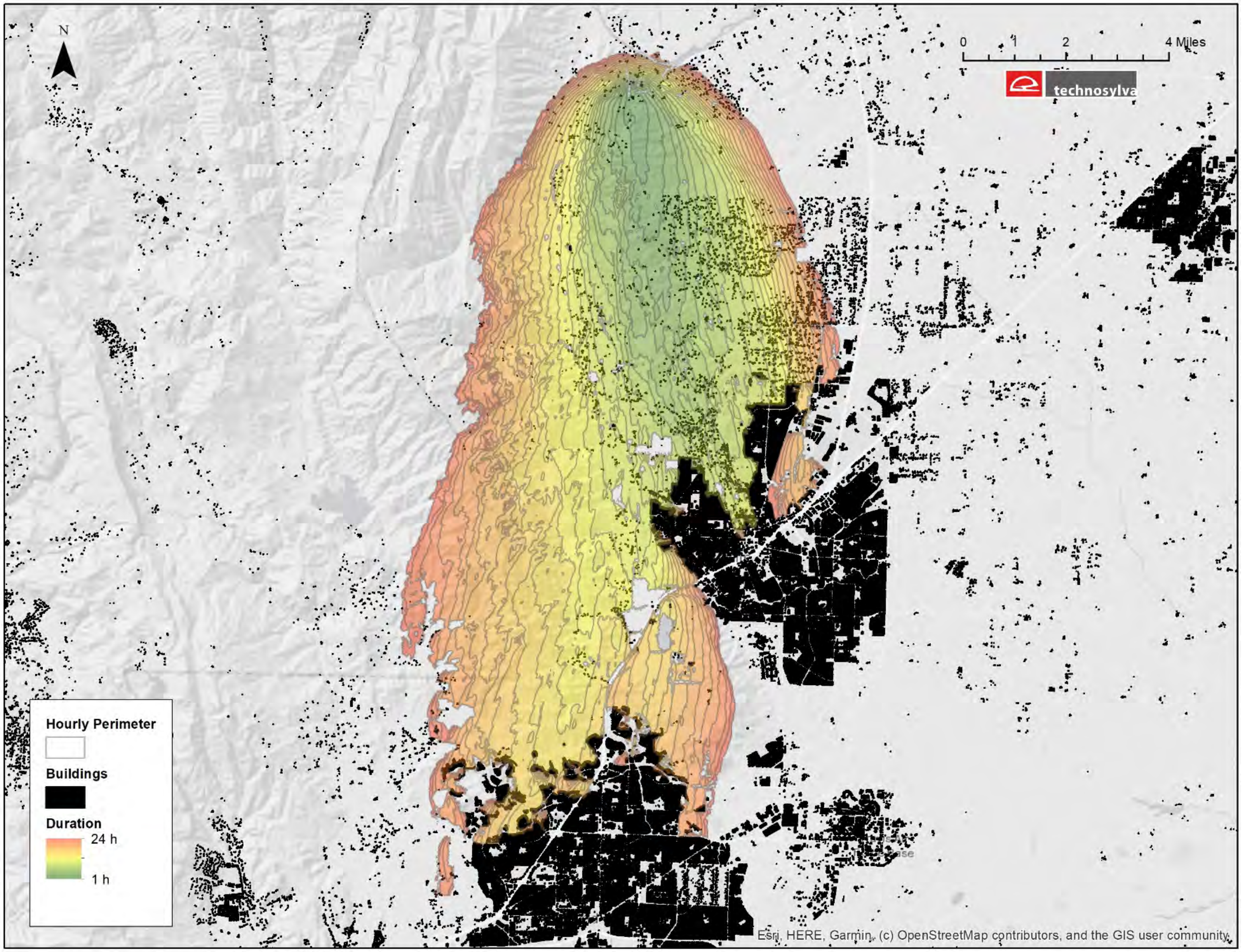
DAMAGE INCIDENT – 1

This damage incident is located in Vacaville near the San Francisco Bay. The fire would mostly burn grass fuel types and combined with shrubs with high wind speeds (20 mi/h) resulting in very high rate of spread exceeding 150 ch/h in some areas of the fire giving rise an IAA = 5. The fire intensity would be low-moderate. The incident is located in a fire-prone area with lots of fires in the last years. The WRAGG fire in 2015 (8,051 ac) or the WINTER fire in 2017 (1,700 ac) are only two examples. The fire impacts on buildings could be very high (almost 7,300 buildings threatened), even considering low encroachment. The amount of population threatened in the October 26 PSPS event is the highest for this event.

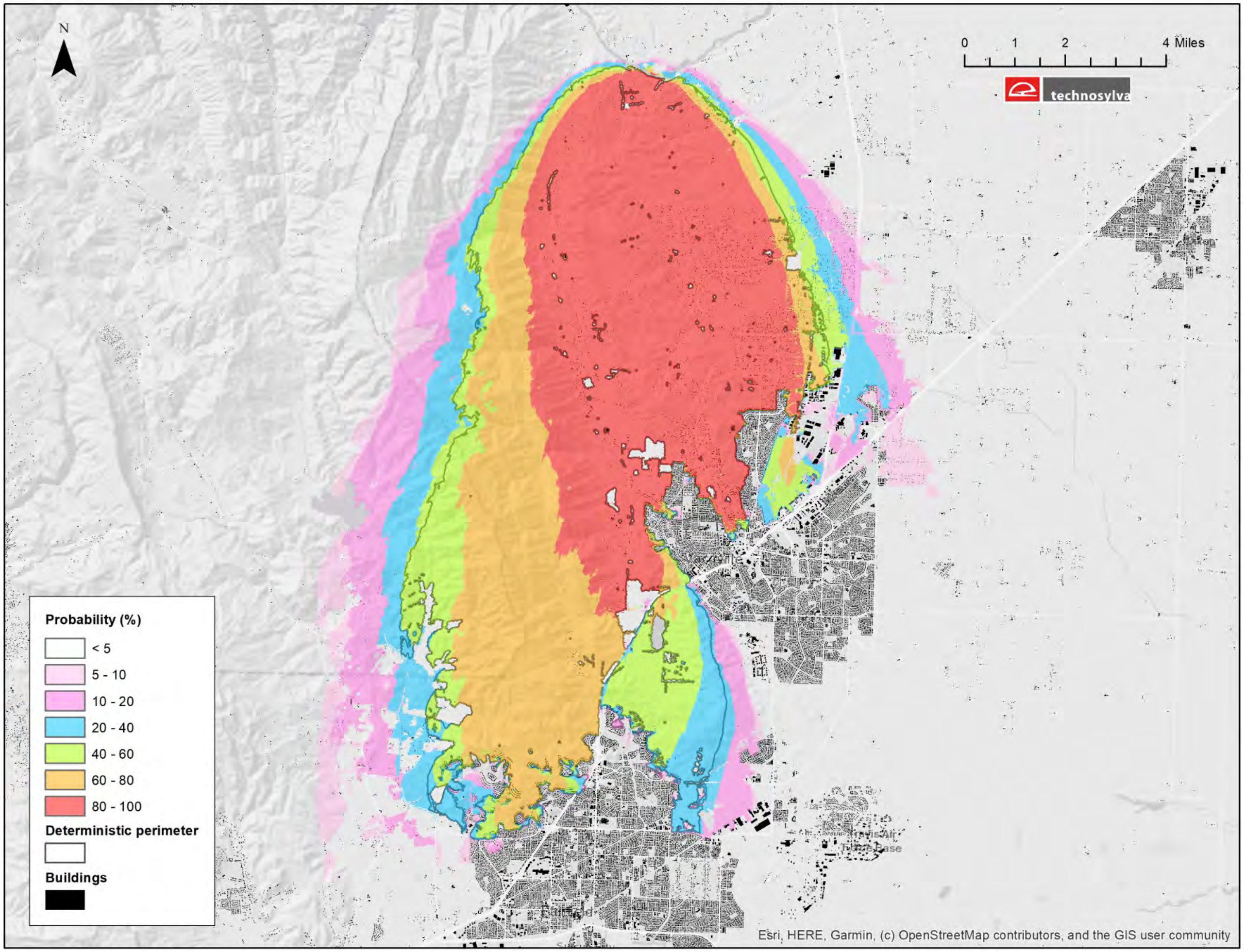
INCIDENT SUMMARY	
Start Time	10/27/19 - 00:00
Duration (hrs)	24
Size (ac)	50,228
Initial Attack Assessment	5 - Extreme
No. of Buildings	6,927
Total Population	13,384
Average ROS	High



DAMAGE INCIDENT NO. 1 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 1 : PROBABILISTIC SIMULATION



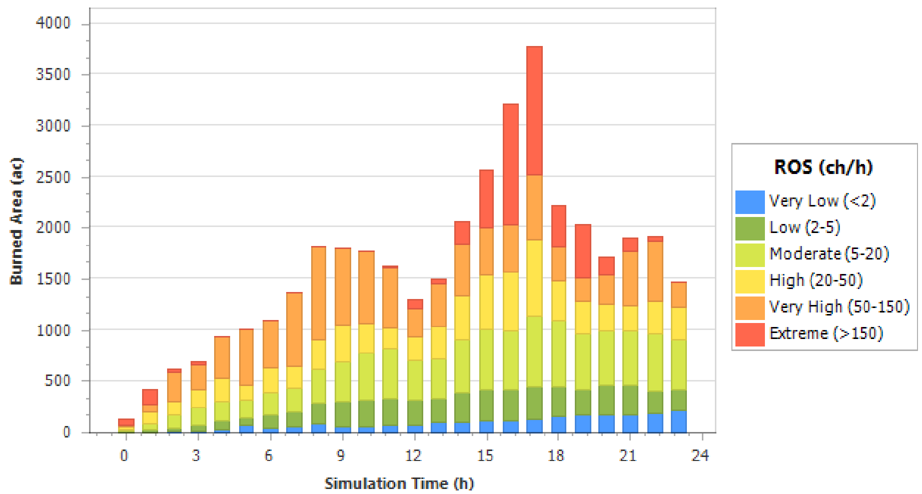
DAMAGE INCIDENT NO. 1

FIRE BEHAVIOR

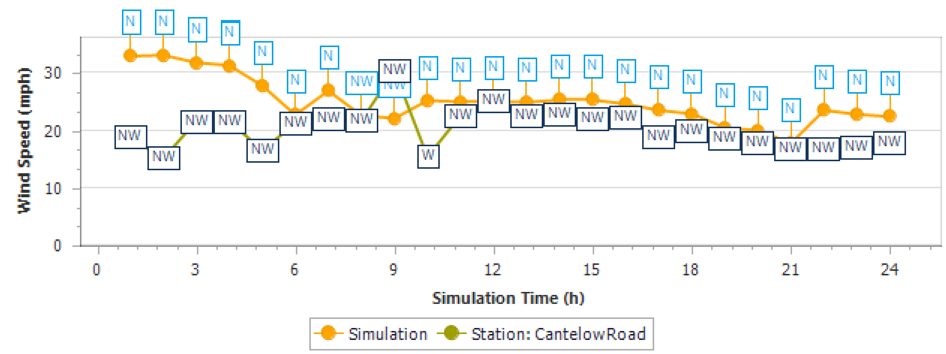
WEATHER

Nearest Station: Blue Sky Road

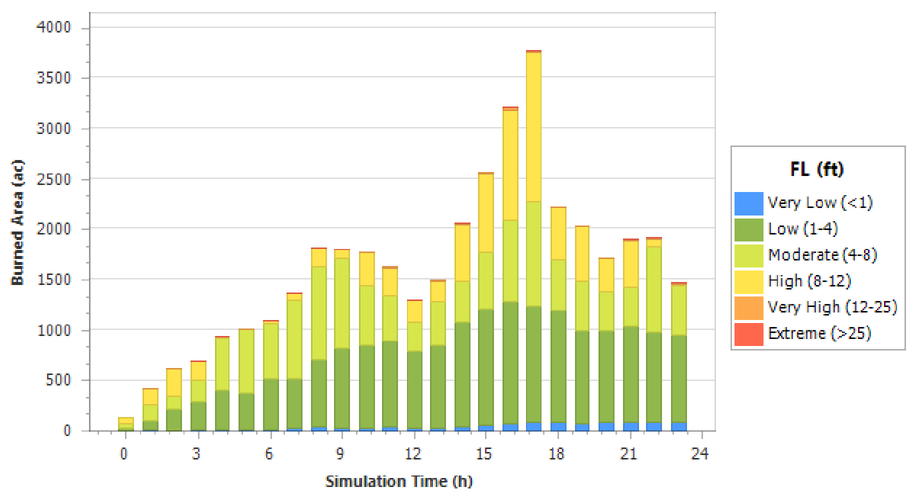
Rate of Spread

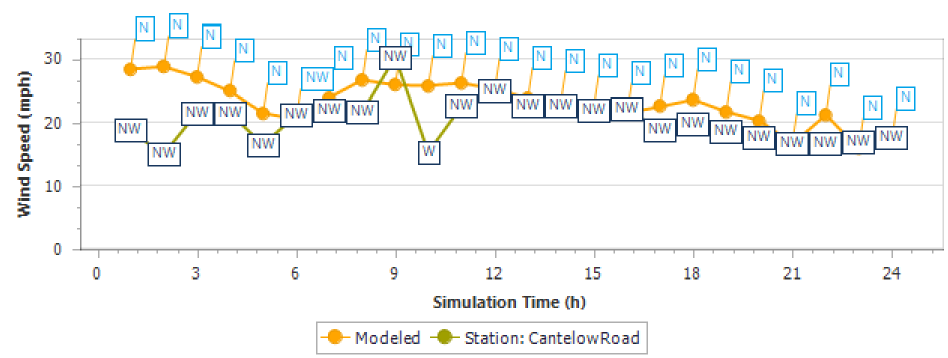


Station ID - PG431
Weather station (Wx) elevation - 618 ft
Fire ignition point (IP) elevation - 164 ft
Distance between Wx and IP - 3.68 mi



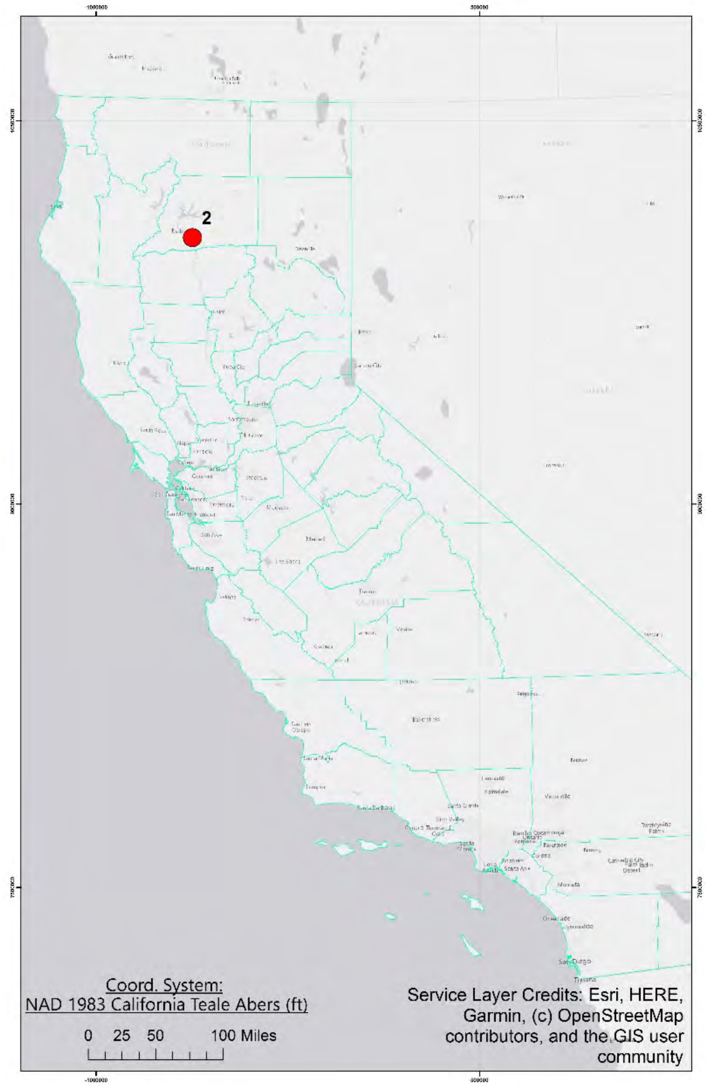
Flame Length





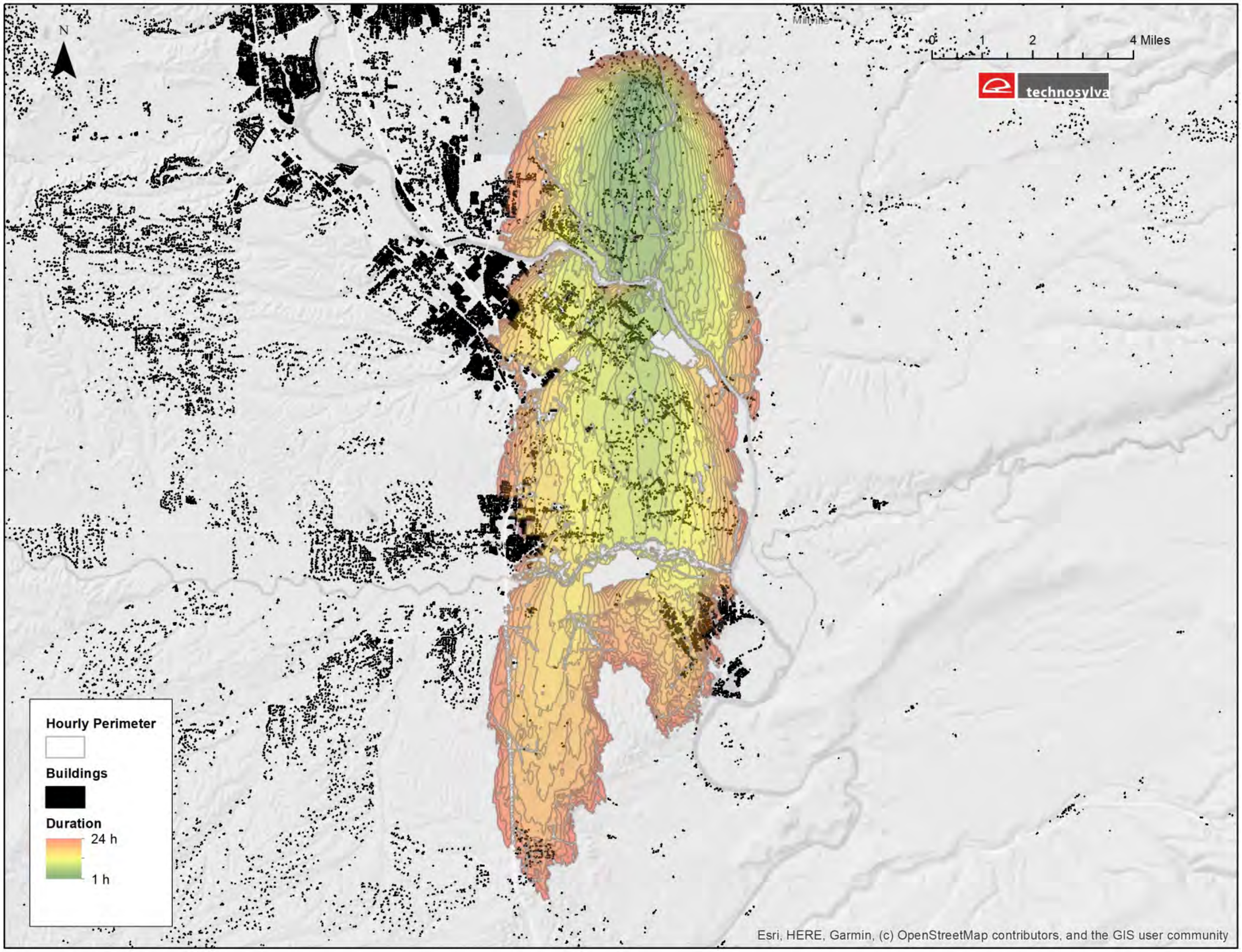
DAMAGE INCIDENT – 2

This incident is located in Redding in the county of Shasta, mostly burning grass fuel types (GR1 and GR2). Fire would spread very rapidly presenting substantial resistance to control with an IAA of 5 (Extreme) with high wind coming from north (20-25 mi/h) although the fire intensity would be low-moderate. Near the damage incident location, there were several large fires in the last decades: JONES (26,202 ac; 1999) and BEAR (10,441; 2004) are two examples. The fire impacts on buildings could be very high with lots of buildings threatened even considering a low encroachment during the fire due to the fuel types burned.

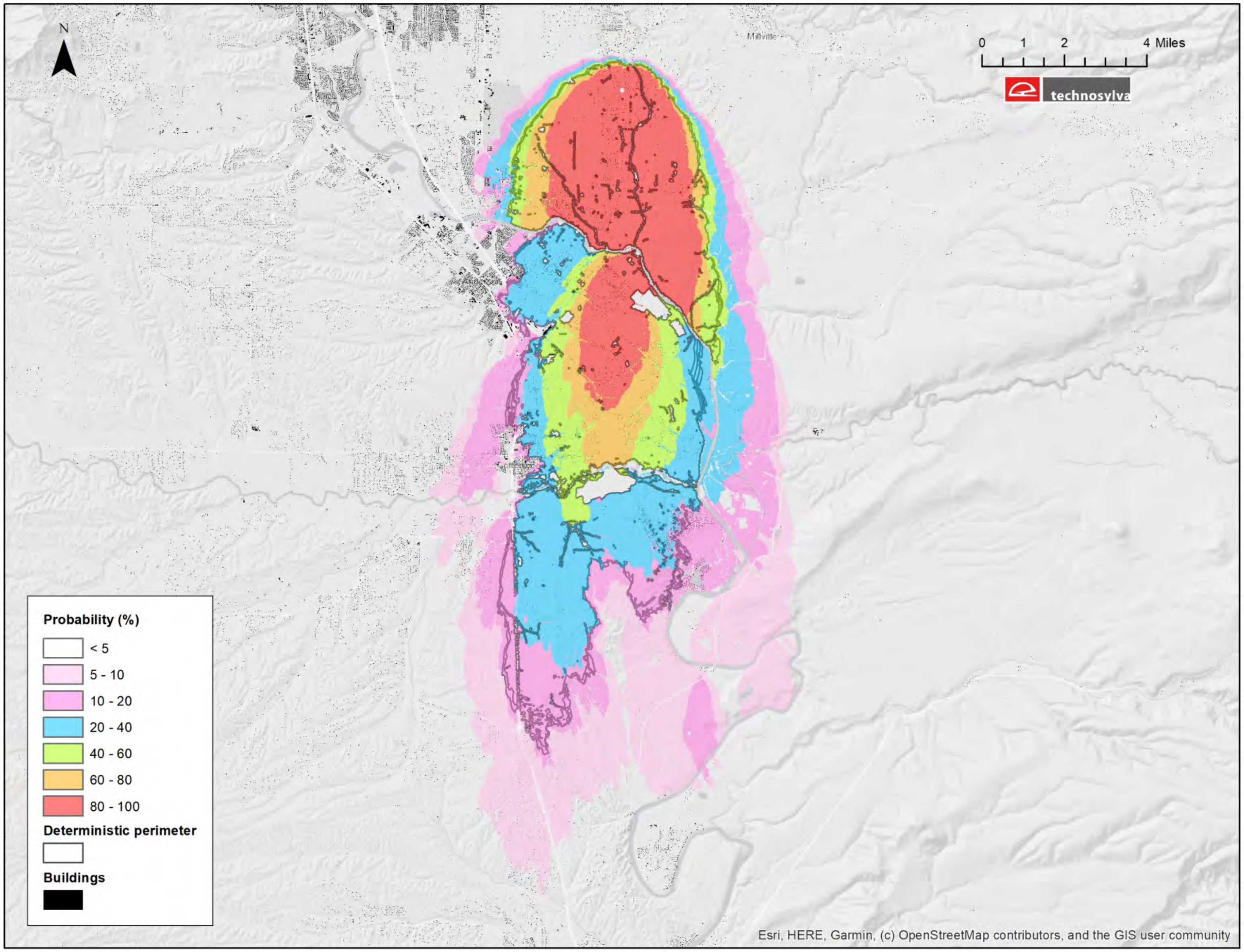


INCIDENT SUMMARY	
Start Time	10/27/19 - 00:00
Duration (hrs)	24
Size (ac)	36,981
Initial Attack Assessment	5 - Extreme
No. of Buildings	4,835
Total Population	7,750
Average ROS	High

DAMAGE INCIDENT NO. 2 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 2 : PROBABILISTIC SIMULATION



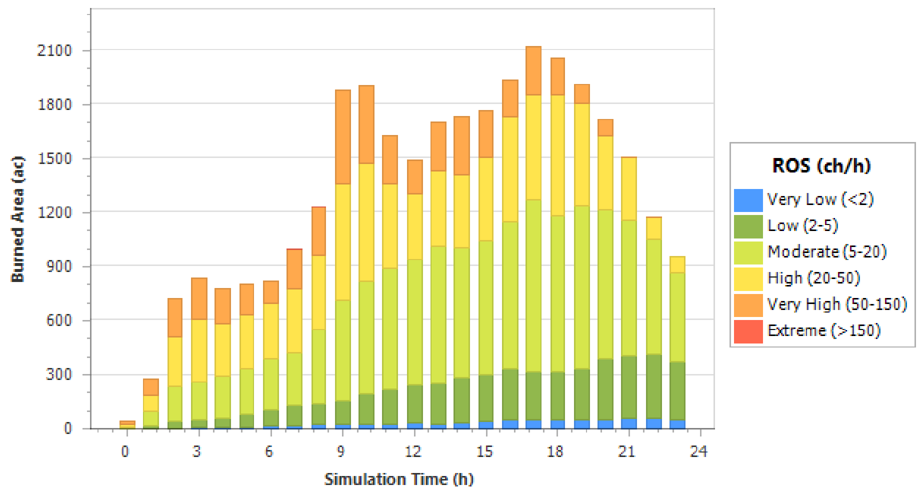
DAMAGE INCIDENT NO. 2

FIRE BEHAVIOR

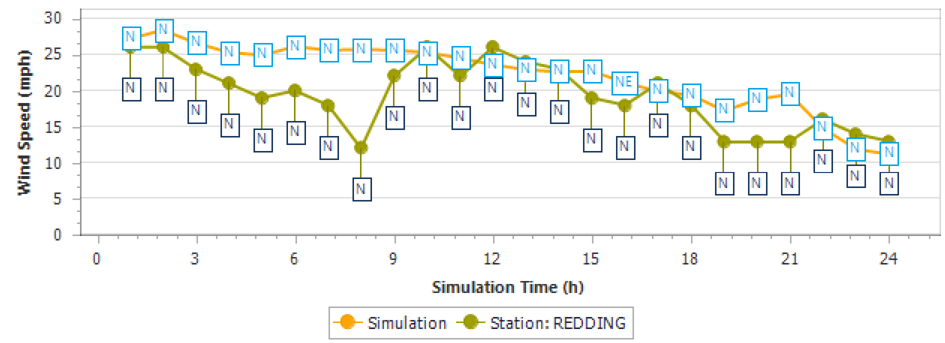
WEATHER

Nearest Station: Blue Sky Road

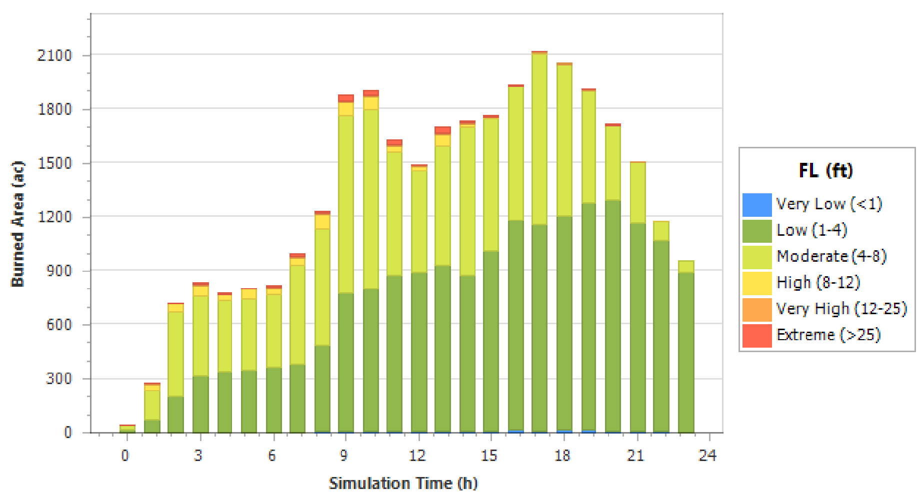
Rate of Spread

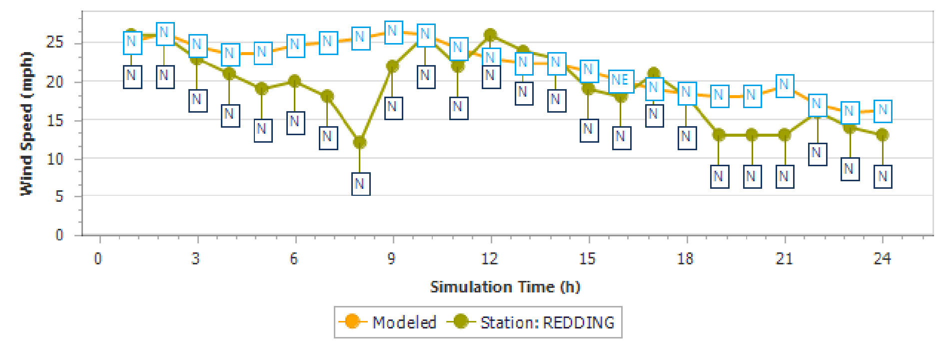


Station ID - RRAC1
Weather station (Wx) elevation - 499 ft
Fire ignition point (IP) elevation - 95 ft
Distance between Wx and IP - 2.83 mi



Flame Length

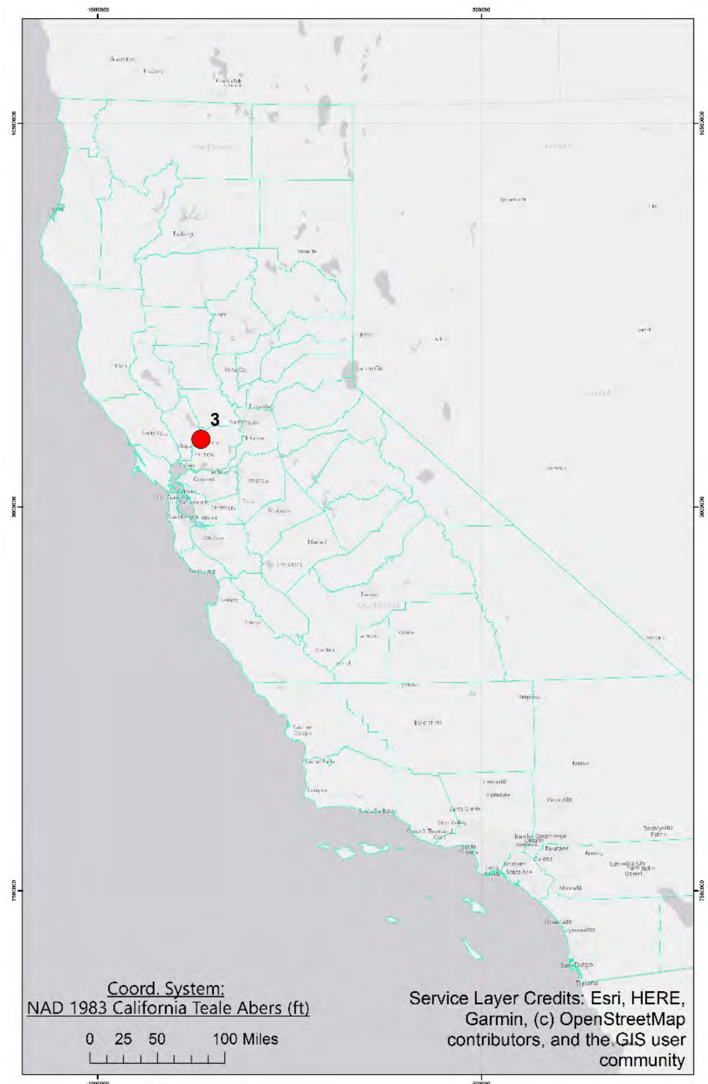




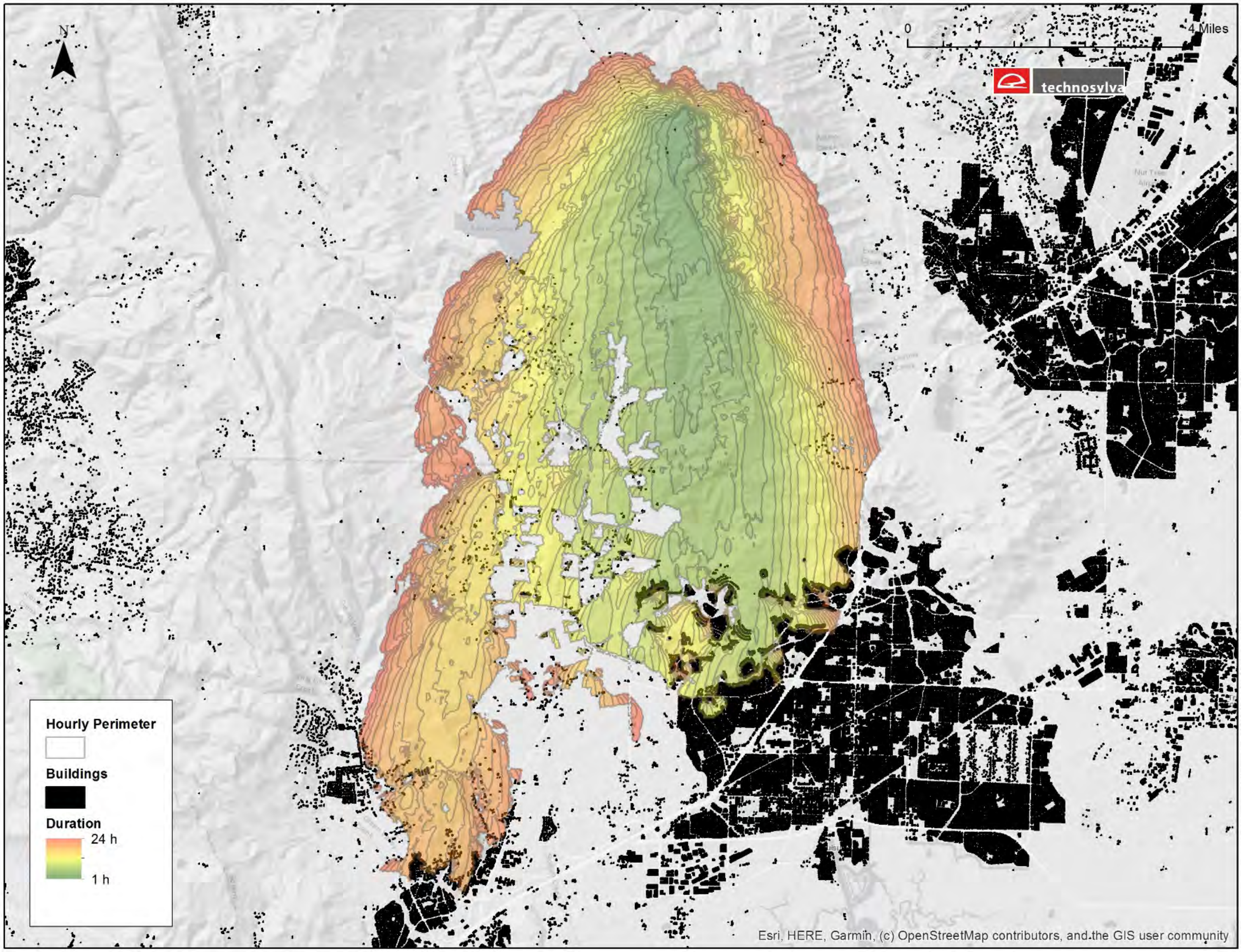
DAMAGE INCIDENT – 3

This damage incident is located in the county of Solano. Fast fire driven by high winds (30 mi/h) on grass fuels that may affect lots of buildings and population due to it could reach the Wildland Urban Interface area of Fairfield. Both the average rate of spread and flame length would be high. The incident is located in an area with lots of historical fire incidents including the Miller fire burning all this area in 1985. The fire impacts on buildings and population could be very high as reflected in the incident summary table.

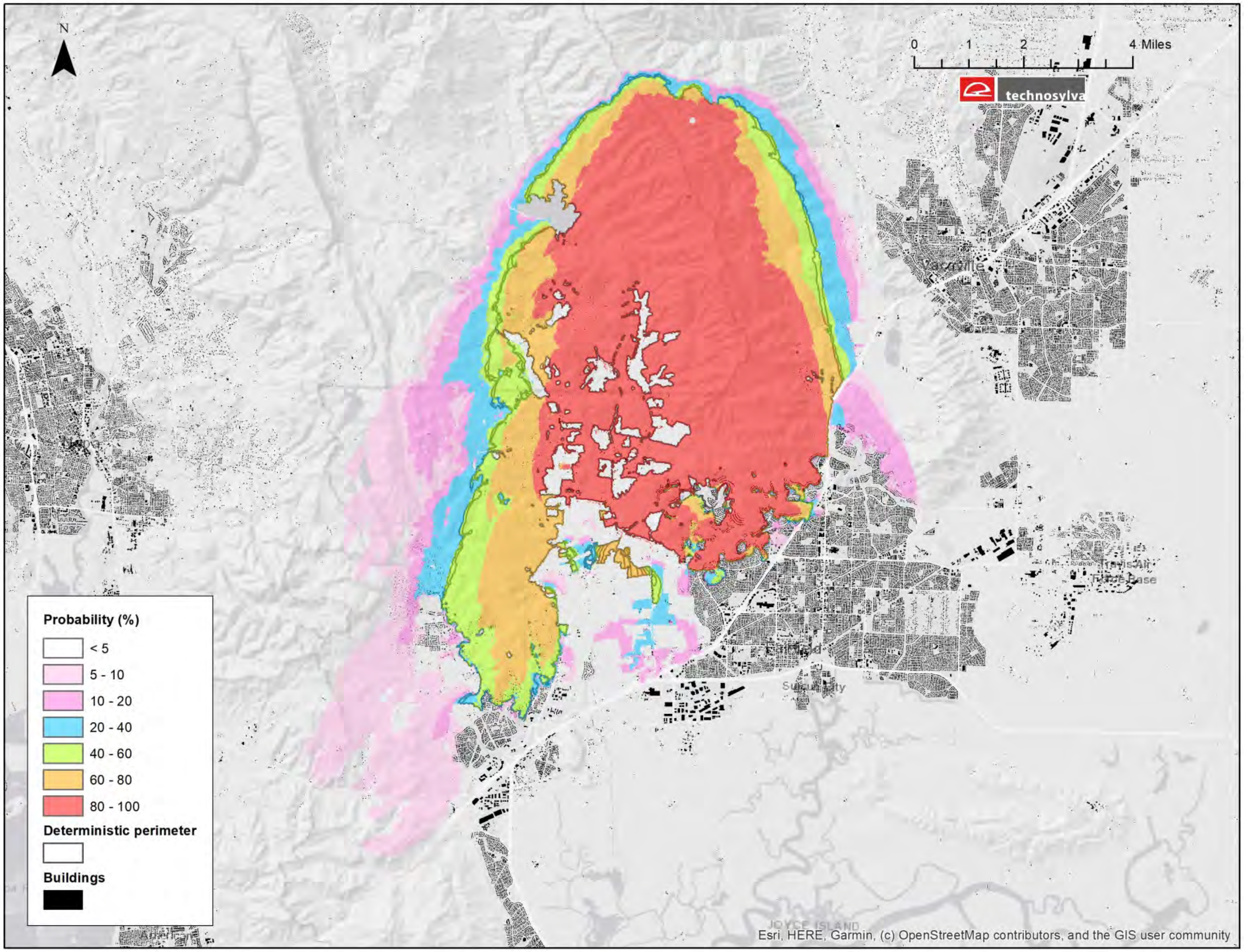
INCIDENT SUMMARY	
Start Time	10/09/19 - 21:00
Duration (hrs.)	24
Size (ac)	8,162
Initial Attack Assessment	5 - Extreme
No. of Buildings	3,169
Total Population	7,211
Average ROS	High



DAMAGE INCIDENT NO. 3 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 3 : PROBABILISTIC SIMULATION



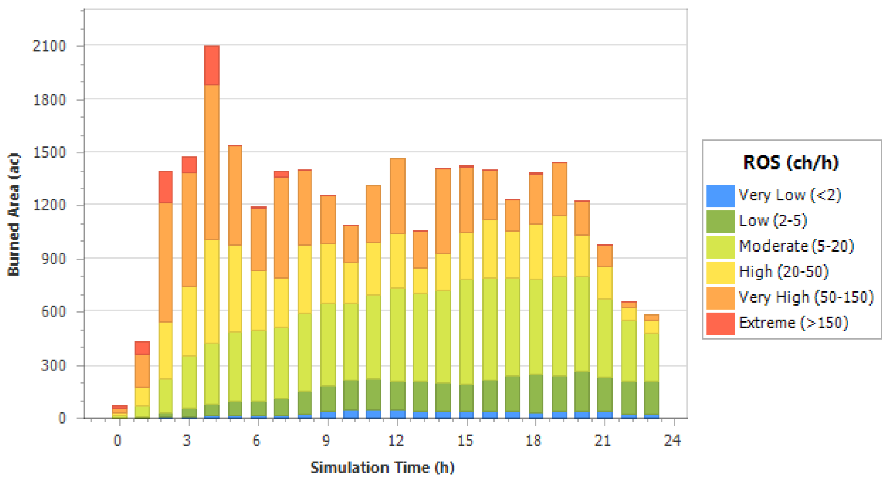
DAMAGE INCIDENT NO. 3

FIRE BEHAVIOR

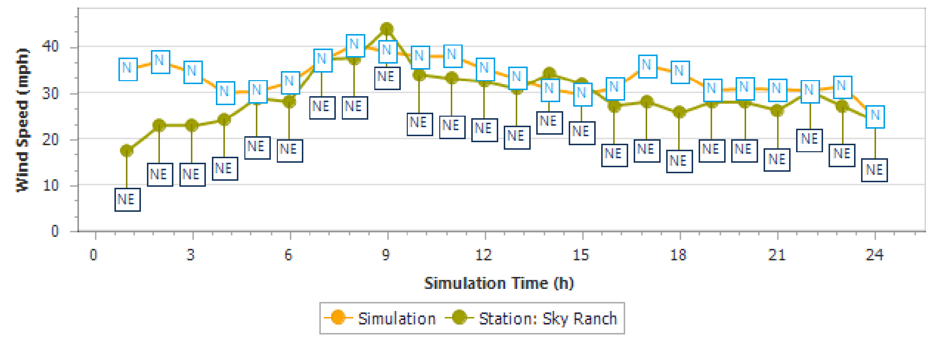
WEATHER

Nearest Station: Cantelow Road

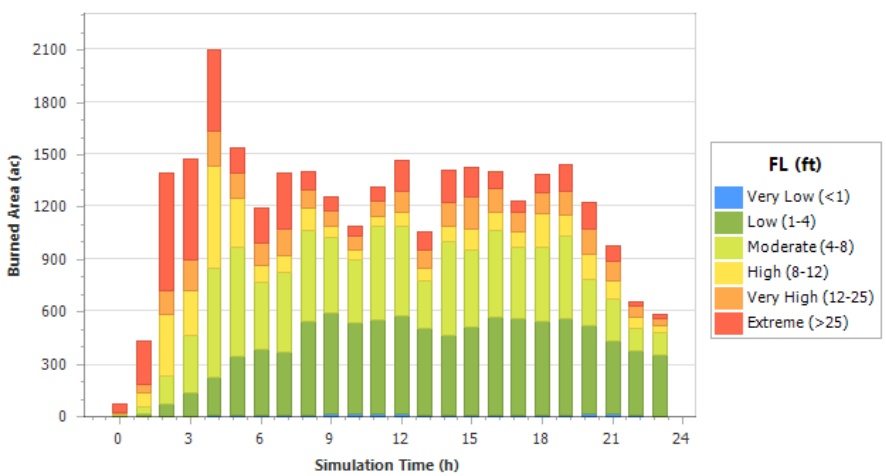
Rate of Spread

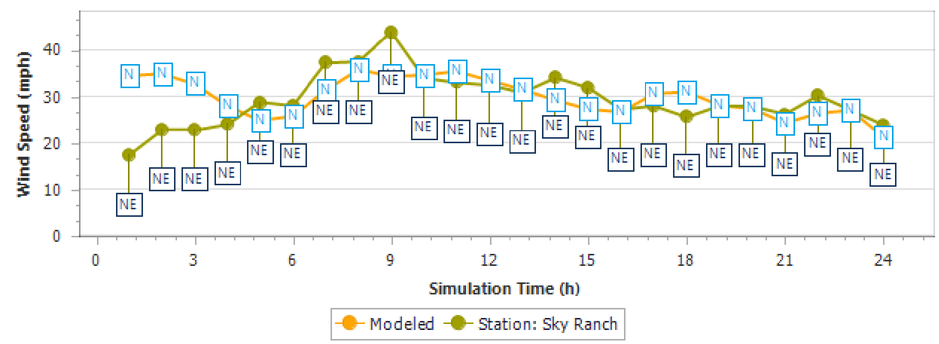


Station ID - PG230
Weather station (Wx) elevation - 2007 ft
Fire ignition point (IP) elevation - 1743 ft
Distance between Wx and IP - 2.25 mi



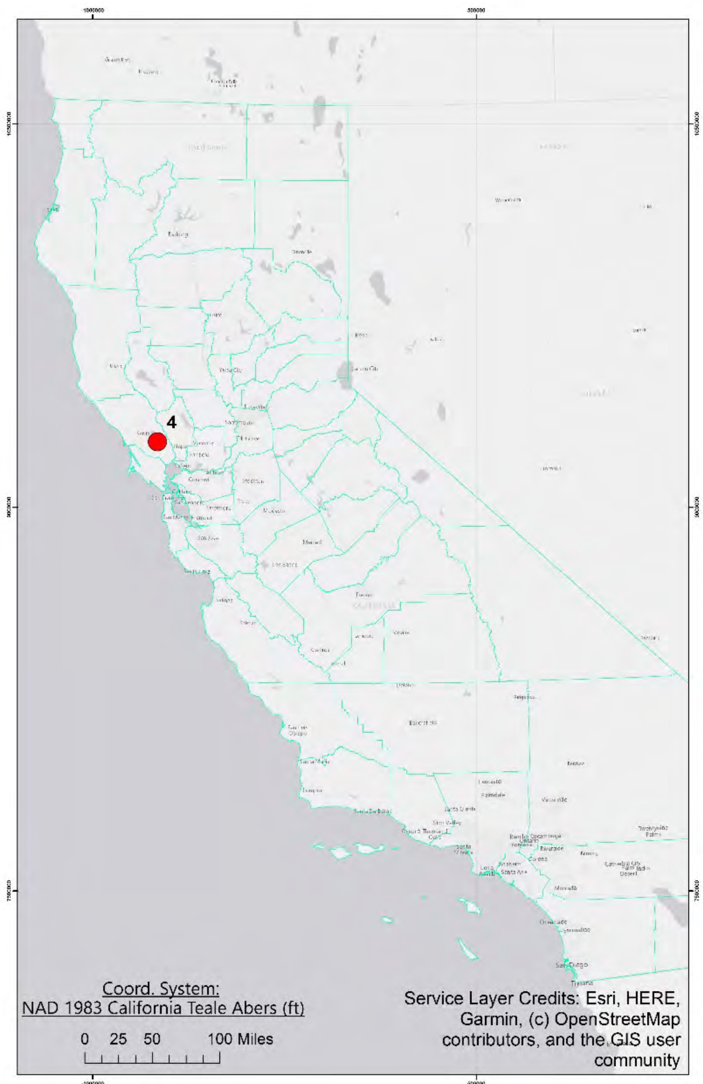
Flame Length





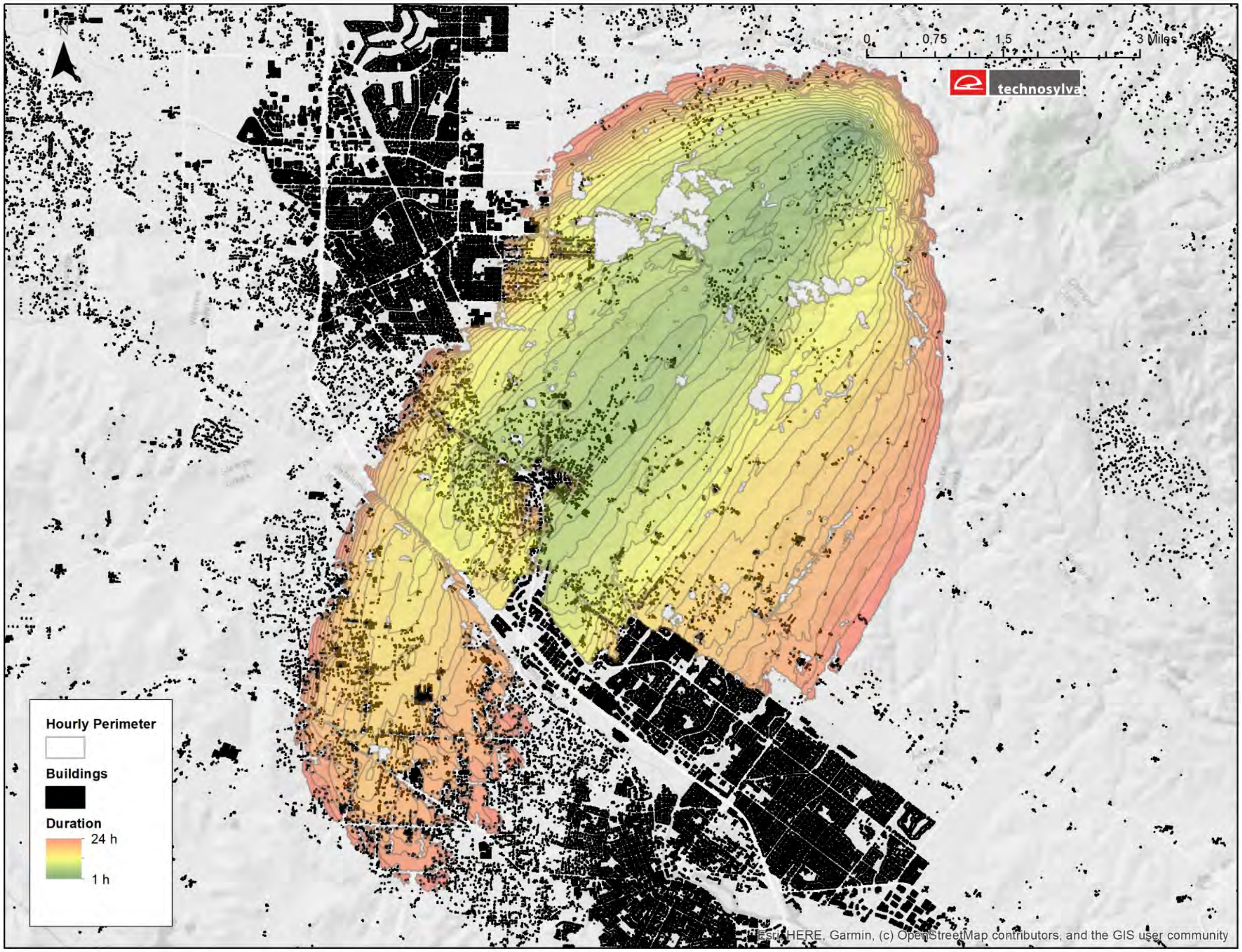
DAMAGE INCIDENT – 4

This incident is located north of San Francisco Bay where the fire could have directly impacted the dense Wildland Urban Interface of Petaluma, potentially causing losses in a high amount of buildings. It would be a wind driven fire (20 mi/h winds from NE on grass fuel types (GR2). The Rate of Spread would be high with moderate fire intensity. Historically, there were a several wildfires in the studied area such as the NUNS fire (55,797; 2017), or the P.G.& E.#5 fire in 1965.

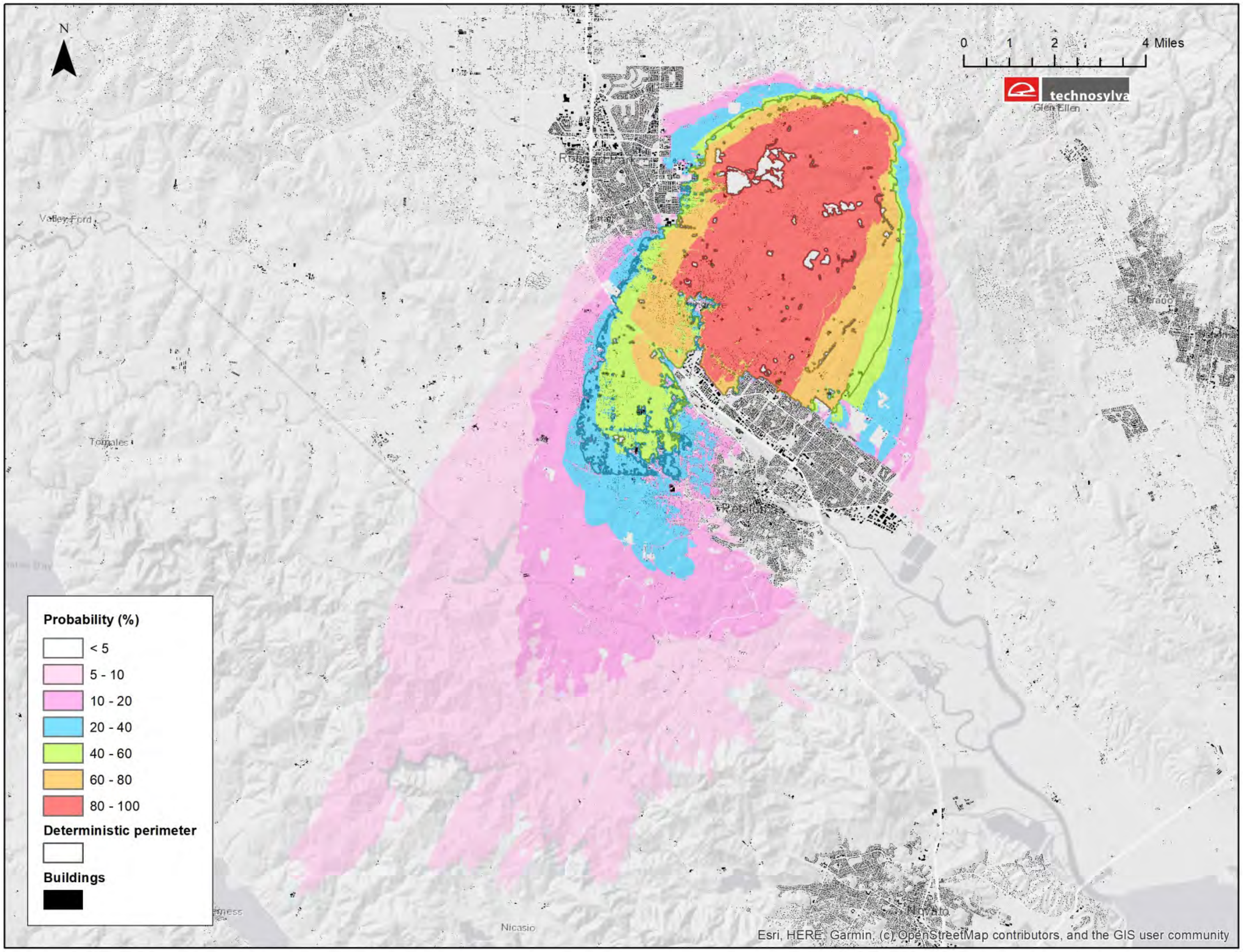


INCIDENT SUMMARY	
Start Time	10/27/19 - 00:00
Duration (hrs)	24
Size (ac)	22,736
Initial Attack Assessment	4 - Very High
No. of Buildings	5,344
Total Population	6,807
Average ROS	High

DAMAGE INCIDENT NO. 4 : DETERMINISTIC SIMULATION



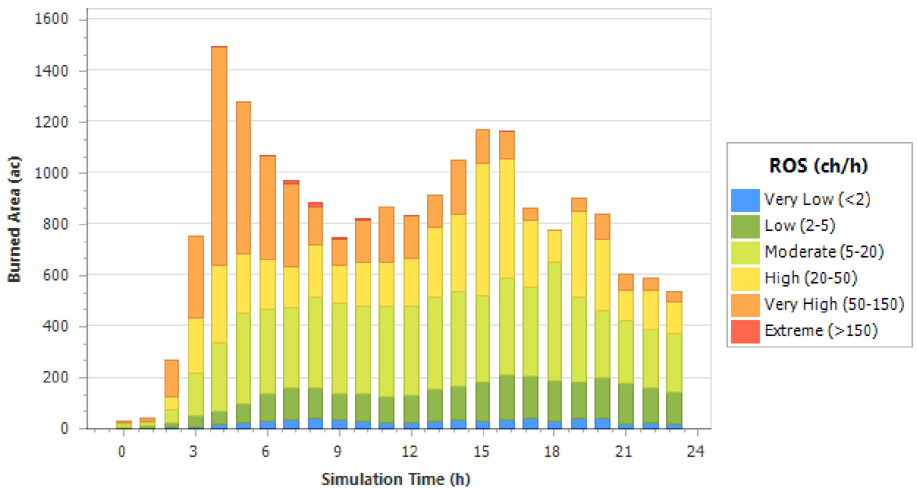
DAMAGE INCIDENT NO. 4 : PROBABILISTIC SIMULATION



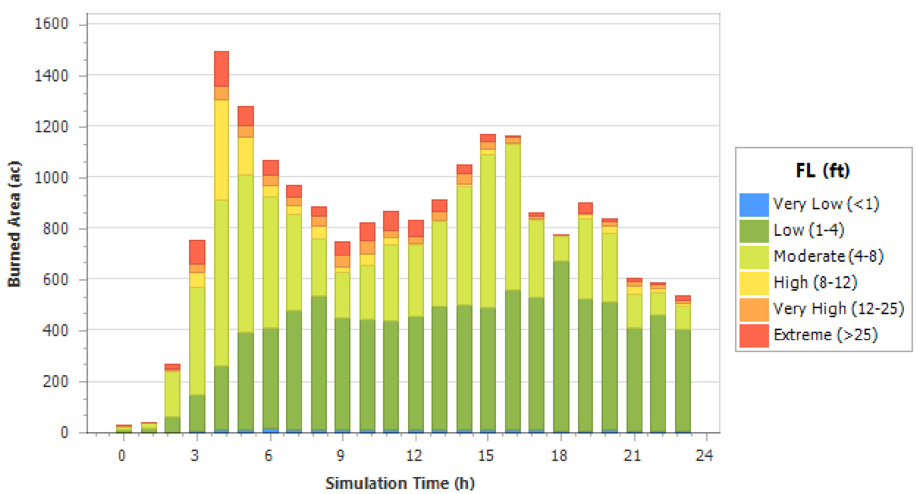
DAMAGE INCIDENT NO. 4

FIRE BEHAVIOR

Rate of Spread



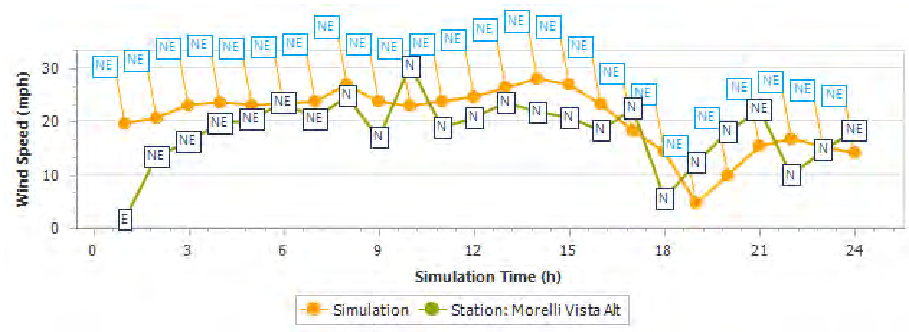
Flame Length

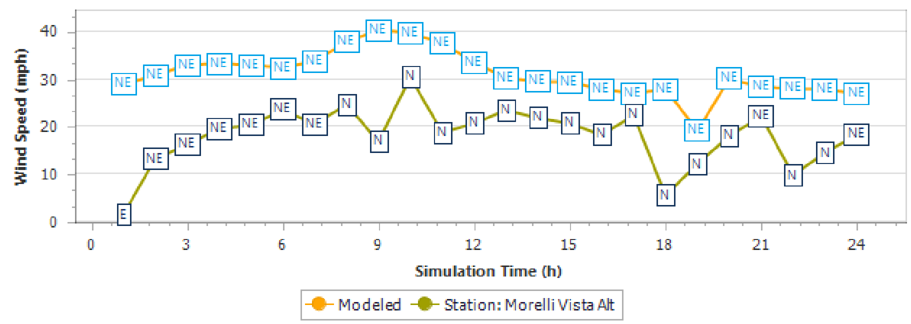


WEATHER

Nearest Station: Gallagher Road

Station ID - PG562
Weather station (Wx) elevation - 1095 ft
Fire ignition point (IP) elevation - 1520 ft
Distance between Wx and IP - 2.33 mi



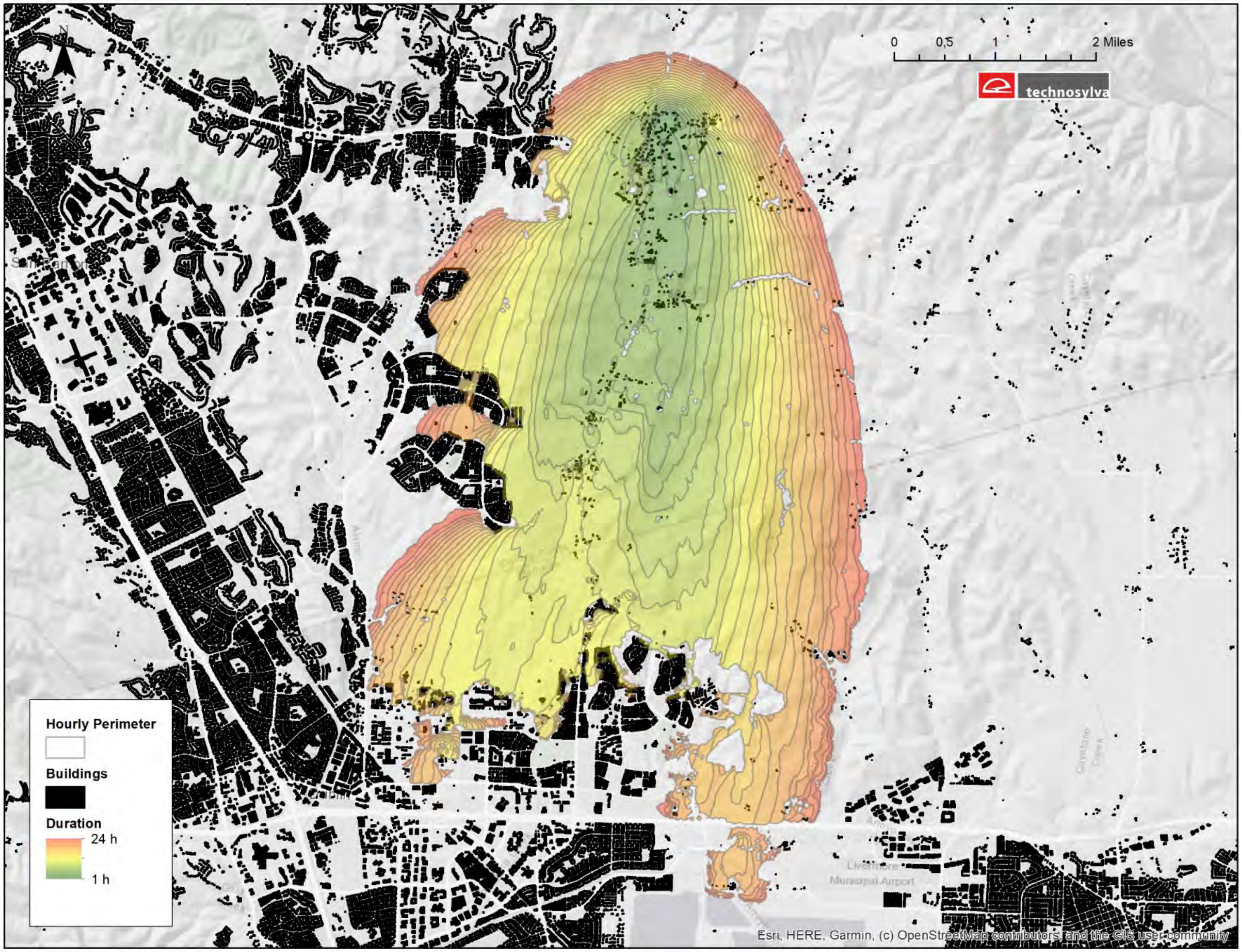


DAMAGE INCIDENT – 5

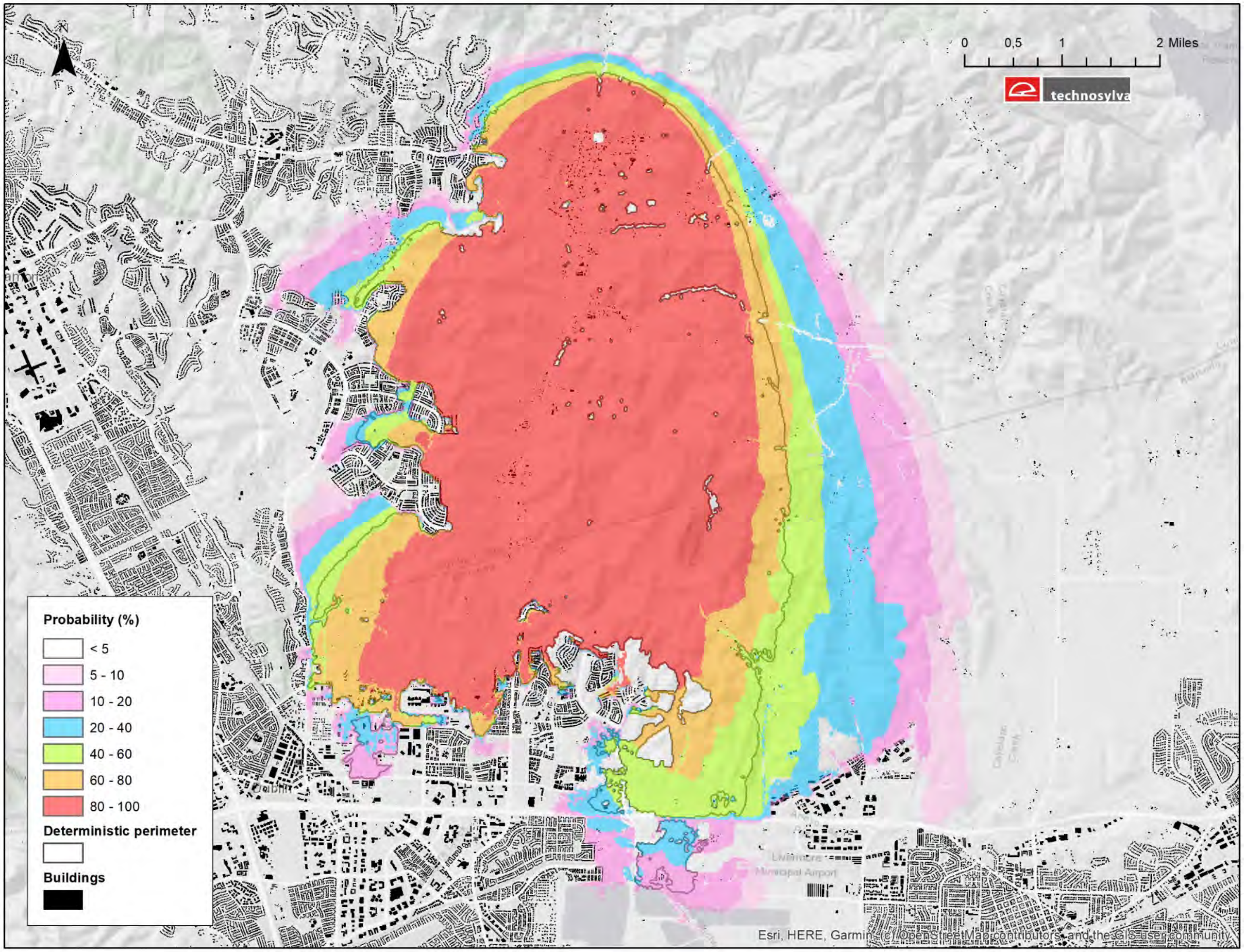
This incident is located in Contra Costa County, mostly burning grass fuel types (GR1 and GR2). The Rate of Spread is high from the fire with values higher than 50 chains/hr due to high winds (30 mi/h) as reflected in the charts below, resulting in an IAA of 4 (Very High). The number of threatened buildings could be very high due to the presence of scattered buildings throughout the landscape and the fire progression and dense urban Wildland Urban. Historically, there were similar fires in the studied area (30-40 years ago): BLACKHAWK (1981), STATE PARK #2 (1961), MITCHELL CANYON.

INCIDENT SUMMARY	
Start Time	10/27/19 - 00:00
Duration (hrs)	24
Size (ac)	15,771
Initial Attack Assessment	4 – Very High
No. of Buildings	1,163
Total Population	6,425
Average ROS	Very high

DAMAGE INCIDENT NO. 5 : DETERMINISTIC SIMULATION



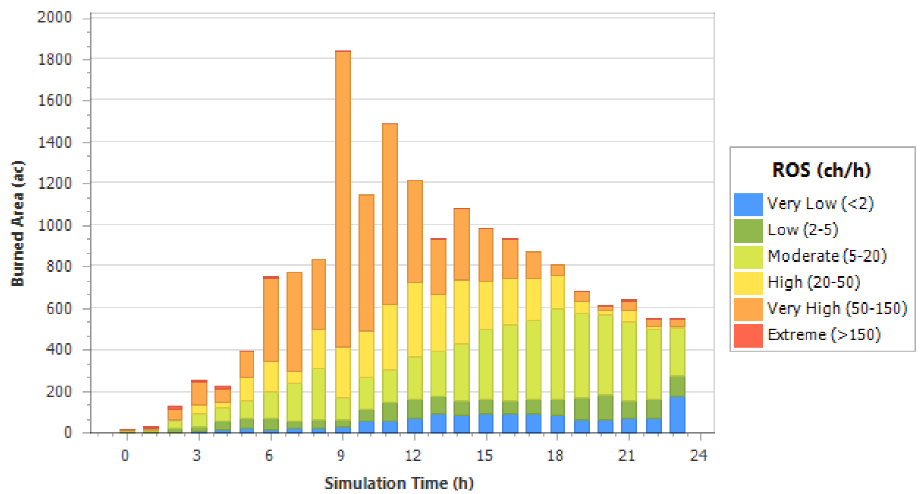
DAMAGE INCIDENT NO. 5 : PROBABILISTIC SIMULATION



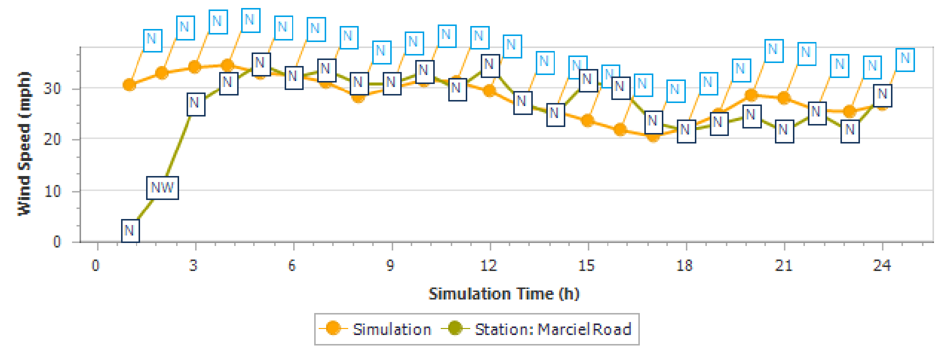
DAMAGE INCIDENT NO. 5

FIRE BEHAVIOR	WEATHER **Nearest Station:** Loma Rica Road

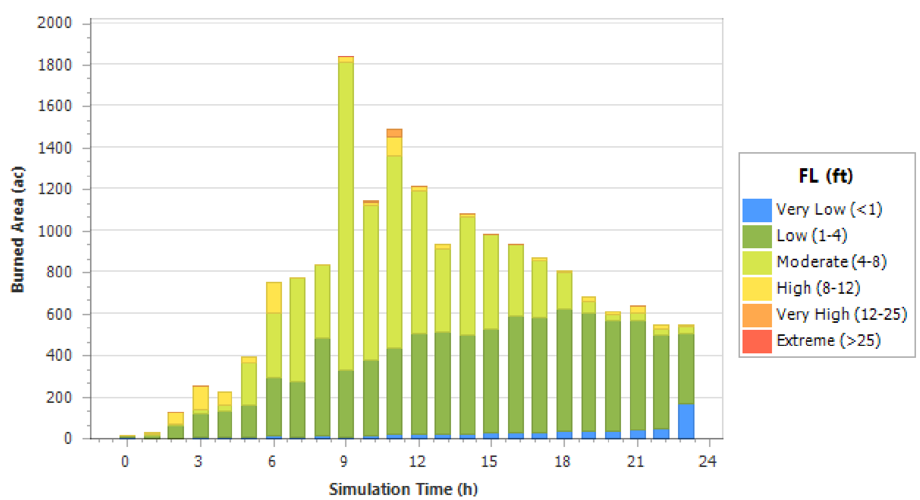
Rate of Spread

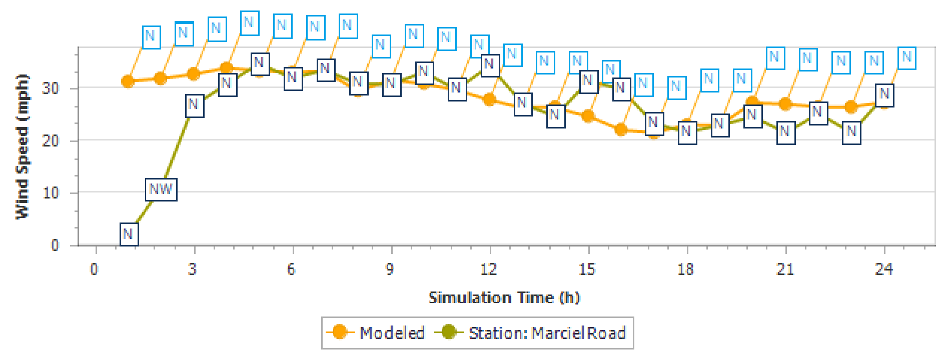


Station ID - PG562
Weather station (Wx) elevation - 1095 ft
Fire ignition point (IP) elevation - 1520 ft
Distance between Wx and IP - 2.33 mi



Flame Length

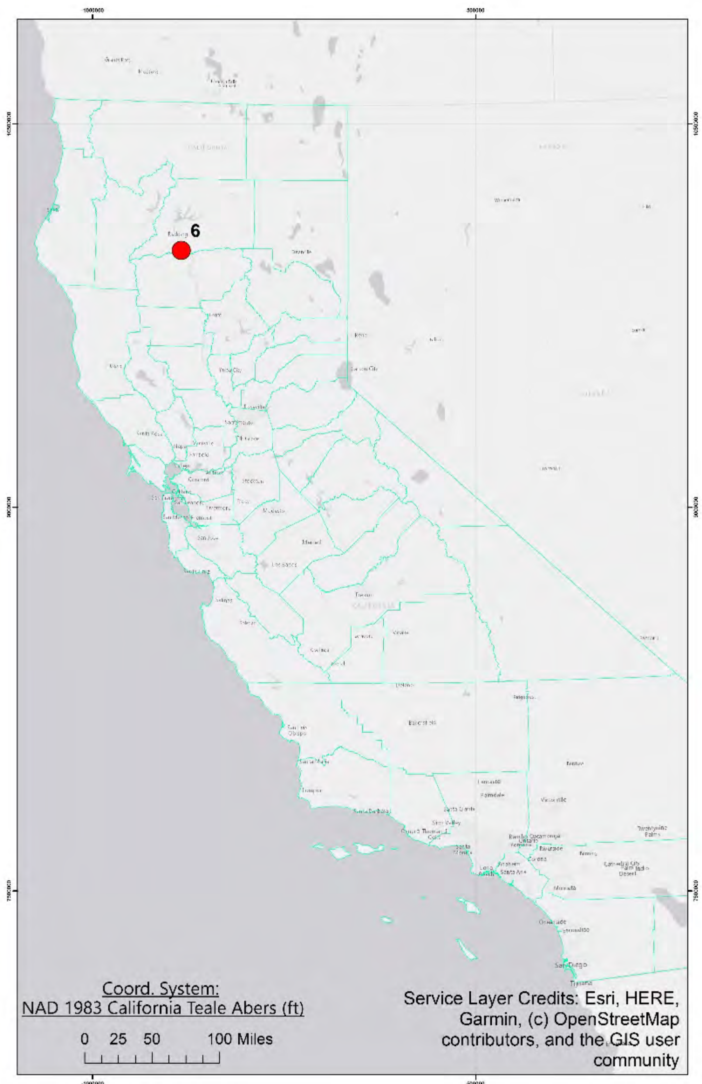




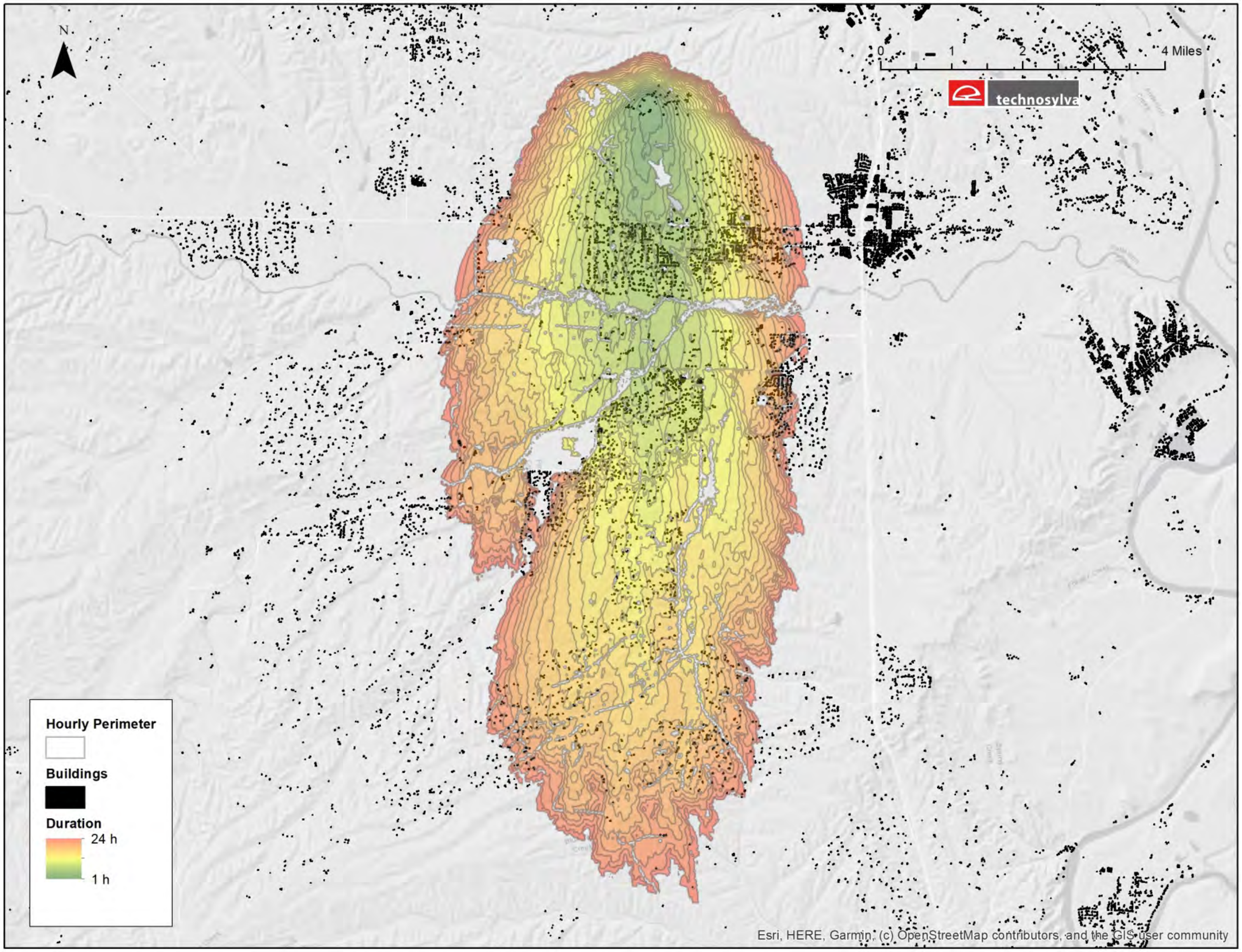
DAMAGE INCIDENT – 6

This incident is located in the county of Shasta in Northern California, in an area with disseminated houses with grass and shrubs (GR2 and GS2) where fire impacts on buildings and population may be high as reflected in our results. The Rate of Spread is moderate presenting high resistance to control in an initial attack (IAA = 5). The flame length is generally low-moderate. It is a fire-prone area with lots of historical fires according to the FRAP CALFIRE dataset.

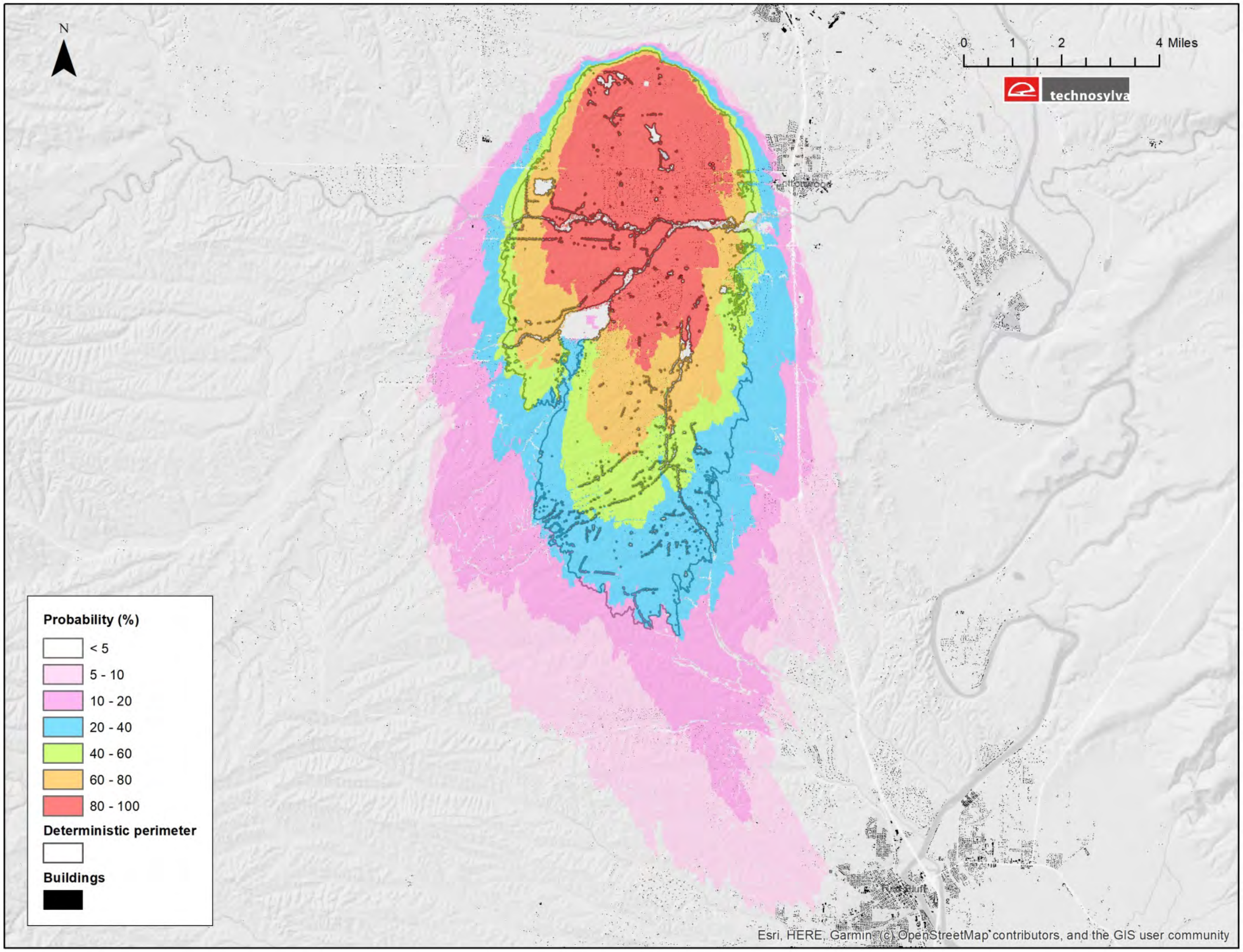
INCIDENT SUMMARY	
Start Time	10/27/19 - 00:00
Duration (hrs)	24
Size (ac)	26,816
Initial Attack Assessment	5 - Extreme
No. of Buildings	3,094
Total Population	4,511
Average ROS	Moderate



DAMAGE INCIDENT NO. 6 : DETERMINISTIC SIMULATION

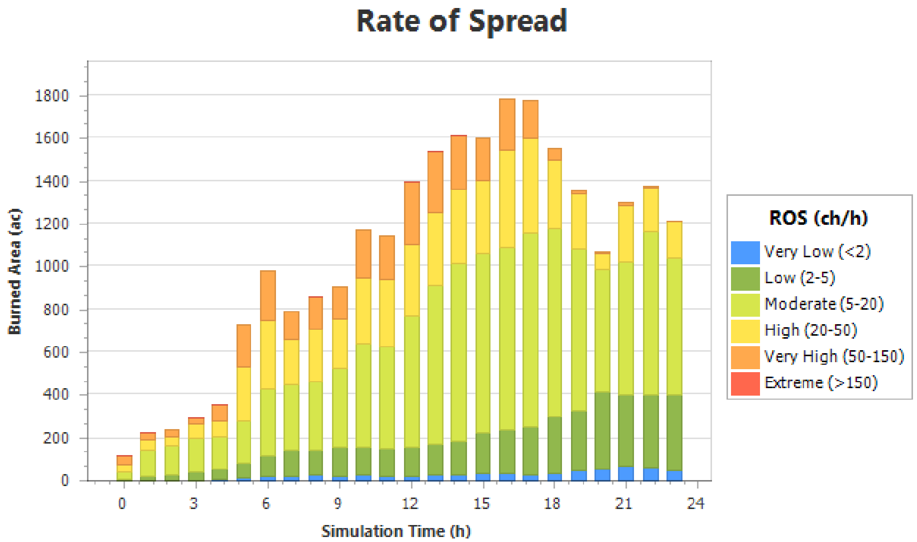


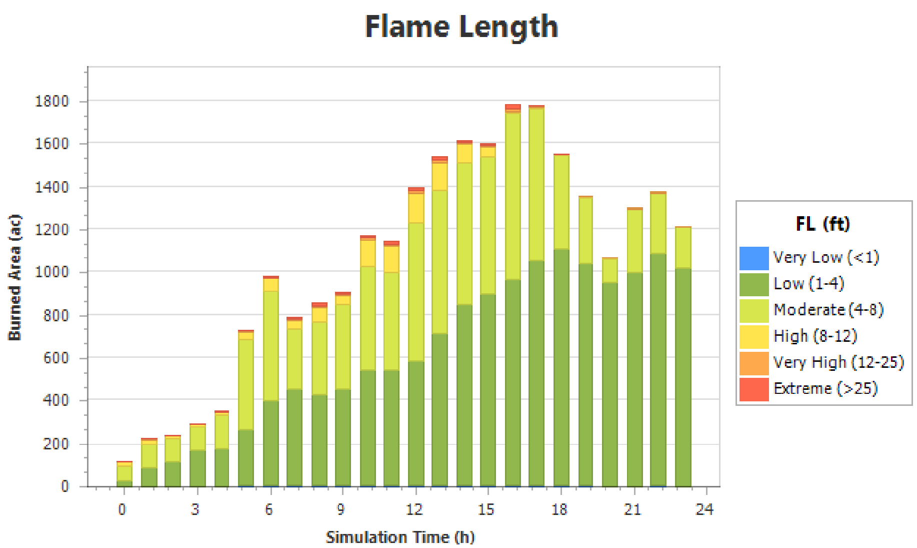
DAMAGE INCIDENT NO. 6 : PROBABILISTIC SIMULATION



DAMAGE INCIDENT NO. 6

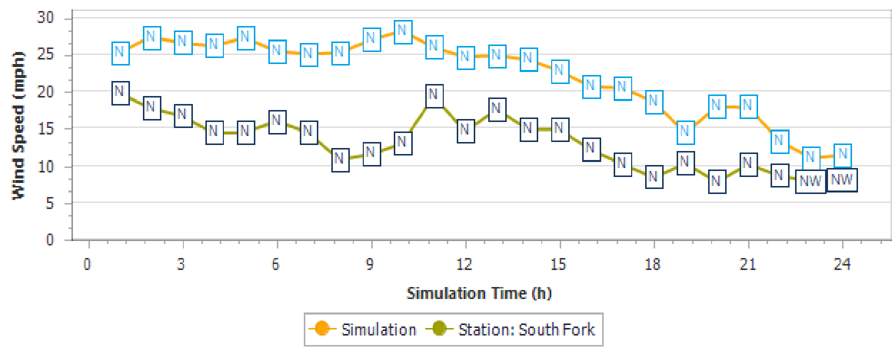
FIRE BEHAVIOR

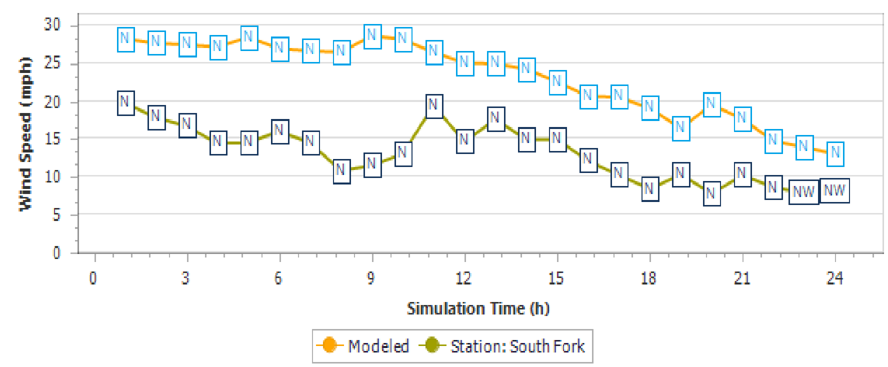




WEATHER **Nearest Station:** Beegum Road

Station ID - PG479
Weather station (Wx) elevation - 521 ft
Fire ignition point (IP) elevation - 707 ft
Distance between Wx and IP - 2.17 mi



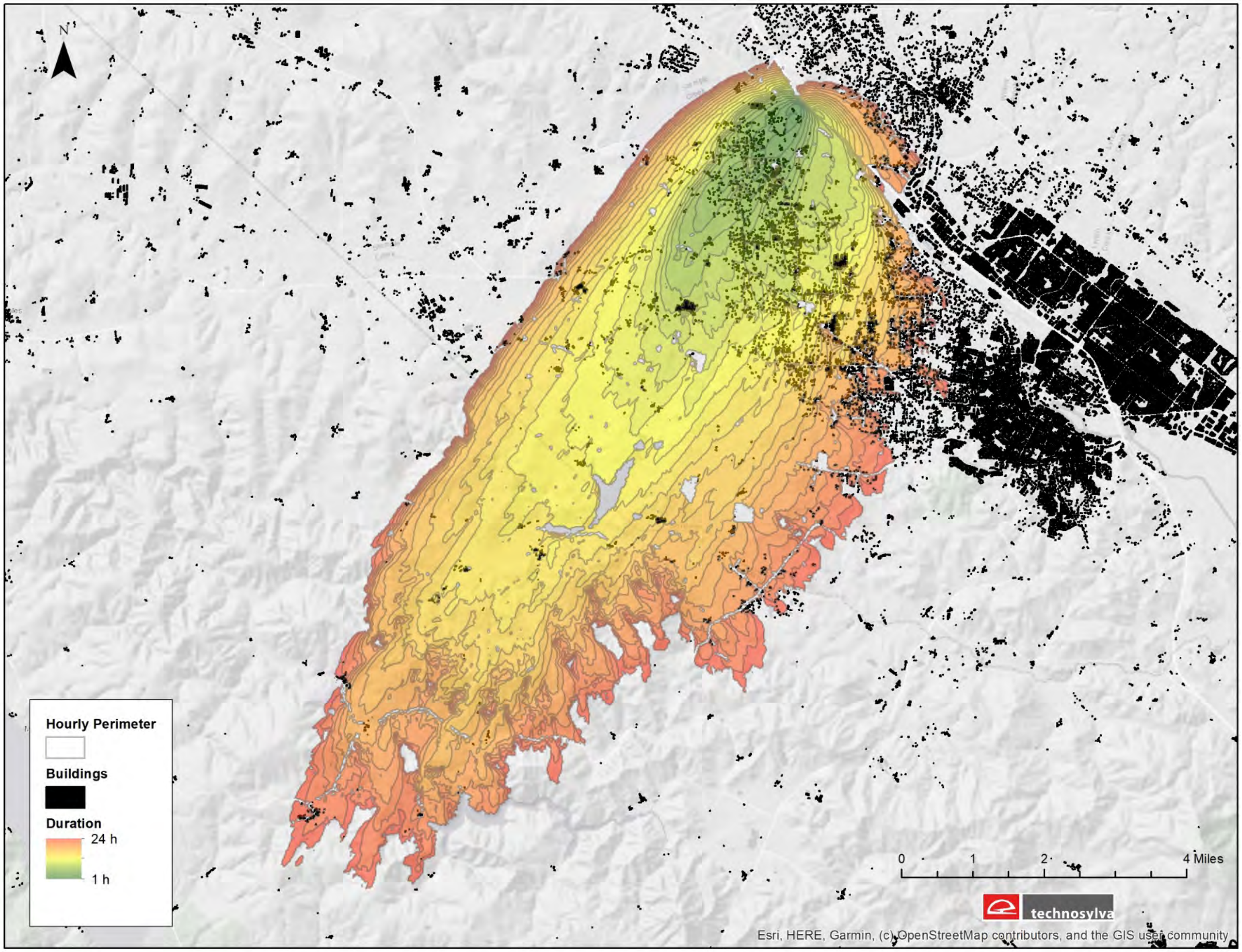


DAMAGE INCIDENT – 7

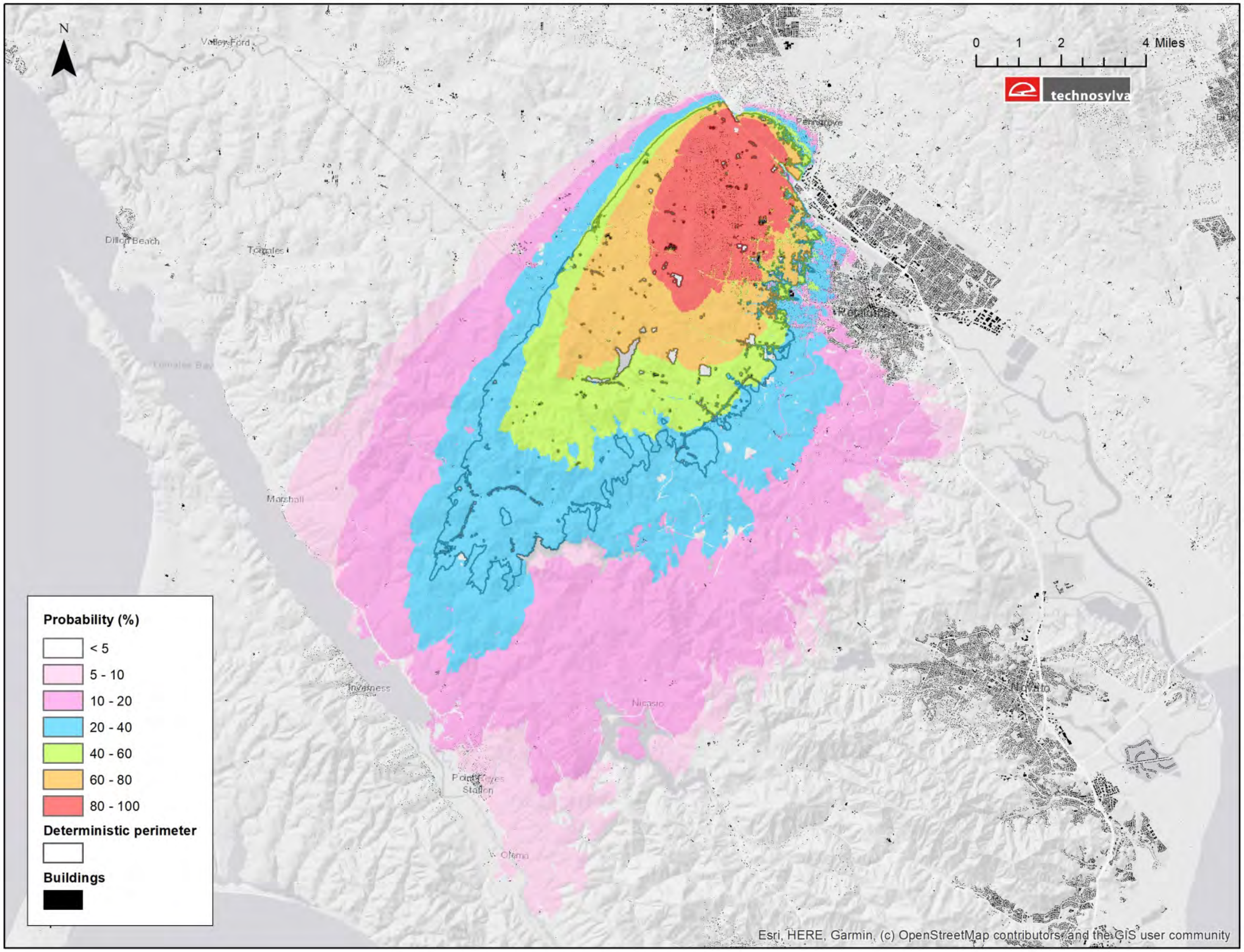
This incident is located north of San Francisco Bay where the fire could have directly impacted disseminated houses near Petaluma. Although the fire could reach the urban dense area of this city, the fire intensity would be lower than damage incident 4, causing less impact on buildings and population. It would be a wind driven fire (20 mi/h winds from NE on grass fuel types (GR2). The Rate of Spread would be high with moderate fire intensity. Historically, there were a several wildfires in the studied area such as the NUNS fire (55,797; 2017), or the P.G.& E.#5 fire in 1965.

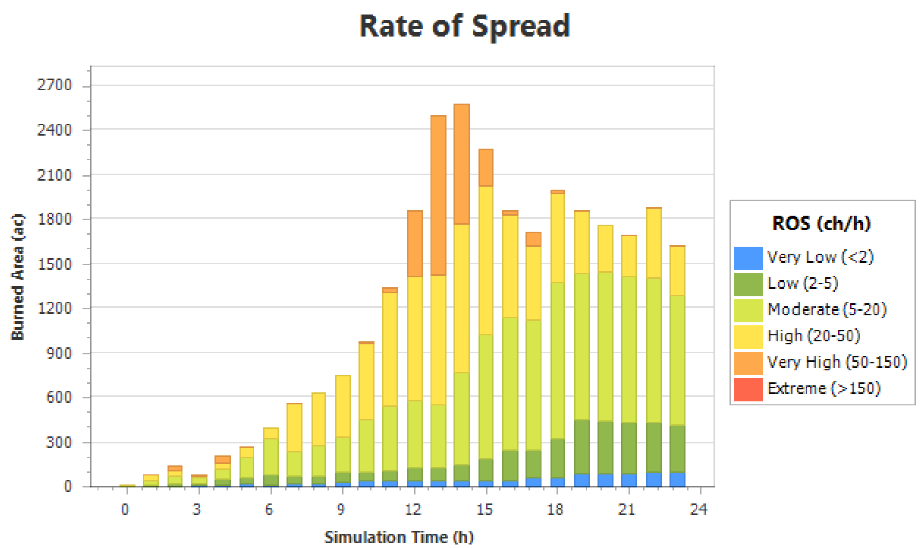
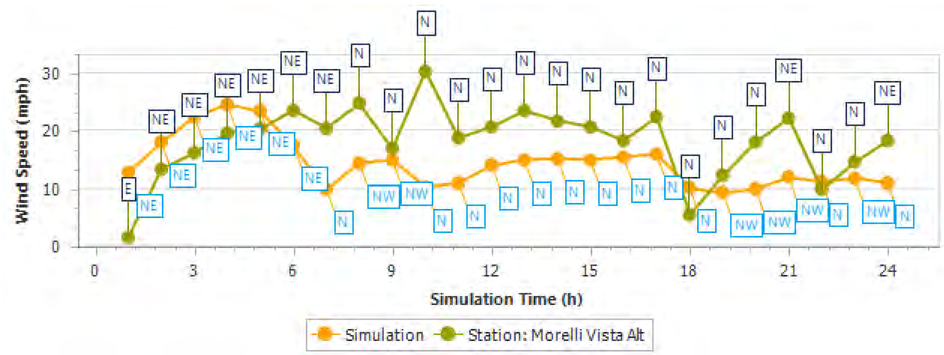
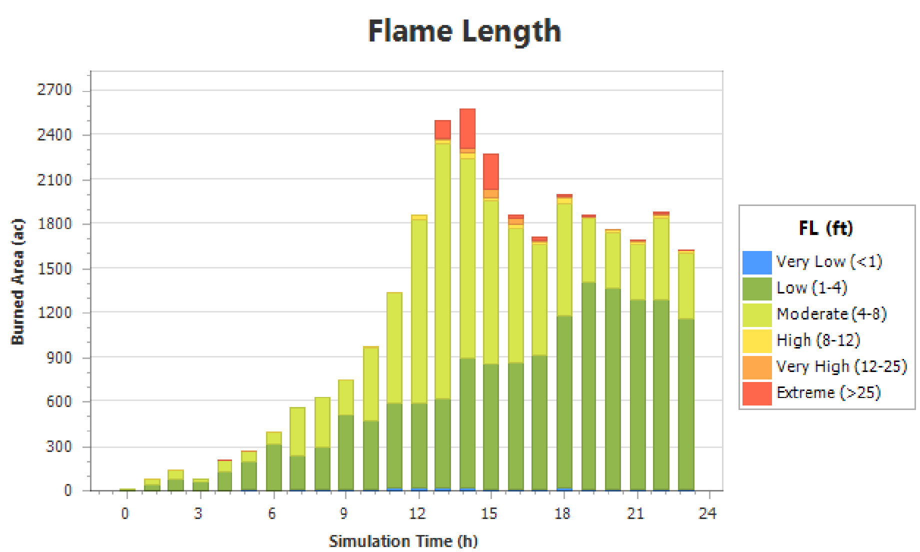
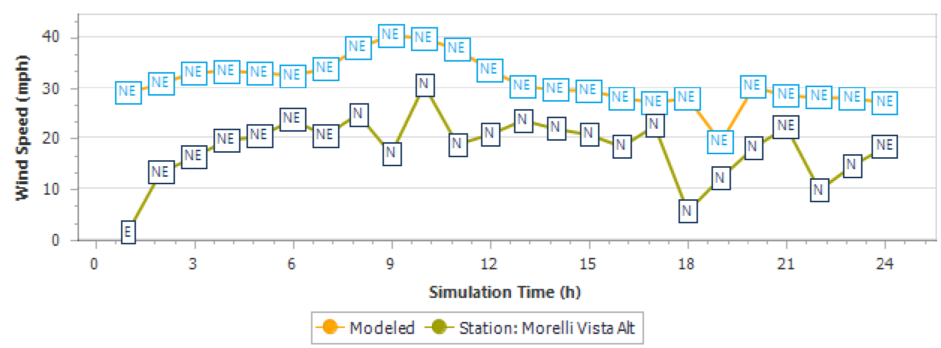
INCIDENT SUMMARY	
Start Time	10/09/19 - 10:00
Duration (hrs.)	24
Size (ac)	10,089
Initial Attack Assessment	4 – Very high
No. of Buildings	4,086
Total Population	4,403
Average ROS	12.9 chains/hr

DAMAGE INCIDENT NO. 7 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 7 : PROBABILISTIC SIMULATION



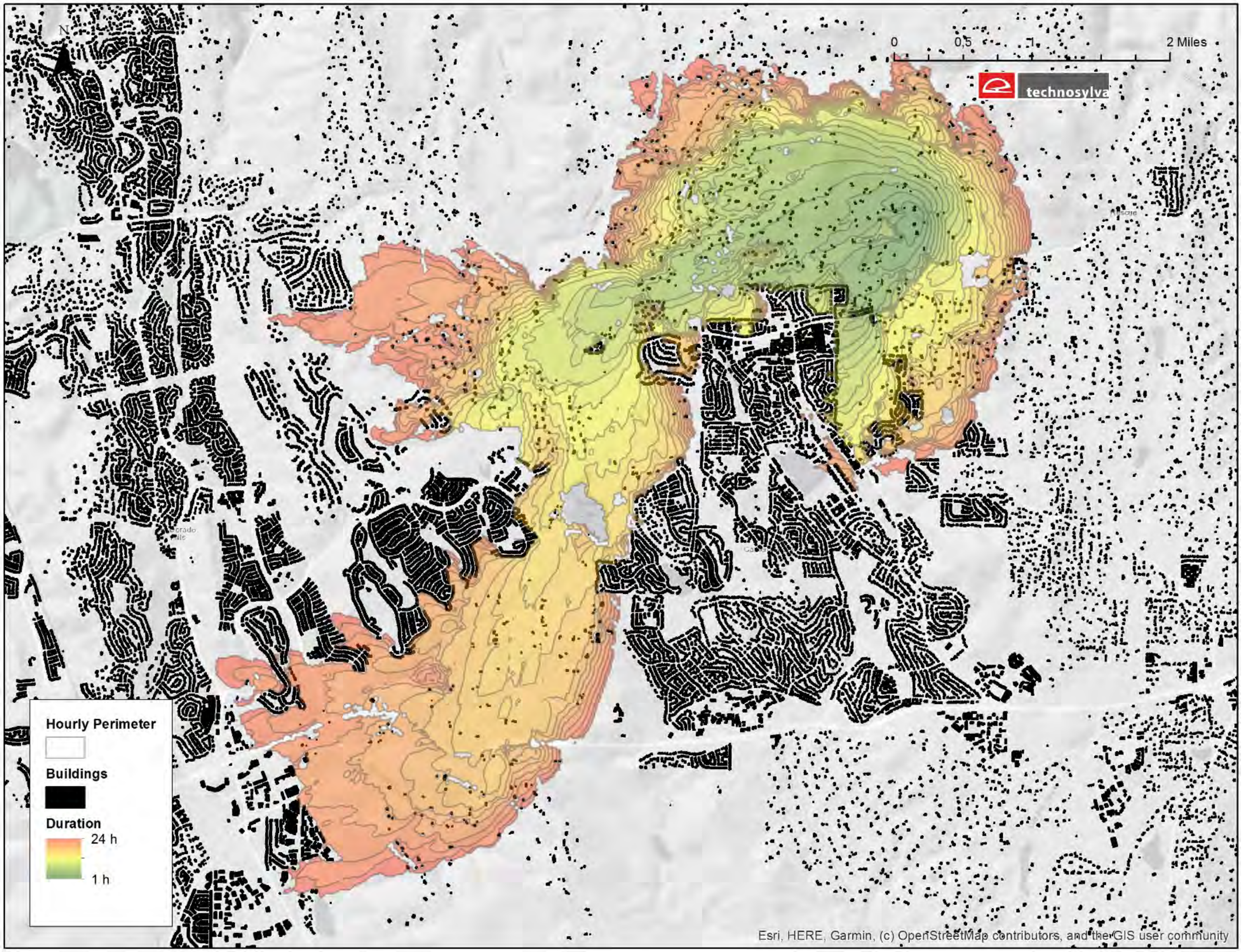
DAMAGE INCIDENT NO. 7	
FIRE BEHAVIOR	**WEATHER** **Nearest Station:** Trouble Lane
	Station ID - PG562 Weather station (Wx) elevation - 1095 ft Fire ignition point (IP) elevation - 118 ft Distance between Wx and IP - 5.52 mi 
	

DAMAGE INCIDENT – 8

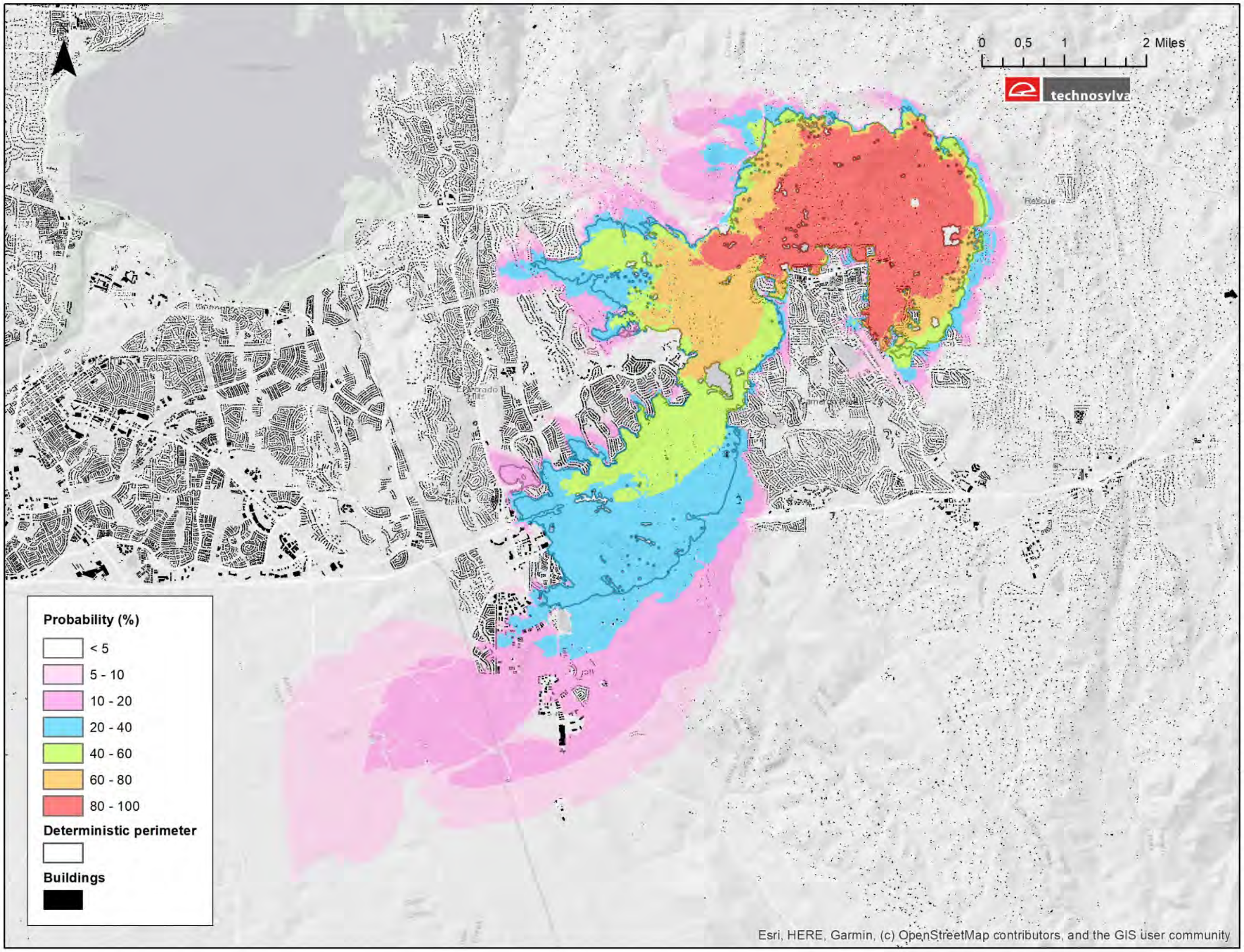
The damage incident was located in the county of El Dorado. The fire would spread with moderate rate of spread and flame length. However, the fire may reach lots of buildings and population due to their proximity to the damage incident location. Note that the initial attack containment would be difficult with IAA = 4. The wind speed was low at the beginning of the fire although increased some hours later up to 10 mi/h.

INCIDENT SUMMARY	
Start Time	10/27/19 - 00:00
Duration (hrs)	24
Size (ac)	8,599
Initial Attack Assessment	4 – Very High
No. of Buildings	1,587
Total Population	4,255
Average ROS	Moderate

DAMAGE INCIDENT NO. 8 : DETERMINISTIC SIMULATION

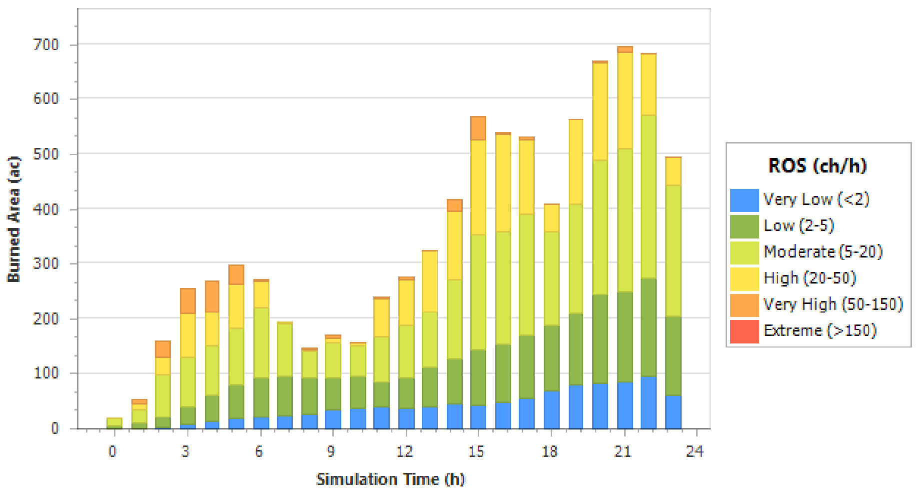


DAMAGE INCIDENT NO. 8 : PROBABILISTIC SIMULATION

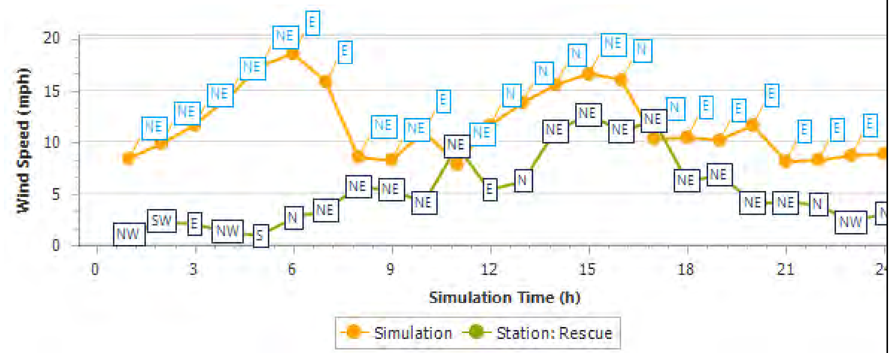


DAMAGE INCIDENT NO. 8	
FIRE BEHAVIOR	**WEATHER** **Nearest Station:** Mt. Hood

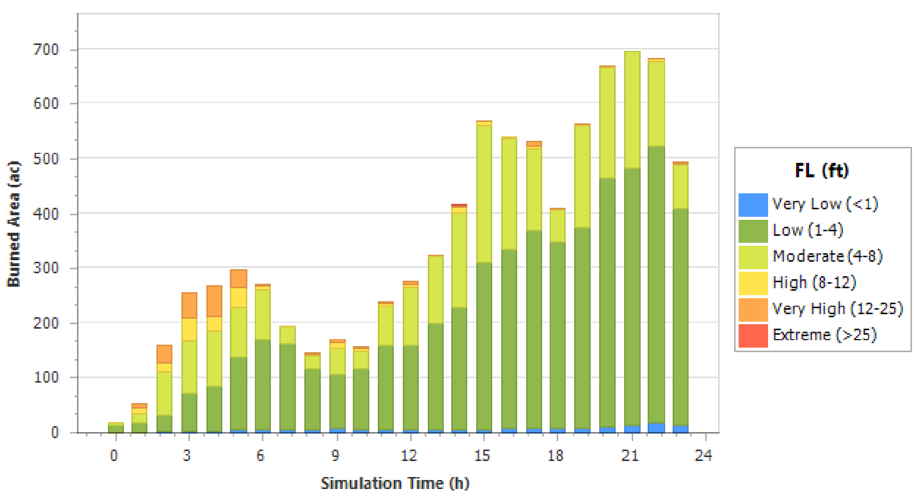
Rate of Spread

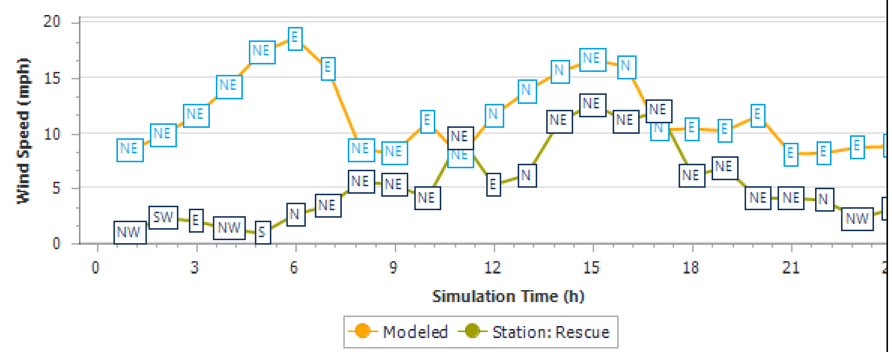


Station ID - PG072
Weather station (Wx) elevation - 1330 ft
Fire ignition point (IP) elevation - 1388 ft
Distance between Wx and IP - 0.48 mi



Flame Length

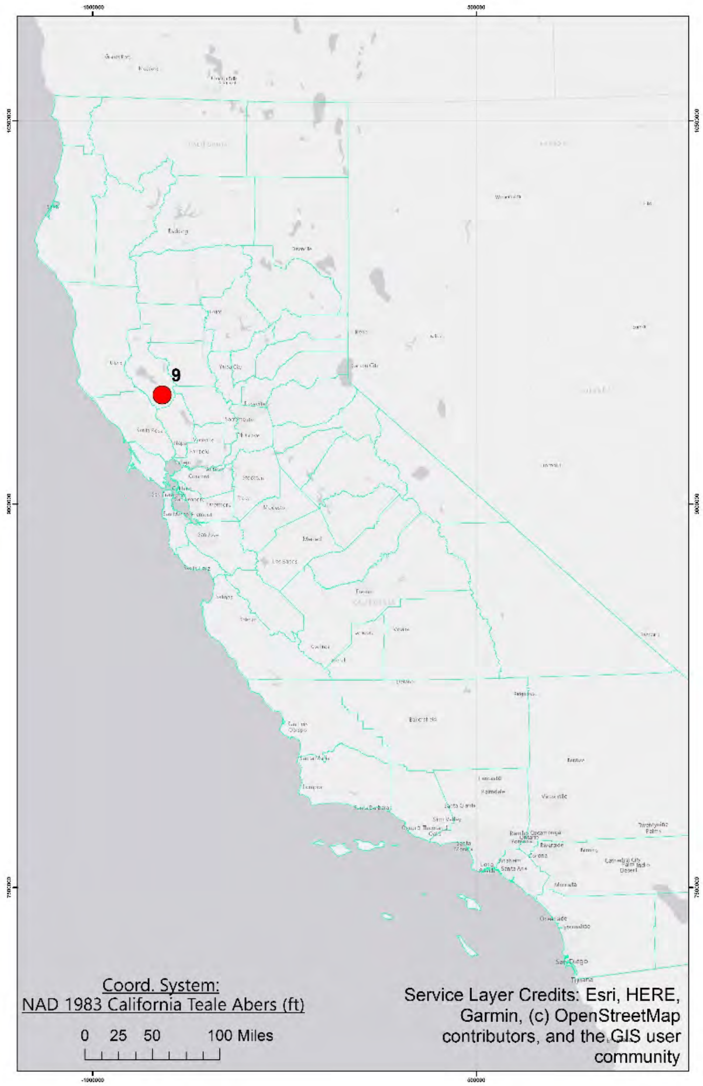




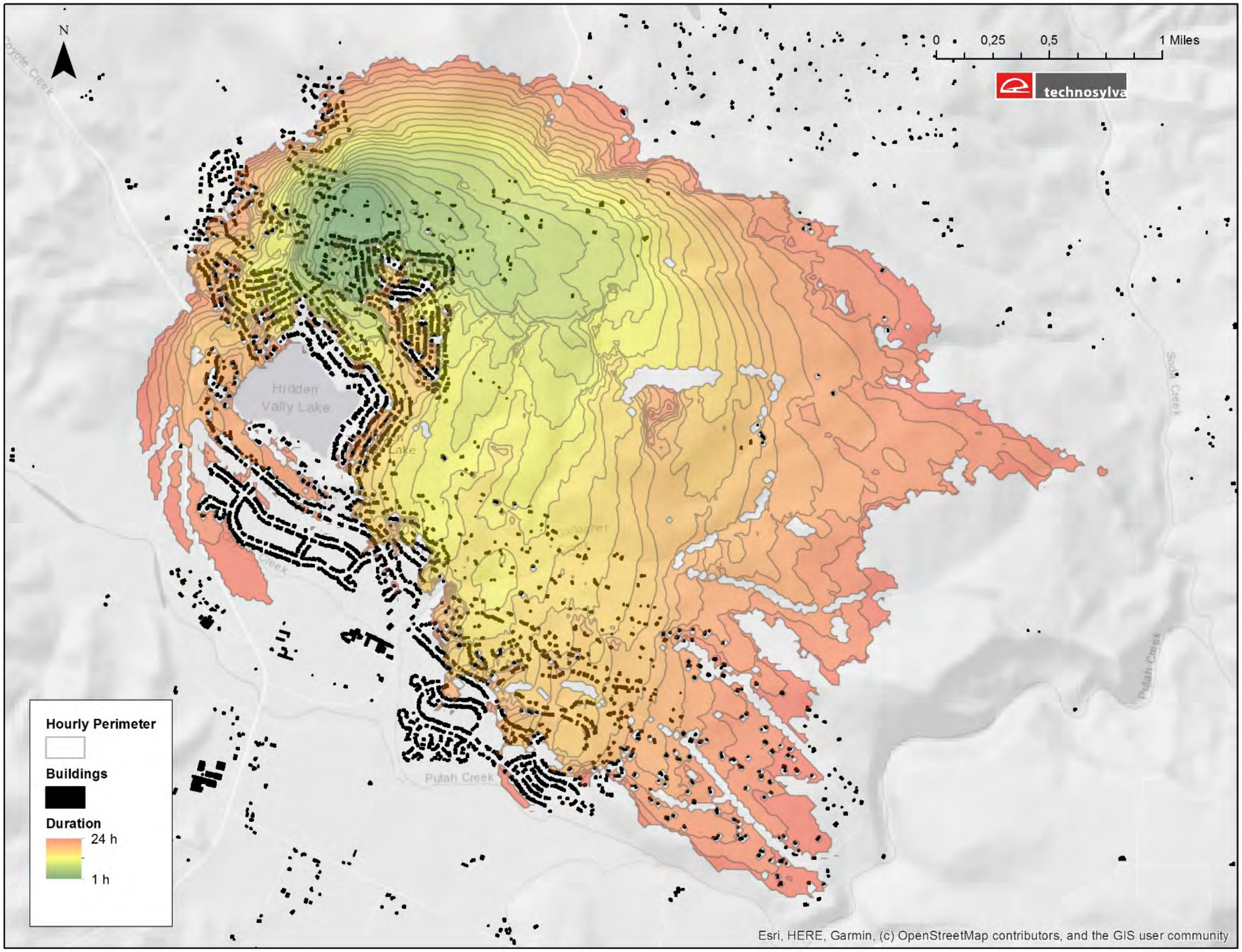
DAMAGE INCIDENT – 9

This incident is located in the Lake County in an area with multiple historical fires: VALLEY (76084 ac; 2015), ROCKY(69636 ac; 2015), JERUSALEM (25118 ac; 2015). The fire would mostly burn grass and shrub fuel types. Fire spreads moderately presenting moderate resistance to control with in an IAA of 3 (High). The fire impacts could be very high due to the high amount of buildings near the ignition location although the fire intensity would be generally low.

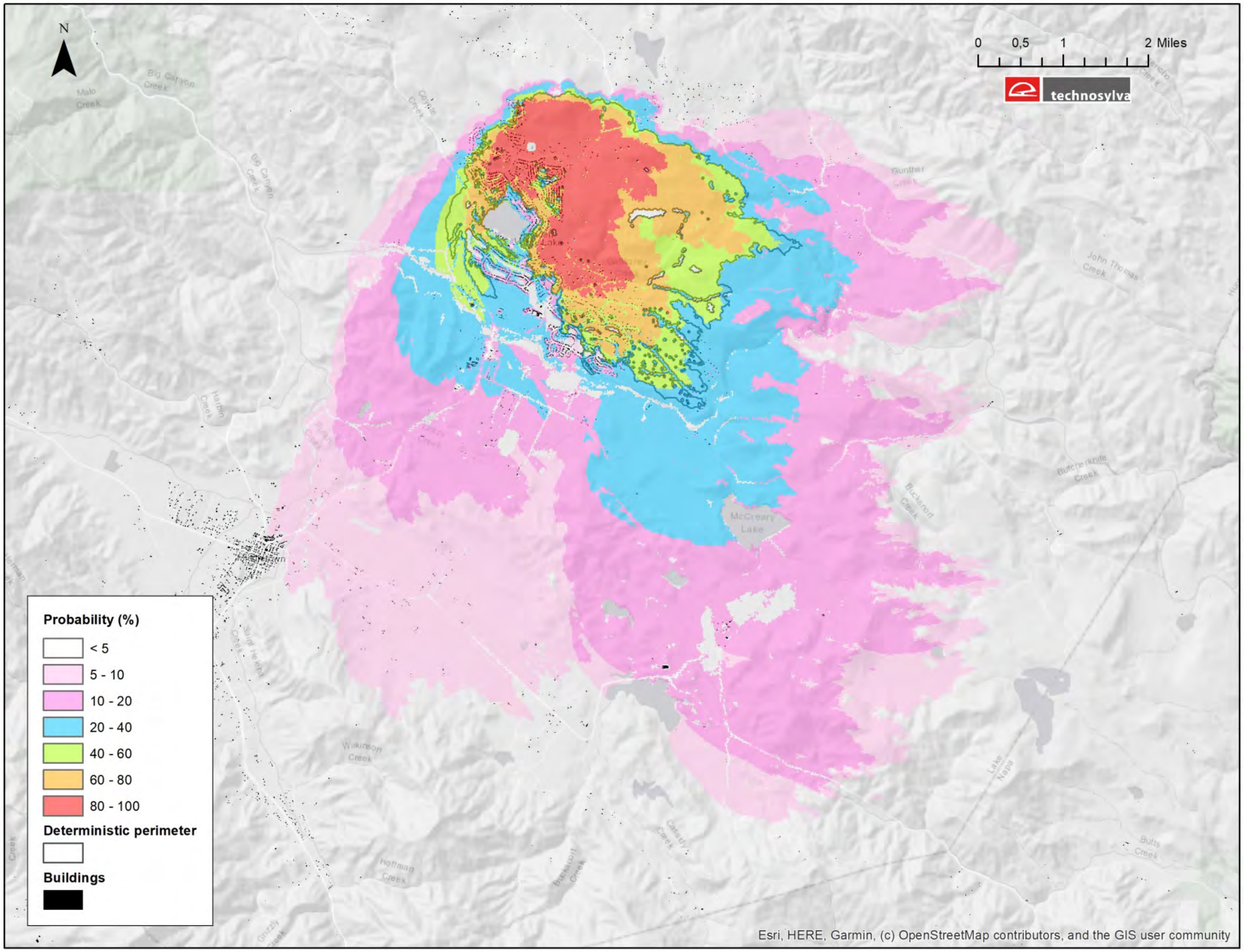
INCIDENT SUMMARY	
Start Time	10/27/19 - 00:00
Duration (hrs)	24
Size (ac)	4,746
Initial Attack Assessment	3 - High
No. of Buildings	1,447
Total Population	3,738
Average ROS	Moderate



DAMAGE INCIDENT NO. 9 : DETERMINISTIC SIMULATION

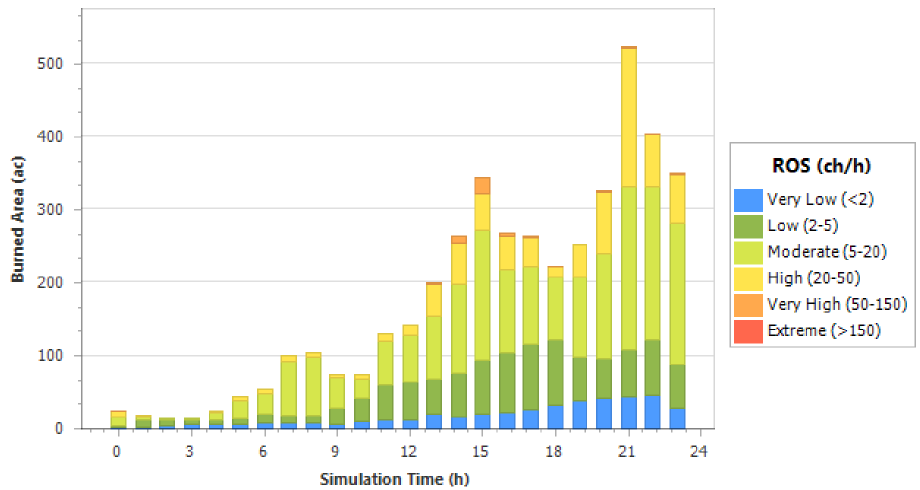


DAMAGE INCIDENT NO. 9 : PROBABILISTIC SIMULATION

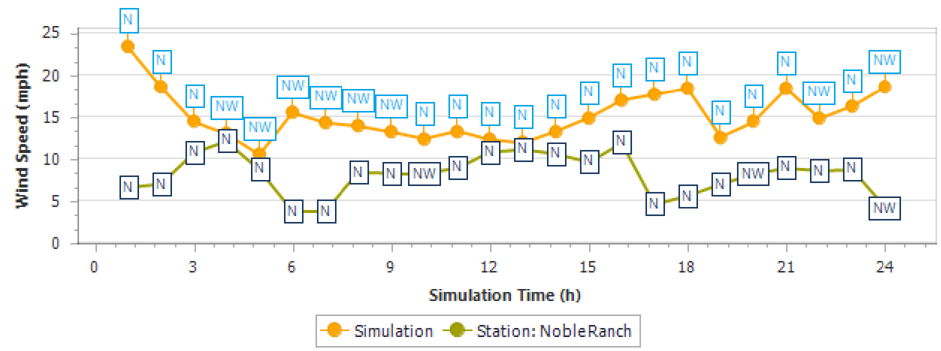


DAMAGE INCIDENT NO. 9	
FIRE BEHAVIOR	WEATHER **Nearest Station:** Sherridan Road

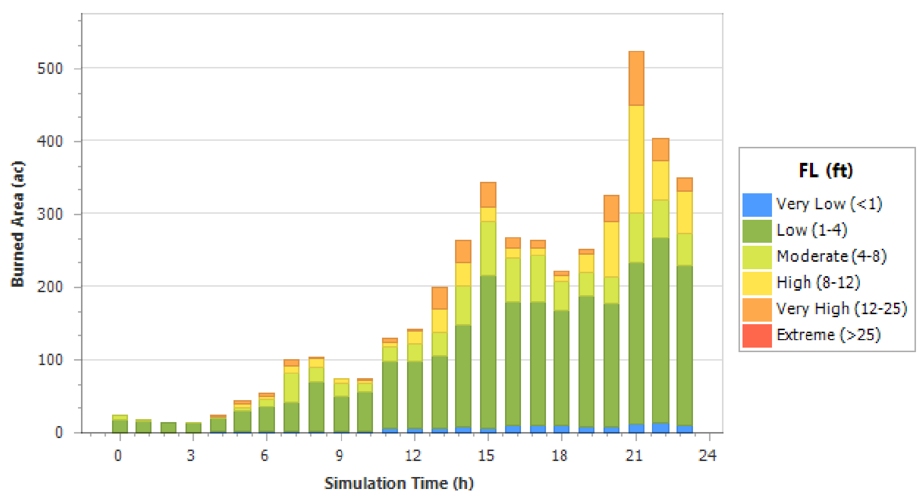
Rate of Spread

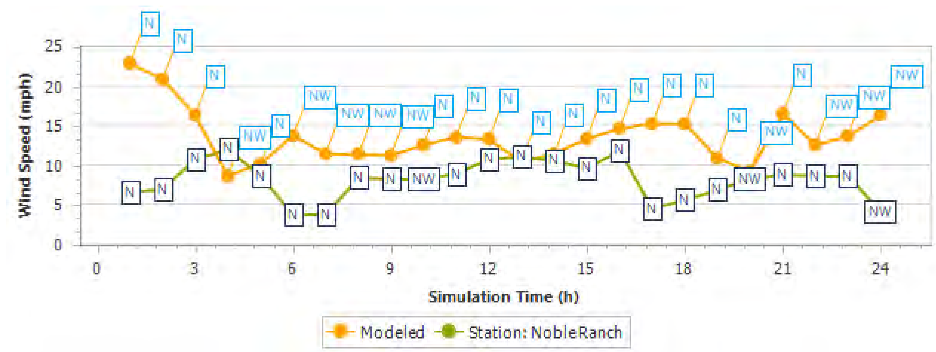


Station ID - PG110
Weather station (Wx) elevation - 1832 ft
Fire ignition point (IP) elevation - 1576 ft
Distance between Wx and IP - 1.45 mi



Flame Length



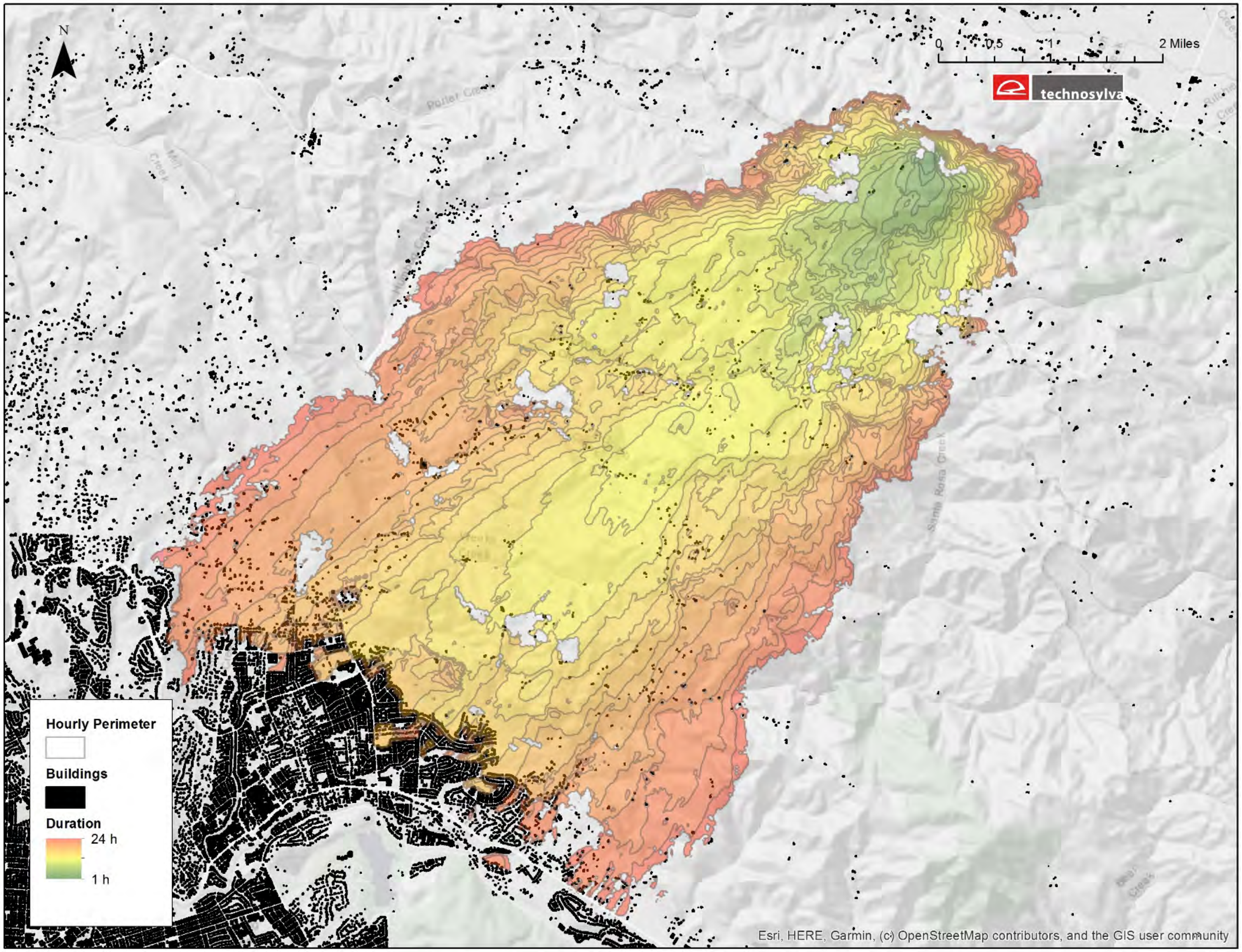


DAMAGE INCIDENT – 10

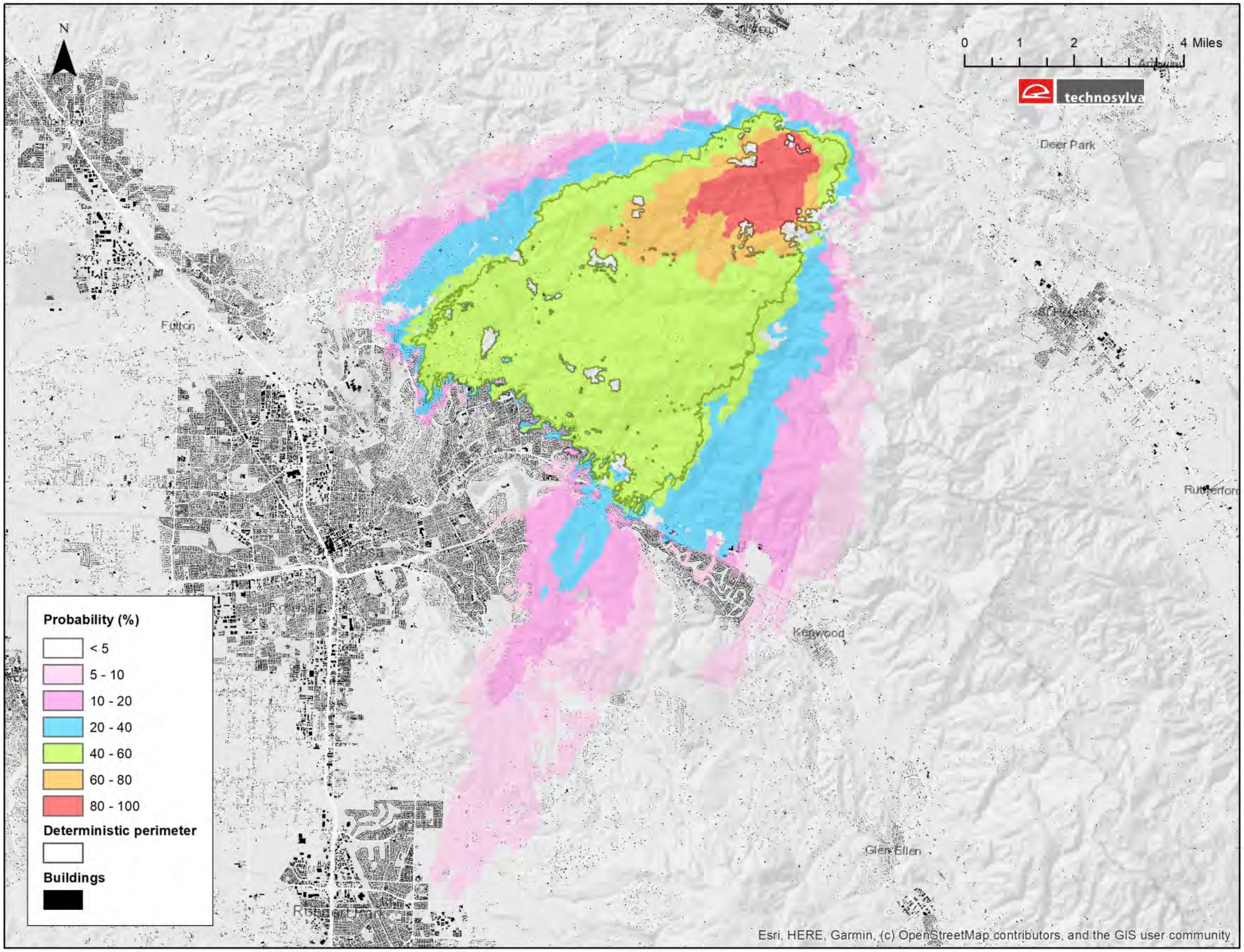
The damage incident was located near Calistoga, in an area near the Tubbs fire (2017). In fact, the potential fire would have a similar fire progression with high winds from NE (up to 40 mi/h). The fire could directly impact the Wildland Urban Interface of Santa Rosa, causing losses in buildings and population. The fire starts growing slowly but increases the intensity and rate of spread in the next hours as shown in the charts. Modeled wind speed would be lower than measured in weather stations as shown in the figures presented below.

INCIDENT SUMMARY	
Start Time	10/09/19 - 5:00
Duration (hrs.)	24
Size (ac)	17,709
Initial Attack Assessment	2 - Moderate
No. of Buildings	1,838
Total Population	3,418
Average ROS	High

DAMAGE INCIDENT NO. 10 : DETERMINISTIC SIMULATION



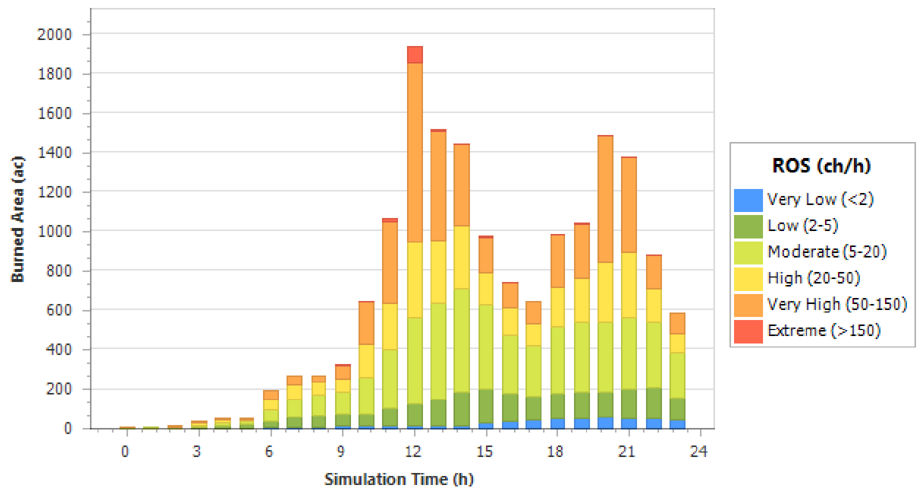
DAMAGE INCIDENT NO. 10 : PROBABILISTIC SIMULATION



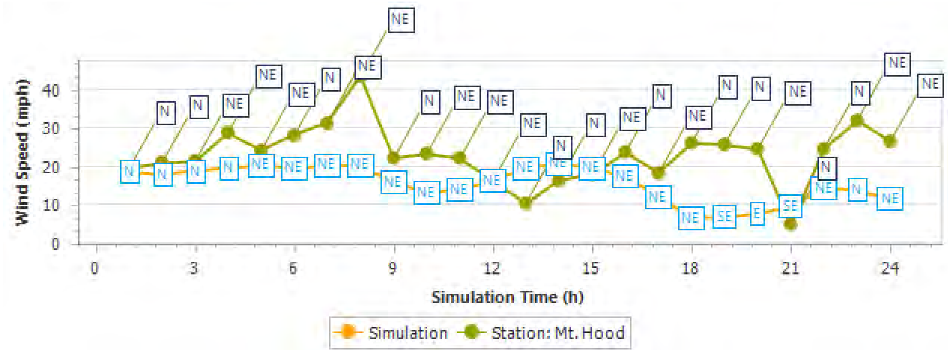
DAMAGE INCIDENT NO. 10

FIRE BEHAVIOR	**WEATHER** **Nearest Station:** Butts Canyon RoadNorth
Rate of Spread	Station ID - PG162 Weather station (Wx) elevation - 1939 ft Fire ignition point (IP) elevation - 1716 ft Distance between Wx and IP - 2.33 mi

Rate of Spread



Station ID - PG162
Weather station (Wx) elevation - 1939 ft
Fire ignition point (IP) elevation - 1716 ft
Distance between Wx and IP - 2.33 mi



Flame Length