PUBLIC UTILITIES COMMISSION
505 VAN NESS AVENUE
SAN FRANCISCO, CA 94102-3298

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 Dates:

September 9-19, 2019
October 2-12, 2019
October 12-21, 2019
October 21-26, 2019
October 27-November 4, 2019

IOU: **Southern California Edison (SCE)**

Prepared by:

Technosylva Inc. (La Jolla, CA)

technosylva

California Public Utilities Commission

2019 PSPS Event Wildfire Risk Analysis Report

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

September 9-19, 2019
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Southern California Edison (SCE)

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 September, October and November 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 several PSPS events detailed in Section 2 that occurred in **Southern California Edison's (SCE)** service territory for the following dates:

- September 9-19, 2019
- October 2-12, 2019
- October 12-21, 2019
- October 21-26, 2019
- October 27-November 4, 2019

The analysis quantifies the potential impacts averted from wildfires that could have been ignited by electric utility infrastructure assets damaged during the PSPS events if they were not de-energized. This damage incident data is compiled from SCE field inspections on asset infrastructure after the 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 be less than calculated. Also, note that the fire modelling 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 buildings. Additionally, this analysis also takes into account input data uncertainty (especially weather and ignition parameters) to analyze the fire propagation and impacts, applying an innovative approach to ensure accurate 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. TECHNICAL METHODS

2.1 Damage Incident Data Collection

The analysis conducted for the PSPS events relied upon SCE's assessment of damage incidents for ignition potential. Data on the damages were obtained from patrols conducted by SCE field personnel subsequent to reenergization. SCE gathers information from Repair Orders generated by Distribution Troublemen, Interruption Log Sheets generated by Switching Center System Operators communicating with field personnel, Outage Management System Incident Manager comments generated by dispatchers communicating with field personnel, and photos provided directly from field resources to IMT Task Force Personnel during a PSPS activation. Information from these sources is entered into SCE's Outage Tracker.

2.2 Fire Modeling

Fire spread simulations were undertaken for the damage incidents identified by SCE using the location of the damage incident as the ignition source, and the date/time estimated for the damage occurring as the start time for the fire simulation. 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 simulation. A key metric is the Initial Attack Assessment (IAA), which quantifies the likelihood of the simulated fire escaping initial attack by suppression resources.[3] This metric helps distinguish fires that may potentially take longer to suppress compared to average fires that would typically be extinguished quickly based on spread characteristics under the specific weather conditions at the time of the event.

2.2.1 Data Processing Methods

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

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 and 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 a summary for the most significant simulations

[3] The IAA index provides an estimation of the difficulty of fire control for initial attack. The index is combination of two sub-indices 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).

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

2.2.2 Fire Behavior Modeling Methods

Fire simulations were performed with Technosylva's Wildfire Analyst™ software. Wildfire Analyst is 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.[4] Numerous enhancements to the published science have been implemented by 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 represents the best publicly available surface and canopy fuels data for the State of California. This data 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 outputs provided the simulated fire spread and associated 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.

The duration of all incident fire simulations was 24 hours.

2.2.3 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 damage incident locations for every PSPS event. The following figure presents an example deterministic fire simulation. Hourly perimeters are shown along with buildings and topographic information.

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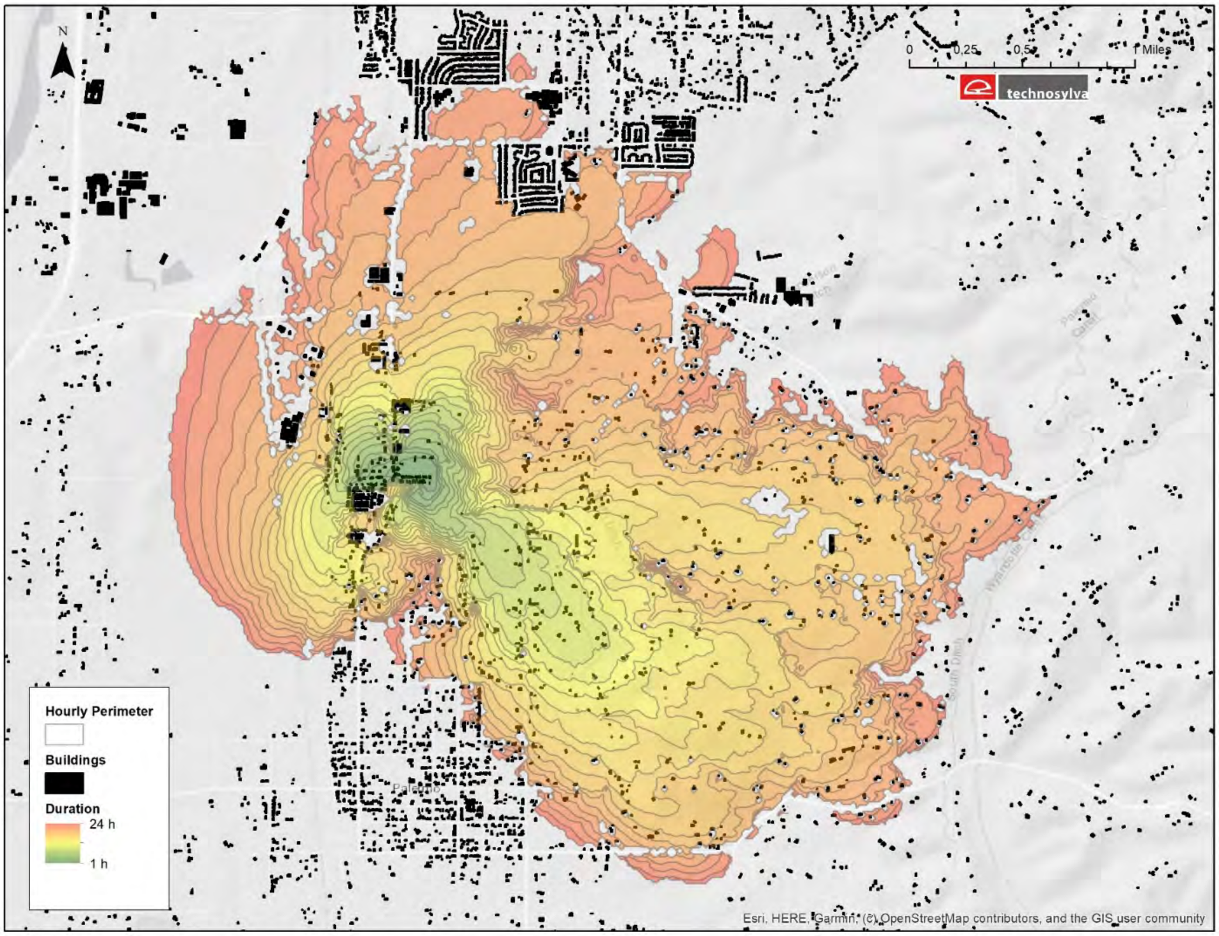
[4] Rothermel, R., 1972. A mathematical model for predicting fire spread in wildland fuels. USDA For. Serv. Intermt. For. Range Exp. Stn. Res. Pap. INT-115. Ogden, UT.

Figure 1. Example deterministic fire simulation.



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[5]. 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 of the uncertainties in the fire incident[6]. This analysis may be helpful in structuring the problems,

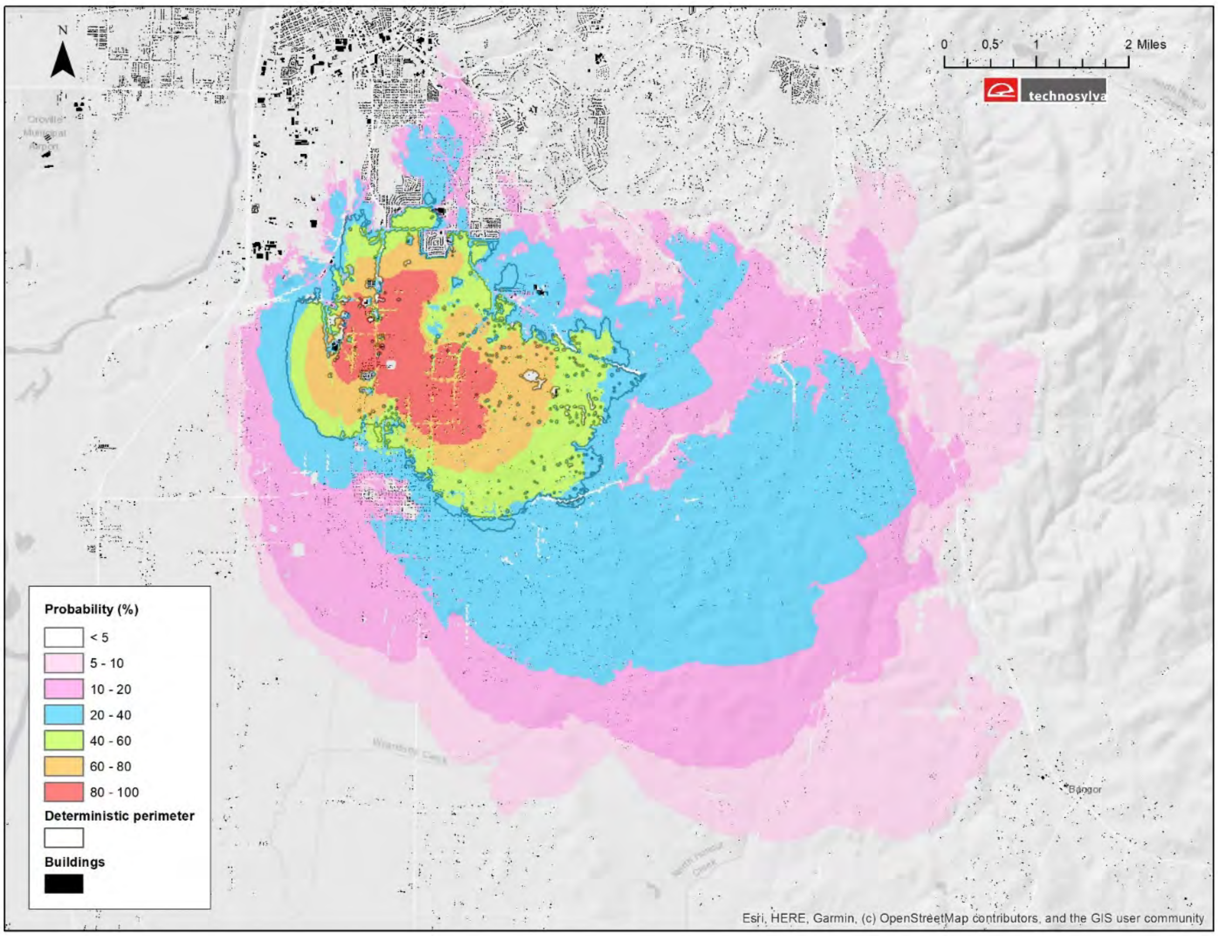
[5] Alexander, M.E., Cruz, M.G., 2013. Are the applications of wildland fire behavior modeling. Environ. Model. Softw. 41, 65–71. https://doi.org/10.1016/j.envsoft.2012.11.001

[6] 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.

integrating knowledge, visualizing the results[7] as well as easing the work of decision-makers by supporting consistent and justifiable decisions.[8]

Since some of the inputs for the damage incidents could vary, probabilistic methods were applied for those most significant fire simulations identified through deterministic simulations. This accounts for possible variation in key input data providing an enhanced analysis of possible spread and consequence. Figure 2 presents an example probabilistic fire simulation for the same ignition location shown in Figure 1. Note that the deterministic boundary is shown as reference to aid in comparison of the two outputs.

Figure 2. Example probabilistic fire simulation.



[7] 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.

[8] 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.

2.2.4 Identifying the Most Significant Incidents

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

1. Total population impacted, using the LandScan 2016 population count data.[9] 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.[10] 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.[11]
5. In some PSPS events, a number of damage incidents were clustered together in close proximity with the same estimated time of damage. In these situations, some of the analysis results were excluded as they would be redundant to evaluate potential impacts. More detailed descriptions are provided for the individual events where this occurred.

2.2.5 Defining Ignition Parameters

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 SCE from their field inspections. Some variation was used in the specific location if the point was found to fall on non-burnable fuels. This was used to accommodate for possible spatial inaccuracy of the ignition location and possible variation of the ignition location due to wind conditions. It is known that in extreme wind conditions sparks from equipment damage may not fall directly below the equipment.

Determining the 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 falling on electrical assets.

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

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

[11] 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.

Accordingly, an estimated time of ignition was used for the damage incident fire simulations based on the following criteria:

1. Estimated time of damage provided by SCE, ensuring the estimated ignition time occurred within PSPS event boundaries. If a circuit relays (not manually opened due to PSPS), SCE assumes that the time of the relay is when the damage occurred. In the case of a PSPS event, where a circuit has been manually de-energized, SCE does not have a way to determine when the damage occurred. In this scenario Technosylva estimated time of damage due to worst conditions for the event and location of that reported damage.
2. In any instance in which the estimated ignition time was not within the PSPS event boundaries, time was adjusted 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 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 damage incidents.

For analysis of 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).

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.

For these PSPS events, damage incidents and locations are identified by SCE field personnel performing post-PSPS event patrols and reported in post-event reports pursuant to Commission Resolution ESRB-8.

SCE does not have a formalized process or quantifiable metric for determining arcing likelihood. The rationale used by SCE to determine which types of damage and conditions found in post- PSPS inspections could result in arcing was based on an examination of photographs and reports from experienced and knowledgeable field personnel. It is important to note that note all causes of potential line arcing are visible through post-event inspection. For instance, vegetation that was blown into a de-energized line may not have caused visible damage to the line but would have caused arcing on an energized line. This potential for arcing that was avoided by the PSPS event would not be visible, quantifiable, or reportable through a post-event inspection. It should be noted that these determinations are binary, and each damage incident is determined to either likely cause arcing or not.

3. OVERVIEW OF PSPS EVENTS

Between September 9th and November 17th, 2019, Southern California Edison (SCE) activated its Emergency Operations Center to perform response operations associated with an elevated weather event with the potential for execution of SCE's Public Safety Power Shutoff (PSPS) protocol. Damages were identified for five PSPS events. These are analyzed in this report. These PSPS events were executed in five phases across different geographic areas as represented in Table 1 and Figure 1. In total, approximately 195,882 customers were impacted.

Table 1. PSPS event phases and times.

De-Energization Event	Start Time	Restoration Completed	Impacted customers
1	09-Sep-2010	19-Sep-2019	14,500
2	2-Oct-2019	12-Oct-2019	24,112
3	12-Oct-2019	21-Oct-2019	444
4	21-Oct-2019	26-Oct-2019	30,521
5	27-Oct-2019	4-Nov-2019	126,364

Over the course of the events, the SCE PSPS notification team completed all required notifications to customers, emergency management agencies (county and state) and elected officials in areas which could be and/or were impacted.

SCE's decision to notify and de-energize customers using the PSPS protocol was made after all the following factors were considered and initiated and no other measures were available as alternatives for maintaining public safety:

- National Weather Service (NWS) Red Flag Warnings for counties that contain SCE circuits in high fire risk areas;
- Ongoing assessments from SCE's in-house meteorologists informed about high resolution weather models and strategically deployed weather stations (e.g., wind speeds, humidity, and temperature);
- The SCE Fire Potential Index (FPI), an internal tool that utilizes both modeled weather and fuel conditions;
- Real-time situational awareness information obtained from field observers positioned locally in high fire risk areas identified as at risk for extreme fire weather conditions;
- Specific concerns from state and local fire authorities, emergency management personnel, and law enforcement regarding public safety issues;
- Expected impact of de-energizing circuits on essential services such as public safety agencies, water pumps, traffic controls, etc.; and
- Other operational considerations to minimize potential wildfire ignitions including current known state of circuit conditions.

Different weather conditions occurred during the course of the aforementioned events reaching peaks wind gusts of up to 60 mph (Sundowner winds) with localized wind gusts reaching as high as 75 mph. Humidity was forecasted to be in the teens in some areas according to National Weather Service (NWS), remaining in the single digits in some days.

Figure 1 shows the SCE PSPS events areas. Figure 2 shows the PSPS areas clustered in the southern part of the SCE service territory. The SCE service territory boundary is also shown in dark grey.

It is important to note that SCE provided PSPS event outage area data for specific PSPS's within the five de-energization events described in their CPUC submittal. These numerous PSPS event areas are shown on the map, and are categorized as follows for the five events.

Some of the PSPS areas overlap across PSPS events. In addition, there are some identical areas for different PSPS events.

A detailed description of the events, including time periods and locations for de-energization footprints, can be obtained from the CPUC web site at:

https://www.cpuc.ca.gov/deenergization/

Figure 3. SCE September-November 2019 PSPS event areas.

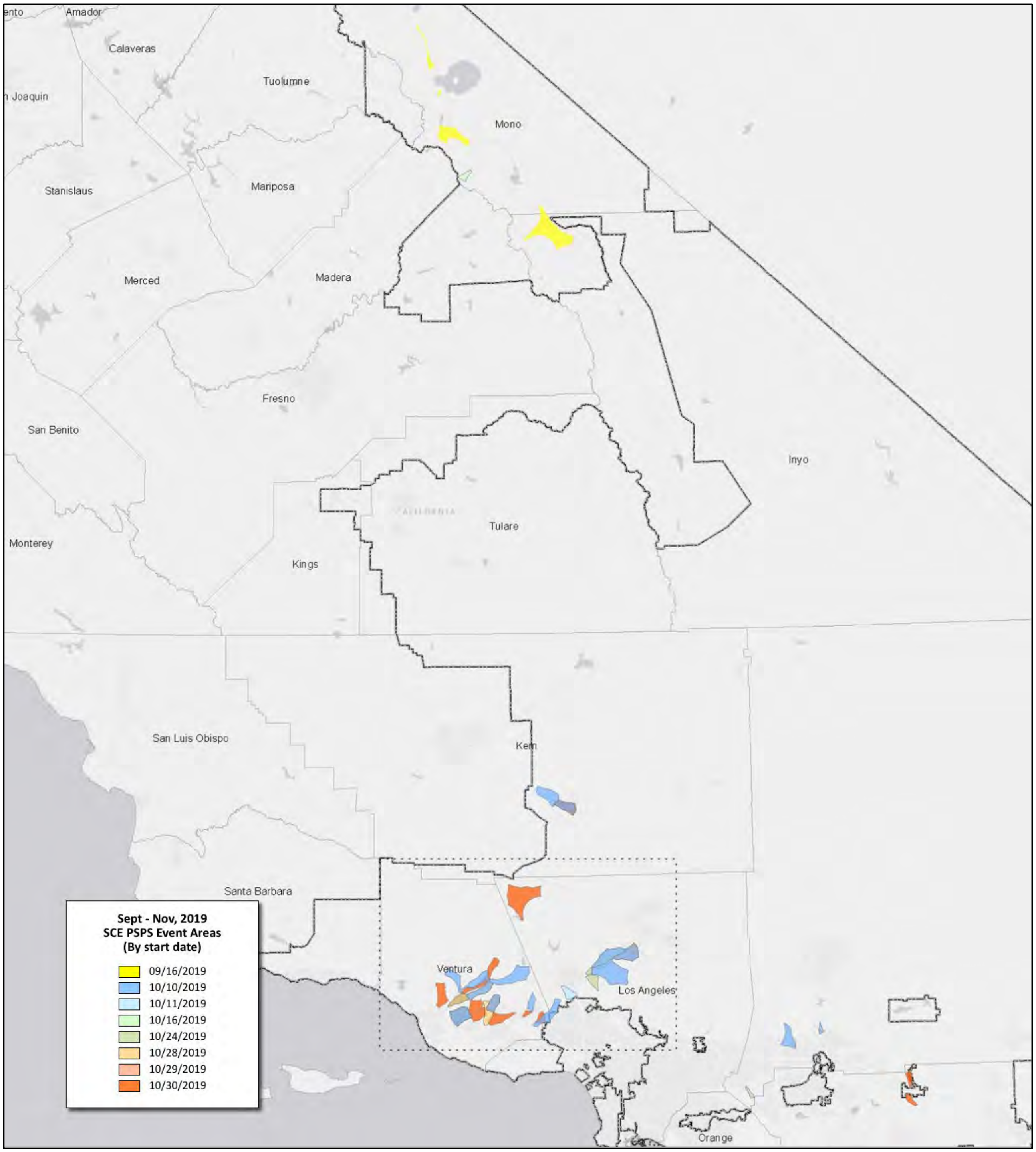
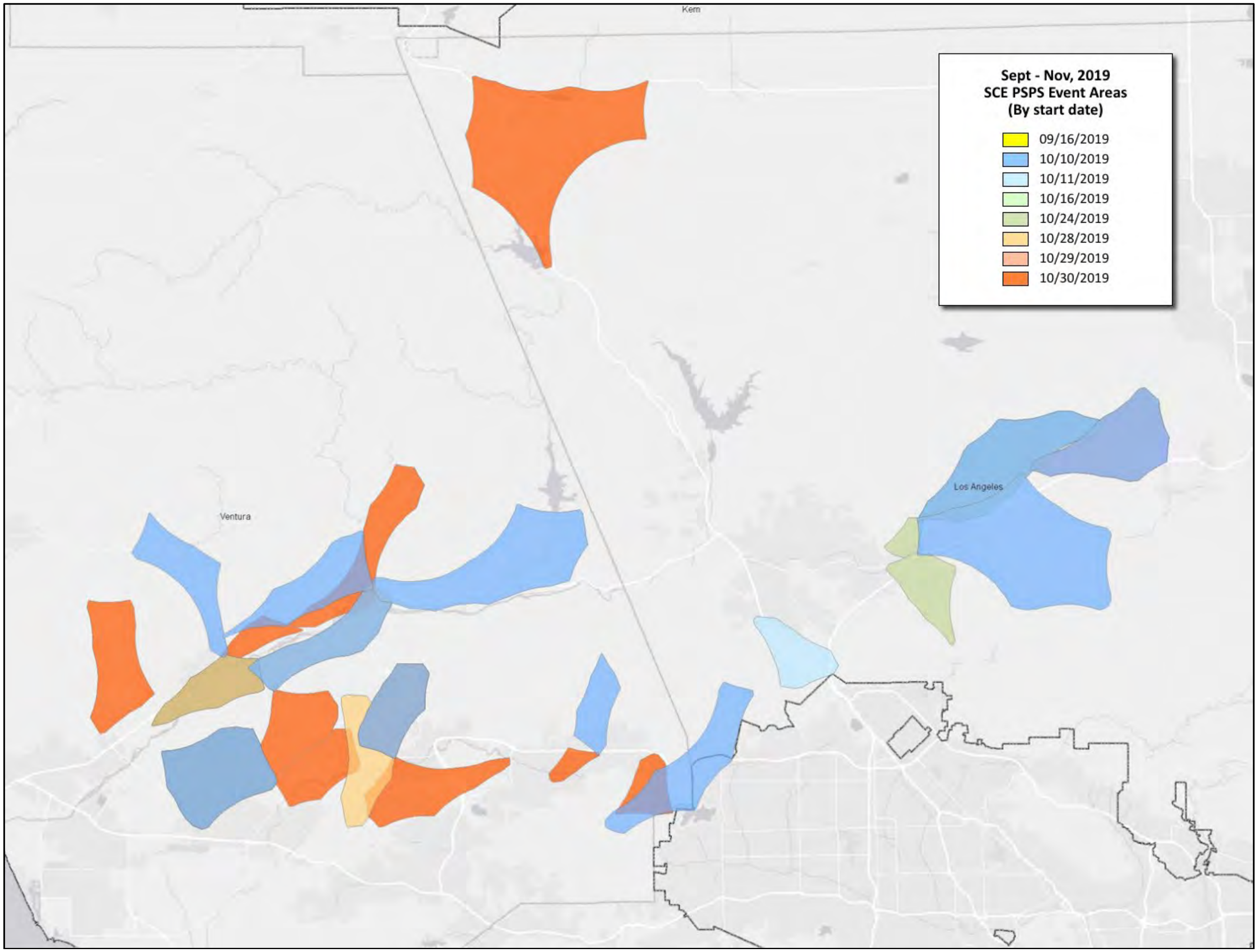


Figure 4. Inset map of PSPS event cluster in southern part of SCE service territory.



4. ANALYSIS OF WEATHER CONDITIONS

4.1 Overview

There are five PSPS events analyzed including September 16, October 10, October 16, October 24, and October 28-30. Of these five events, September 16 and October 16 are classified as minor events based on the number of damage incidents. Lack of incidents has led to the decision to have limited weather analyses for these minor events.

More thorough analyses were performed for October 10, October 24, and October 28-30 which involved summarizing the synoptic weather setup and the surface-based observations associated with each. The territory that SCE is responsible for is susceptible to the risk of both the Santa Ana Winds and the Sundowner Winds which are isolated events, but both are downslope windstorms and notorious for elevated fire danger. The Santa Ana Winds have been extensively studied and it is known that a few topographic gaps exist which produce the most extreme winds. The gaps that fall within the territory of SCE include the Soledad Canyon, Newhall Pass, Cajon Pass, and Banning Pass. A surface weather station near each pass, as shown in Appendix A, have been selected to represent the conditions experienced in each locale. Further, two sites have been chosen in Santa Barbara to monitor the conditions of any potential Sundowner Wind event. In the interest of brevity, the data for Santa Barbara and the Banning Pass have not been shown, but their data are included when generalizing each event with respect to sustained winds, gusts, and relative humidity (RH). The table below generalizes observed conditions during each event and is only intended to compliment the in-depth analyses provided in Appendix A. The last two rows are shaded in grey as they are referenced as one event with regards to a PSPS, but there were two separate Santa Ana events associated with this PSPS.

Table 2. Observed weather conditions during each event.

Date	Sustained Winds	Gusts	RH
16-Sep-19	~ 10-18 knots	~ 15-30 knots	~ 20-50%
10-Oct-19	~ 20-30 knots	~ 30-50 knots	< 10%
16-Oct-19	~ 10-18 knots	~ 15-23 knots	~ 20-50%
24-Oct-19	~ 20-40 knots	~ 35-60 knots	< 10%
28-Oct-19	~ 15-40 knots	~ 30-55 knots	~ 10-20%
30-Oct-19	~ 25-45 knots	~ 40-70 knots	<10 %

4.2 Observed Weather Versus Modeled Conditions

Observed and modeled weather conditions (especially, wind speed and direction) were analyzed and compared for all PSPS damage incidents. Both modelled weather prediction data provided by SCE, 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 modeled weather conditions 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.

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 input is consistent to model potential fire behavior and progression. The modeled values are totally reliable to model the fire progression, especially considering the probabilistic simulations executed for this report dealing with weather uncertainty.

5. SUMMARY OF DAMAGE INCIDENTS

5.1 Summary of All PSPS Event Damage Incidents

A total of 64 damage incidents were reported by SCE for all 2019 PSPS events, including incident location and estimated time of damage. Only 55 damage incidents had the potential to ignite a wildfire through electric arcing according to the data received from SCE and their field inspections. Of the 55 possible ignition points, one of them was located outside PSPS boundaries provided by SCE and, subsequently, it was removed from the analysis. Finally, 54 possible damage incidents were used to conduct the analysis.

Figure 5 presents the locations of the damage incidents relative to all the PSPS event areas. PSPS events are color coded based on date. A unique identification number is provided for each damage incident. The numbering of the incidents reflects the ranking of population impacts derived from the fire spread simulations. For example, the number 1 incident contains the most amount of potential population impacts while incident 54 contains the least amount of potential population impacts. Impacts are measured in terms of population and buildings impacted, and acres burned.

Dashed lines show two areas where a clustering of damage incidents occurs. Additional maps are presented in Figures 6 (cluster 1) and 7 (cluster 2). Note map scale varies for each map.

5.2 Summary of Individual PSPS Event Damage Incidents

Table presents a summary of the damage incidents for each individual PSPS event.

Table 3. Summary of analysis results for damage incidents by PSPS event.

SCE Event	PSPS Event Start Date	Total Damages Reported	Damages Expected to Ignite a Fire
1	Sep 16, 2019	5	4
2	Oct 10, 2019	17	17
3	Oct 16, 2019	1	1
4	Oct 24, 2019	15	12
5	Oct 28-30, 2019	26	20

Some of these event areas overlap as shown in Figures 5, 6 and 7. Accordingly, individual maps are presented showing the damage incidents for each event in Figures 8 through 12. Labels for the damage incidents represent the overall ranking for population impacts for all PSPS events. Note map scale varies for each map.

The following events overlap for the areas identified in the maps.

Figure 6

- Area 1 is an overlap of 10/24/10 and 10/30/19 events
- Area 2 is an overlap of 10/10/19, 10/24/19 and 10/30/19 events
- Area 3 is an overlap of 10/10/19 and 10/28/19
- Area 4 is an overlap of 10/10/19 and 10/30/19

Figure 7

- Area 1 is an overlap of 10/10/10 and 10/24/19 events
- Area 2 is an overlap of 10/10/19 and 10/29/19 event

Figure 5. Damage incidents relative to all SCE PSPS event areas.

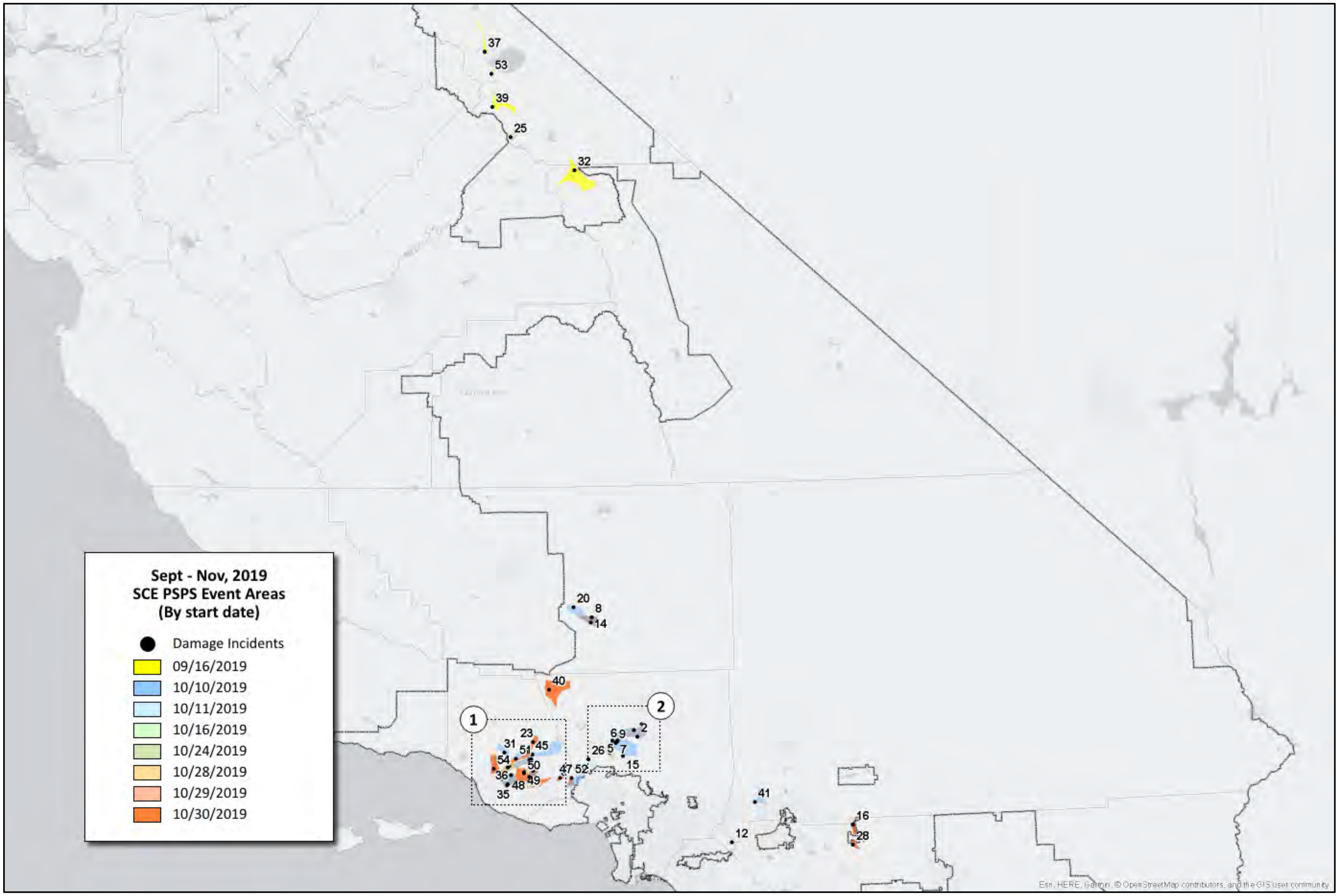


Figure 6. Map of damage incident cluster 1.

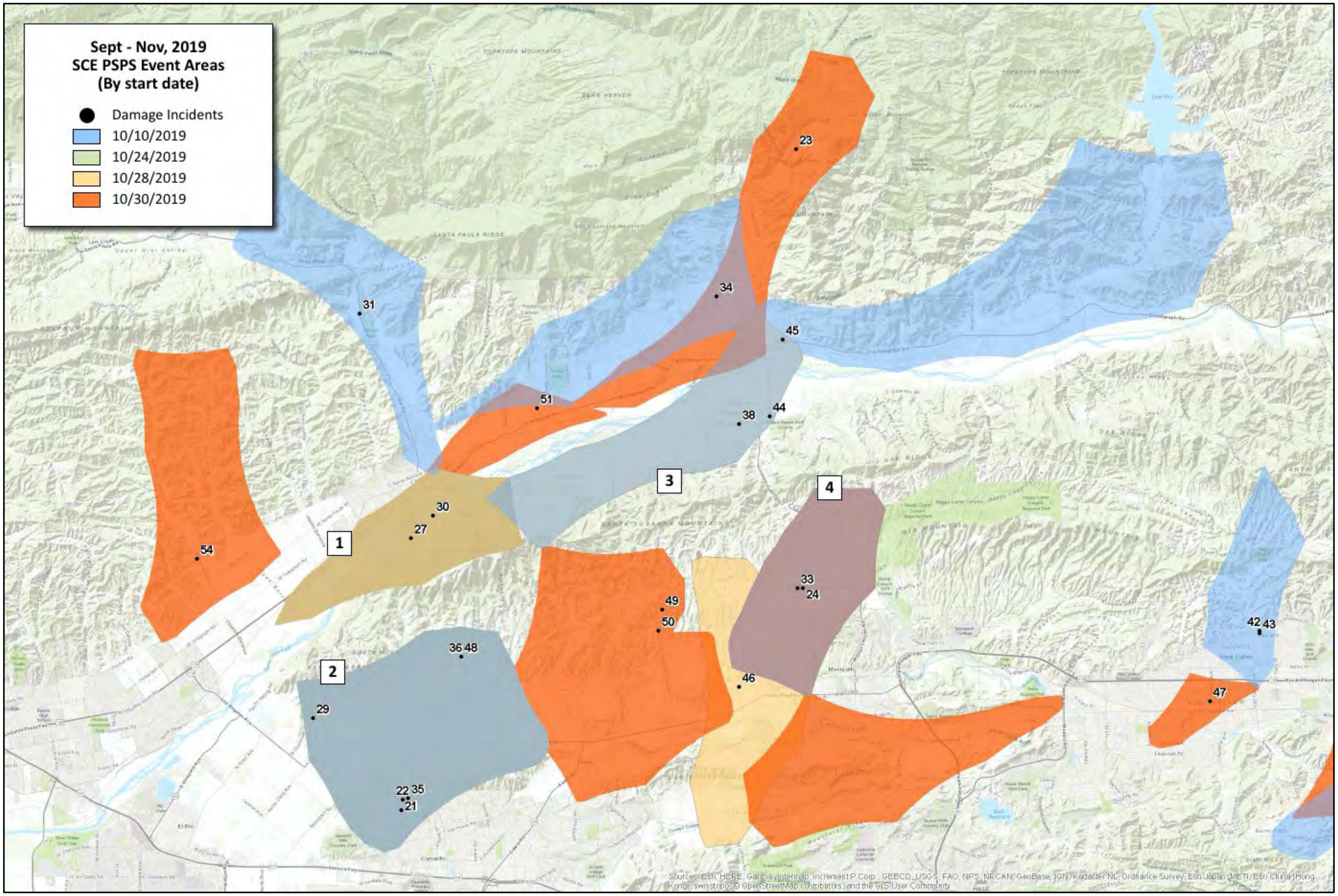


Figure 7. Map of damage incident cluster 2.

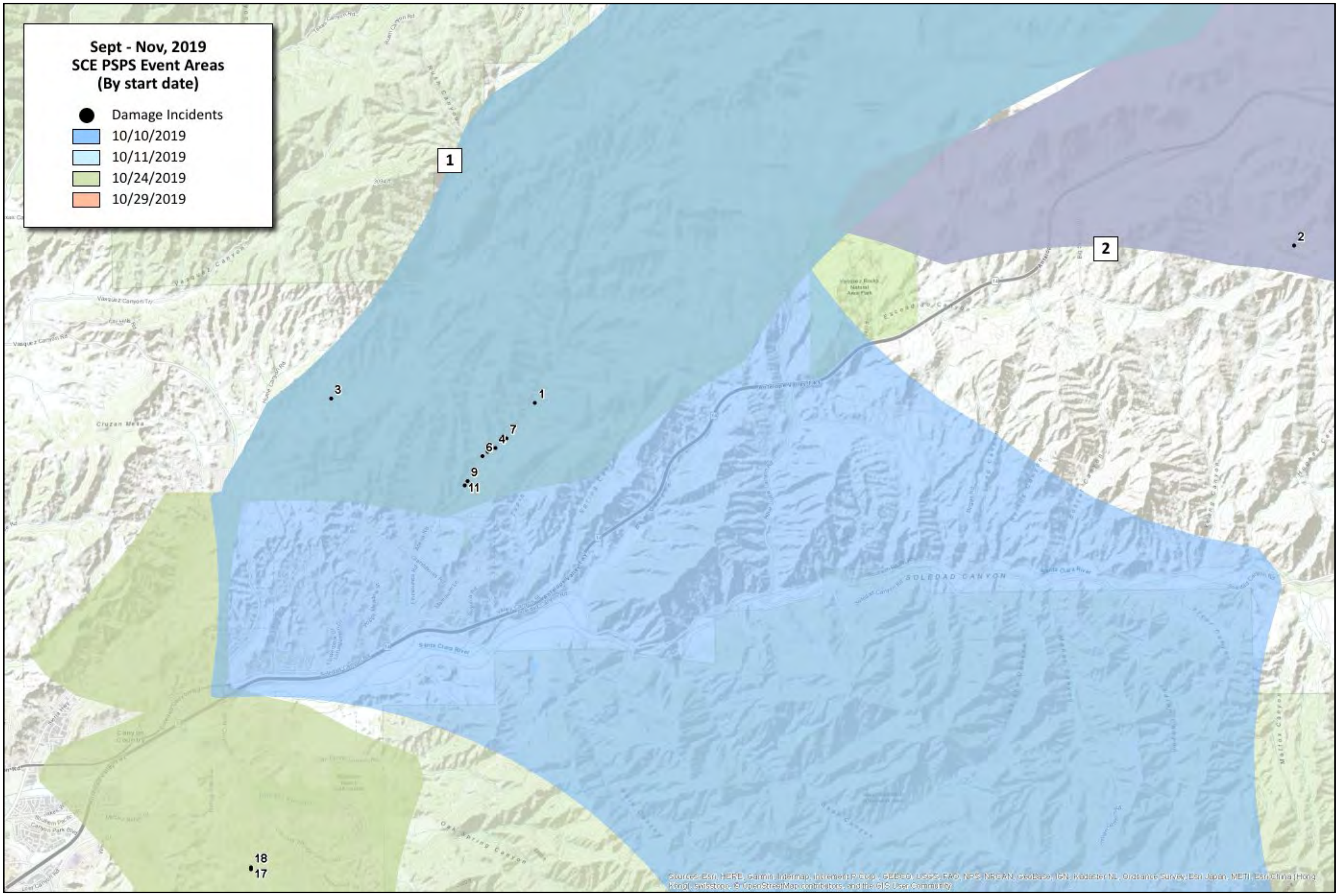


Figure 8. Damage incidents for the September 16th ,2019 SCE PSPS event.

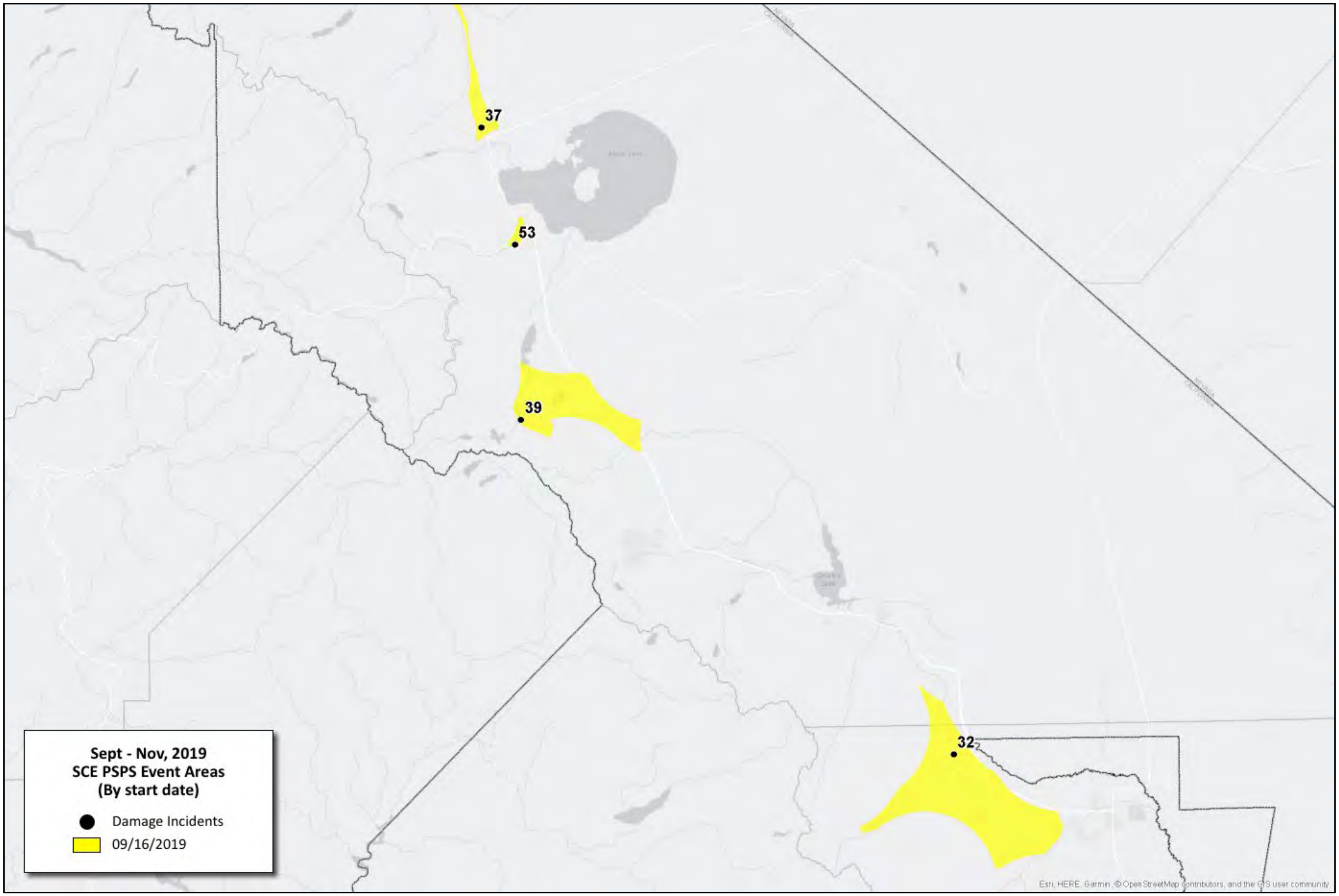


Figure 9. Damage incidents for the October 10 ,2019 SCE PSPS event.

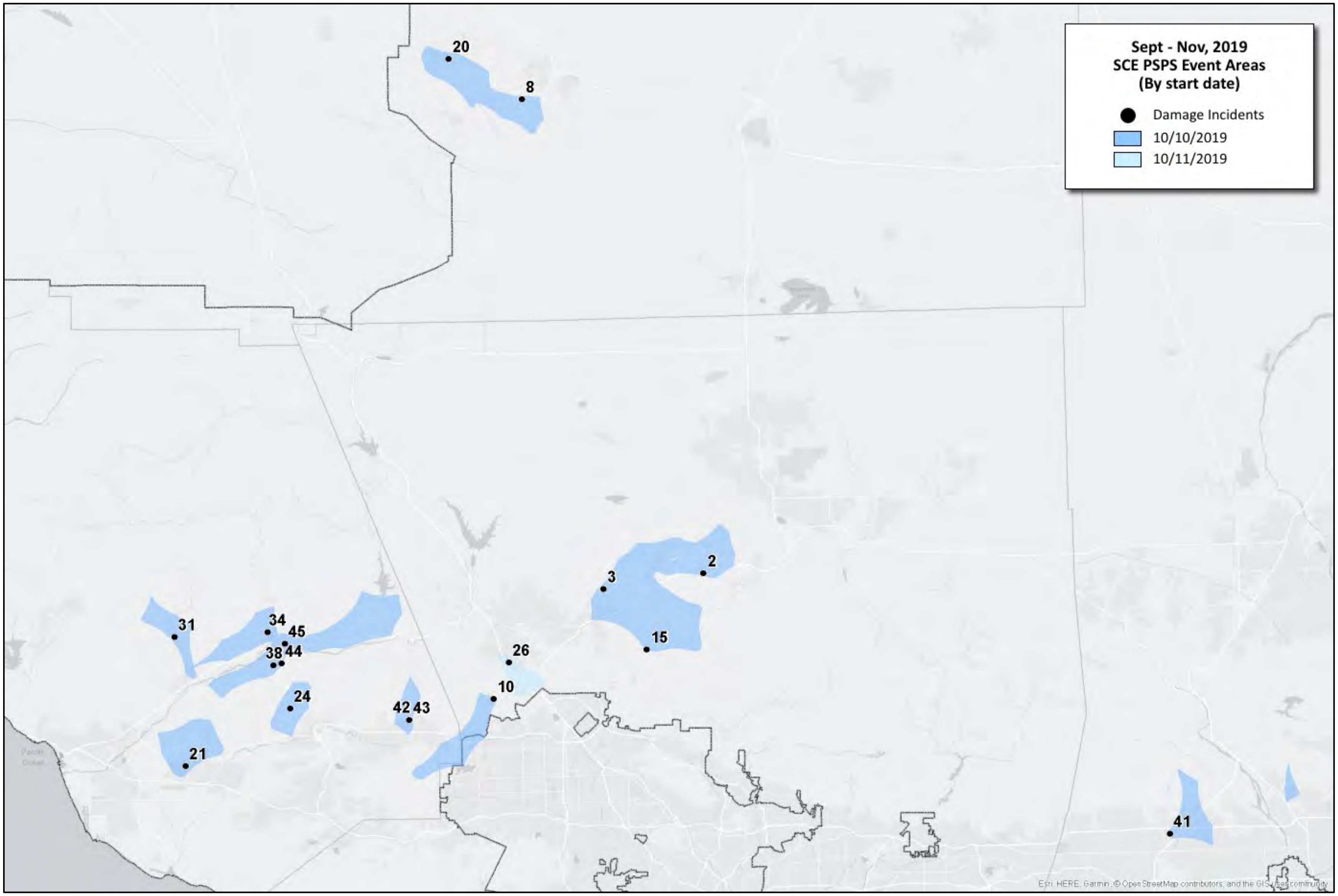


Figure 10. Damage incidents for the October 16, 2019 SCE PSPS event.

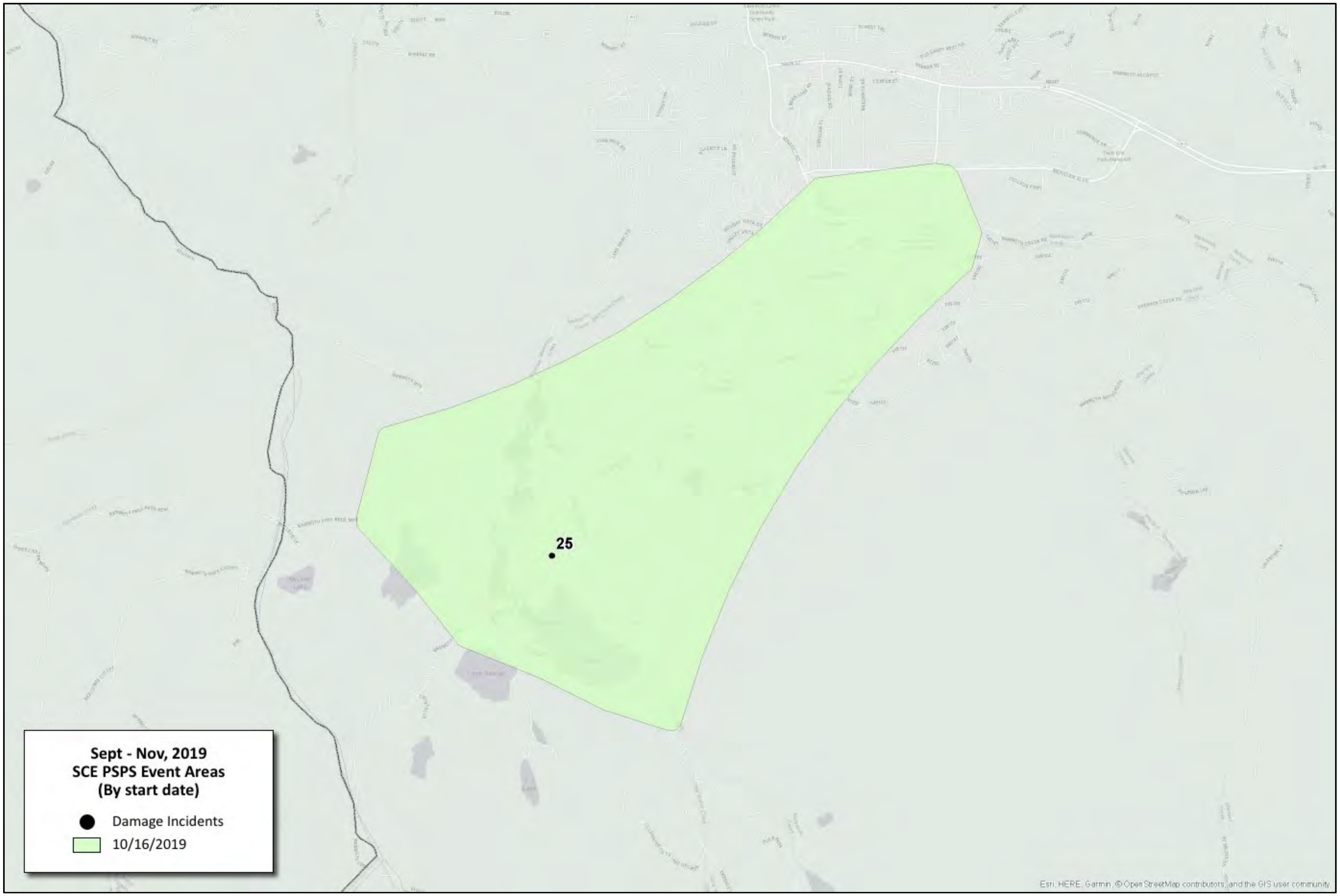


Figure 11. Damage incidents for the October 24, 2019 SCE PSPS event.

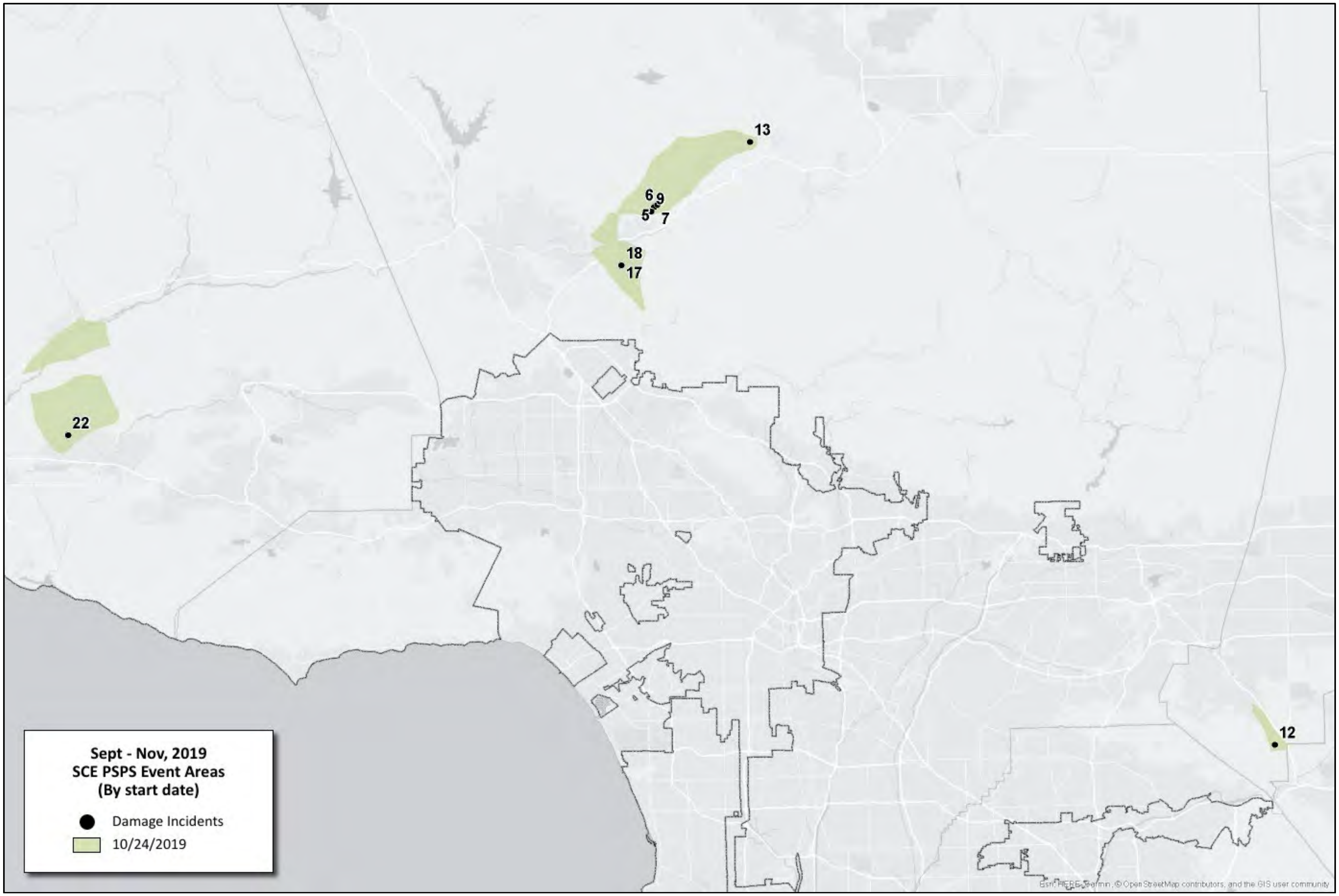
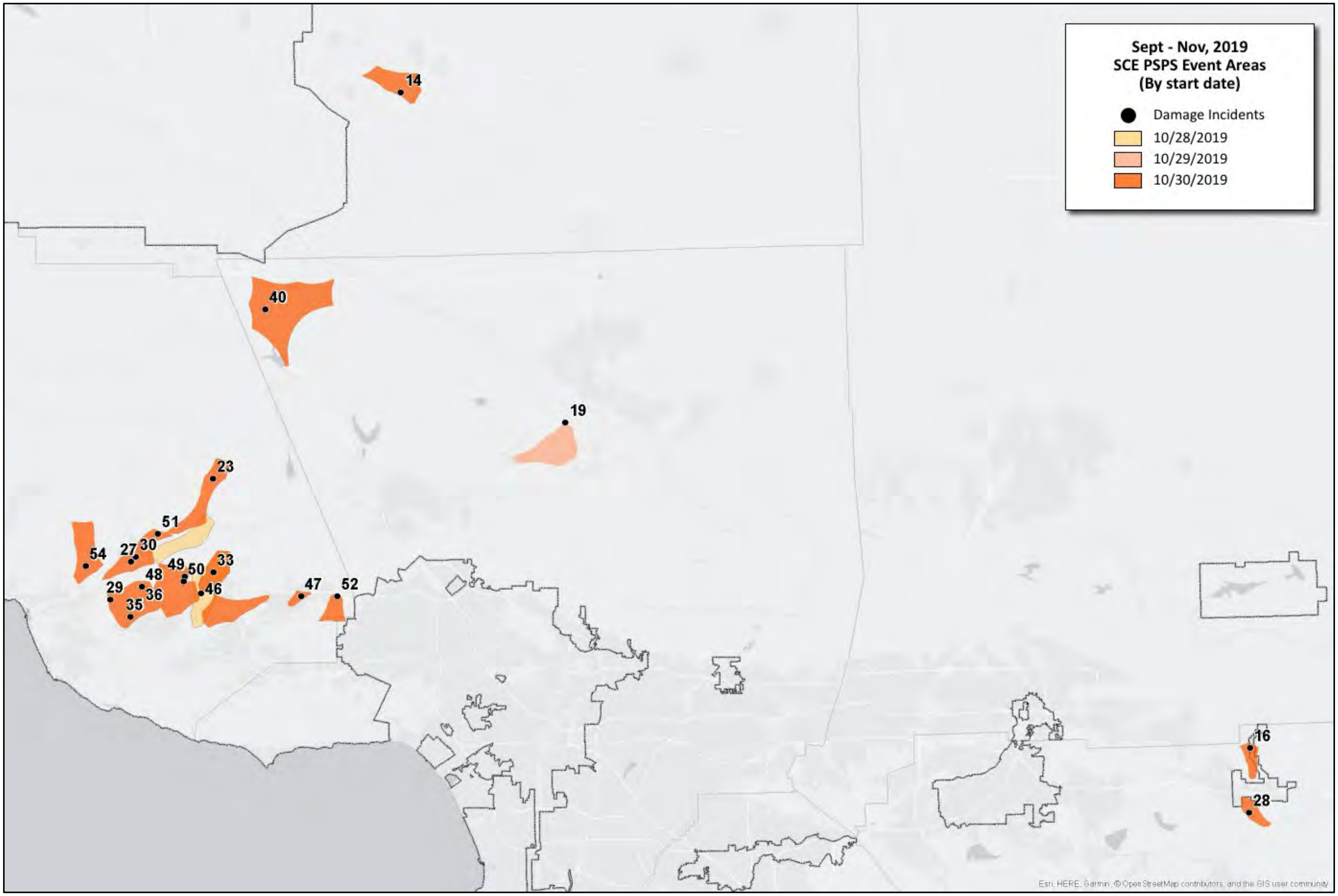


Figure 12. Damage incidents for the October 27-November 4, 2019 SCE PSPS event.



5. SUMMARY OF ANALYSIS RESULTS

5.1 Summary of Results for All Damage Incidents

Fire spread simulations were undertaken for the 54 damage incidents using the location of the damage incident as the ignition source, and the date/time estimated for the damage occurring as the start time for the fire simulation. The simulations were run for a 24-hour duration. Impacts to buildings, population, and acres burned were calculated for each fire simulation.

Table 4 shows the number of buildings affected, population impacted, and acres burned for all 54 fire incident locations, after averaging 100 fire simulations during a 24 hour fire duration for each incident location, totaling 54,000 fire simulations conducted. More than 25,000 buildings and 55,000 people may have been affected by fires simulated for the identified damage incidents. Additionally, the fires may have burned approximately 365,000 acres.

These figures are calculated considering 1 incident by fire cluster. Predicted fire behavior is high for most of fire simulations, especially in terms of rate of spread, resulting in high to extreme IAAs. Therefore, it seems reasonable that shutdowns were executed based on these results. Note that all of these results do not consider fire suppression.

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 SCEs decision to shutoff power. This was the purpose of this analysis.

Table 4. Summary of analysis results for all damage incidents by PSPS event.

SCE Event	PSPS Event Dates	Total Damages Reported	Damages Expected to Ignite a Fire	Total Population Impacted	Total Buildings Impacted	Total Acres Burned
1	Sep 16, 2019	5	4	102	139	12,541
2	Oct 10, 2019	17	17	29,578	12,908	178,721
3	Oct 16, 2019	1	1	204	76	826
4	Oct 24, 2019	15	13	17,631	7,621	80,151
5	Oct 28-30, 2019	26	20	8,467	4,690	93,547
			Total	**55,982**	**25,434**	**365,786**
			Maximum	7,547	3,716	42,151
			Average	1,191	541	7,783
			Standard Deviation	2,185	938	11,259

5.2 Selecting Significant Incidents

Once the fire spread prediction analysis was completed for all 54 damage incidents, specific criteria was applied to identify the most significant incidents. Worst cases were identified considering the criteria described in Section 2.2.4.

For situations where a cluster of damage incidents existed, a single worst-case damage incident simulation was selected based on the chronology of the incidents, the proximity of the incidents, the direction of fire spread, and the population impacted. A clustering of damage incidents occurred in three SCE PSPS events:

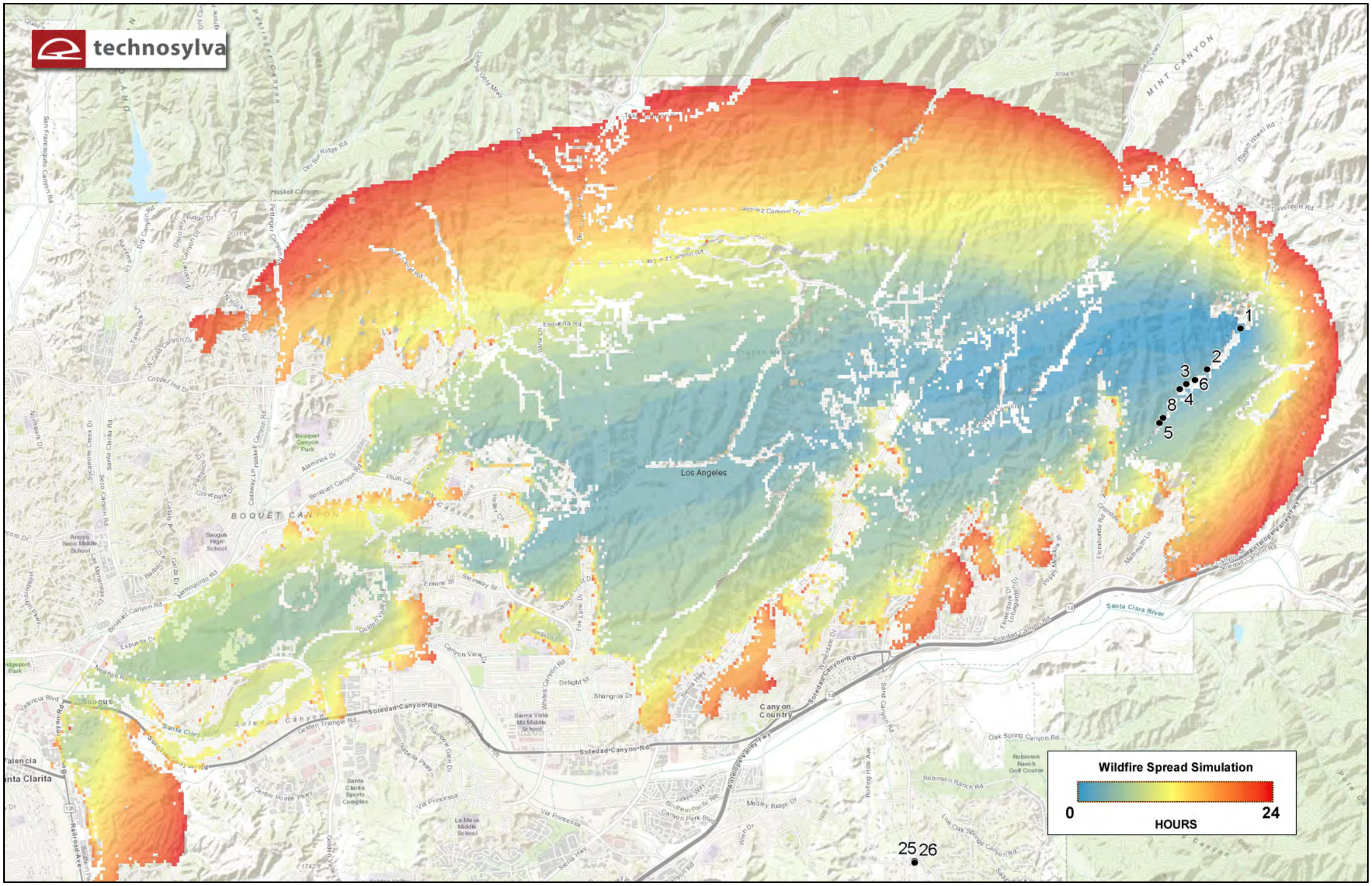
- October 24th, 2019
- October 30th, 2019

Clustering of damage incidents was most prevalent in the October 24th, 2019 PSPS event. A series of 7 damages occurred very close to each other on a specific circuit, all with the same estimated time of damage. Figure 13 shows this example where incidents 2 through 6, and 8, were excluded from the analysis summary because they are immediately contained within the simulated spread of damage incident 1, when considering the direction of spread. Damage incident 1 was included as it was upstream of the spread, and also had the highest impacts. In this situation including impacts from incidents 2-6, and 8 would be redundant and inappropriate, especially considering that impacts were substantial from these excluded incident simulations.

For the October 24th event, 7 damage incidents were excluded.

For the October 30th event, 3 damage incidents were excluded.

Figure 13. Example of incident clusters for significant incident number 1 during the October 24th, 2019 PSPS event.



5.3 Summary of Results for Significant Incidents

Using the criteria described in Section 2.2.4, the most significant fire incidents were identified from the 54 damage incidents based on criteria described in the previous section. The following tables list these incidents. Incidents are numbered by a ranking of potential population impacts starting at 1 for all PSPS events. The IAA is shown as guide for potential to spread rapidly and exceed initial attack. The following tables present the significant incidents for the following PSPS events:

- September 16th, 2019 – none
- October 10th, 2019 – 5 of 17 incidents
- October 16th ,2019 - none
- October 24th, 2019 – 4 of 12 incidents
- October 30th, 2019 – 2 of 20 incidents

5.3.1 October 10, 2019 Significant Incidents

Table 5. List of significant incidents for the October 10, 2019 SCE PSPS event.

Damage Incident Rank	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
2	Los Angeles	7,467	3,716	42,151	5
3	Los Angeles	6,566	2,220	14,032	5
8	Kern	5,515	1,600	22,845	5
10	Los Angeles	4,793	2,174	24,637	5
15	Los Angeles	3,783	1,693	29,854	3

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

5.3.2 October 24, 2019 Significant Incidents

Table 6. List of significant incidents for the October 24,, 2019 SCE PSPS event.

Damage Incident Rank	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
1	Los Angeles	7,547	2,674	15,426	5
12	San Bernardino	4,235	1,008	20,357	5
13	Los Angeles	4,135	3,147	36,899	5
17	Los Angeles	1,458	608	7,300	3

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

5.3.3 October 28-30, 2019 Significant Incidents

Table 7. List of significant incidents for the October 28-30th, 2019 SCE PSPS event.

Damage Incident Rank	County	Population Impacted	Buildings Impacted	Acres Burned	IAA
14	Kern	3,953	927	10,838	3
16	Riverside	2,967	2,163	19,378	4

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

Although large fires usually produce high impacts on buildings, population and the landscape, the ignition location and potential propagation play a key role on determining final impacts. In these PSPS events, all selected damage incidents derived to large wildfires causing high impacts. However, whereas the damage incident 1 clearly had the highest impact on population, the damage incident 2, 13 and 15 had the largest impact on burned area.

Figure 14 summarizes the population and buildings impacted for the most significant incident simulations.

Figure 14. Summary of population and buildings impacted for the significant incidents.

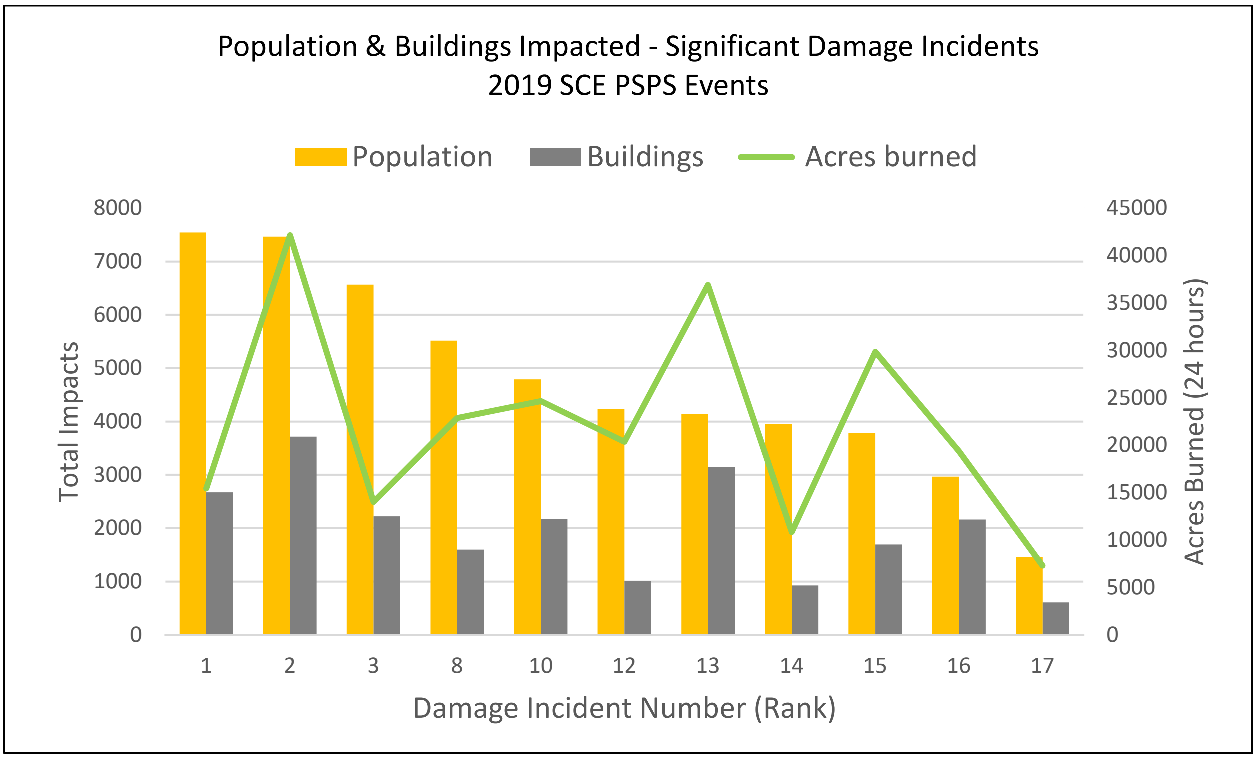


Figure 15 and 16 present maps showing the location of the significant incidents identified in Table 3.

Figure 15. Map of the significant damage ignition locations.

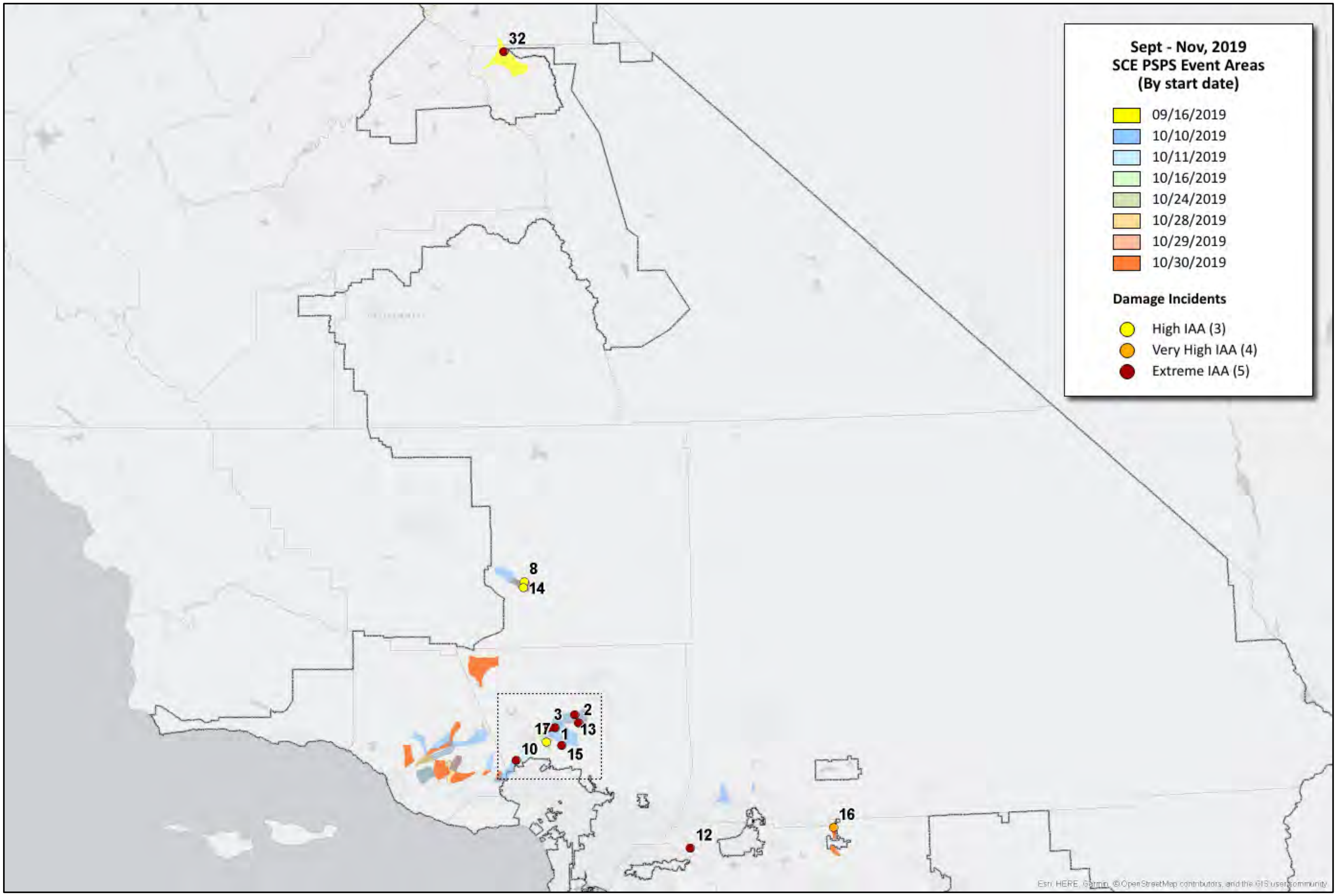
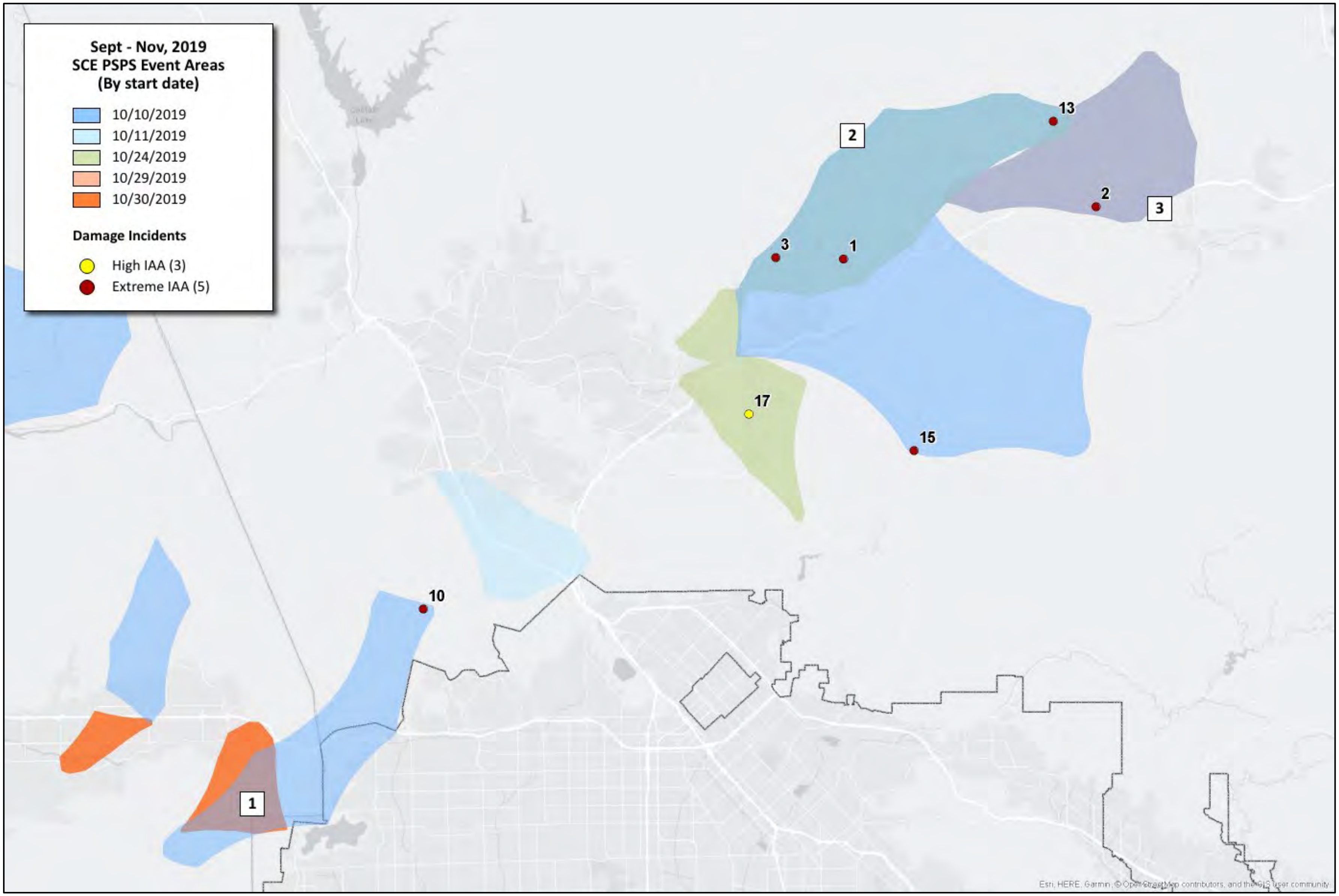


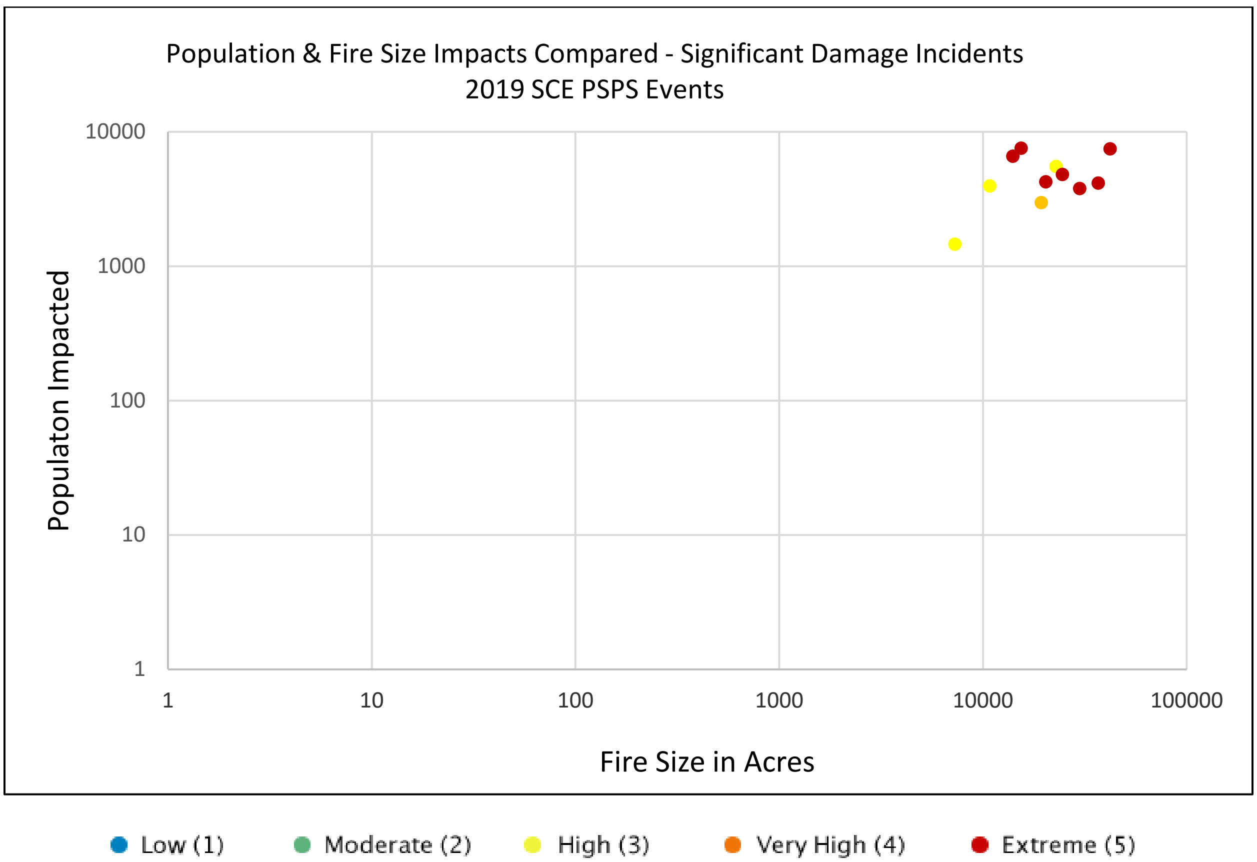
Figure 16. Inset map of significant damage incidents.



Fire simulations with an intense fire behavior (flame length and 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, in line with our results for the selected damage incidents. However, note that 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 moderate IAA values also had high impacts. This is shown in the list of significant incidents where 3 of the 11 had an IAA of 3 (Moderate).

Figure 16 presents the population impacts of each fire simulation for significant damage incidents as a function of size (acres burned). Fires are color coded by IAA. This chart shows that all fire simulations had moderate to extreme IAA index values. These fire simulations are significant from the start and are likely to escape initial attack. Most of them resulted in large impacts.

Figure 17. Number population impacts as a function of fire size for the significant incidents. Colors represents IAA values



In summary, the following conclusions are reached:

- Generally large fires result in large impacts but moderate size fires can also result in large impacts.
- Fires with the highest IAA have large burned areas and usually large impacts but not always. This reflects that fires with high IAA are significant from the start.
- Also, 17 damage incidents could have only caused an impact less than 10 people. This reflects the need of an independent analysis for each damage incident.

6. SUMMARY OF ACTIVE WILDFIRES DURING THE PSPS EVENT

This section summarizes the active wildfires that occurred during the PSPS events in California. 555 fire incidents were recorded in the IRWIN system within the SCE Service Territory during the 2019 SCE PSPS events in California. This is considered very high fire activity.

However, wildfires were less frequent in the SCE PSPS event areas during the timeframe of the events. Twenty two (22) fires are located inside the PSPS event boundaries during this timeframe, including the Maria Fire (10,000 acres) and Tick Fire (4,615 acres) fires. Figure 17 presents the IRWIN reported fires within the SCE Service Territory. Figure 18 presents the IRWIN reported fires located within the SCE service territory for the PSPS event timeframes. Figure 19 shows an inset map for the IRWIN incidents inside the PSPS event areas.

Figure 18. Wildfires occurring during the PSPS event.

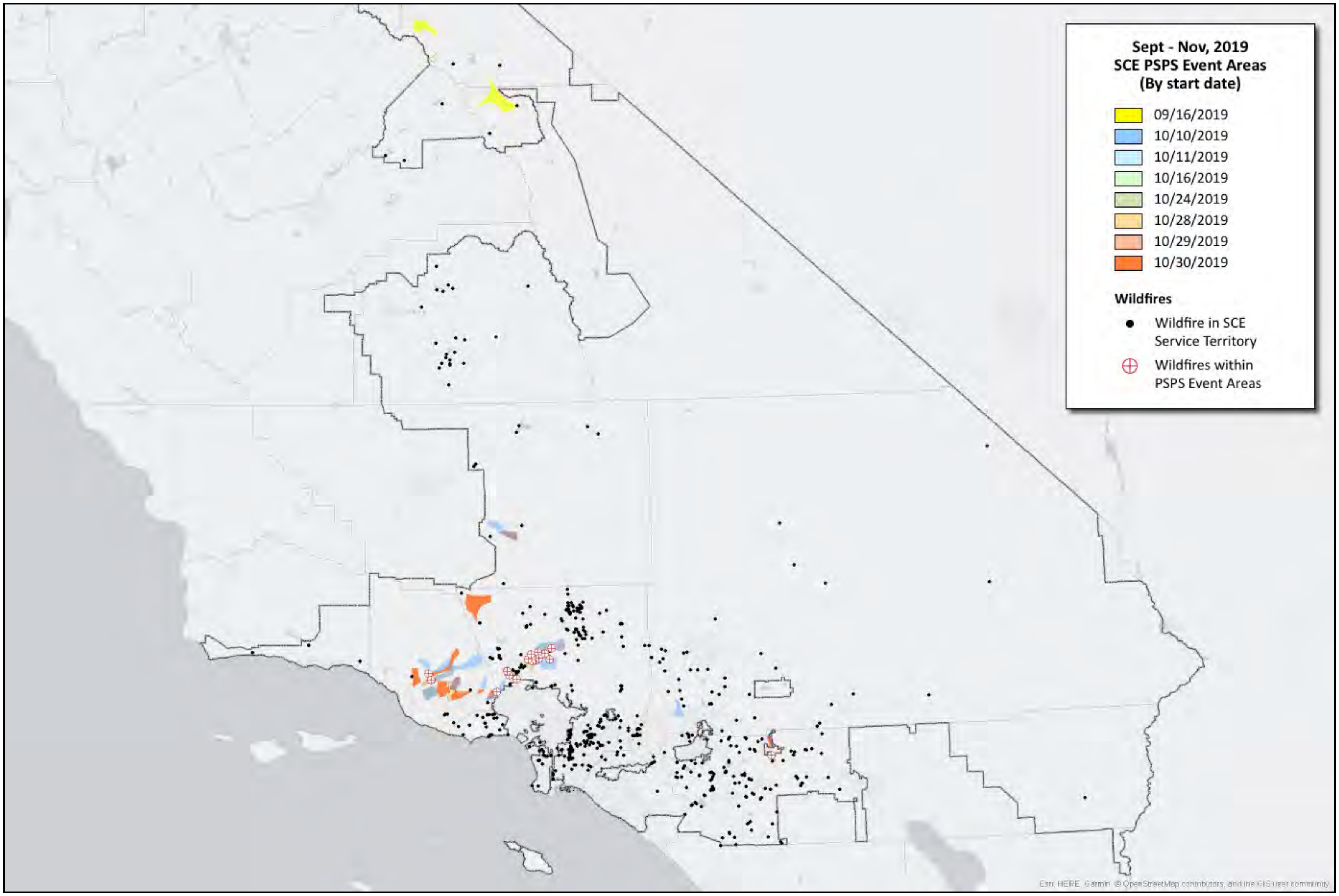
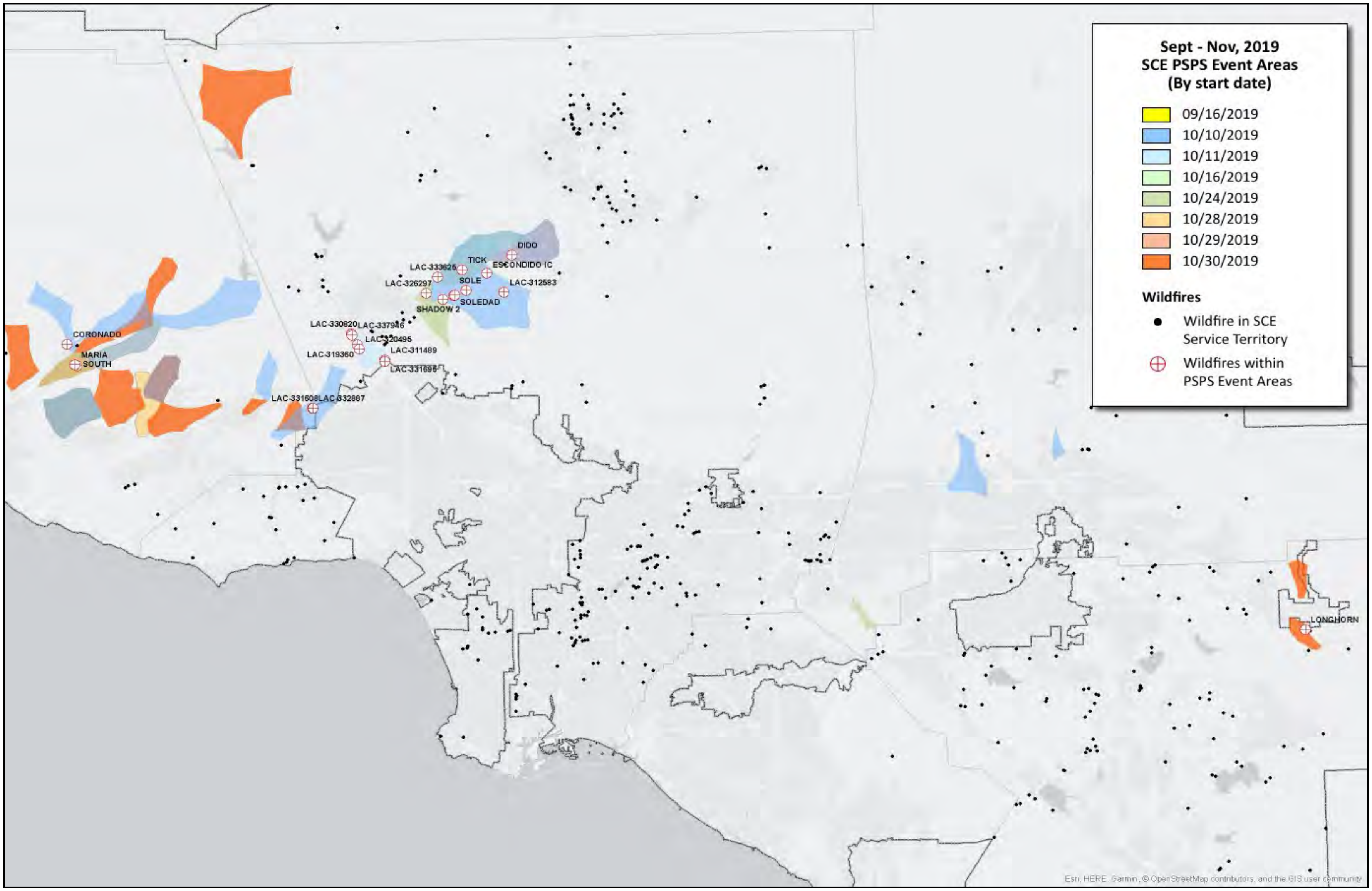


Figure 19. Inset map of wildfires within PSPS areas.



7. CONCLUSIONS

7.1 Findings

- Fifty-four (54) damage incidents were identified in the 2019 PSPS events for the SCE territory. Damages sustained to de-energized PG&E facilities during these events could have impacted more than 25,000 buildings and 55,000 people and burned approximately 365,000 acres. The potential impacts of each damage incident depends on specific environmental conditions (i.e. fuels, weather, topography, etc.) and the exposure of assets (buildings, population) near the incident ignition locations. The variability in fire impact between damage incidents was high among incidents and not all fires in the same day would create the same impact. For instance, 16 damage incidents would have only caused an impact less than 10 people, reflecting the need of analyzing all incidents independently.
- Figure 20 presents a map showing the damage incidents classified by population impacts. Two more detailed inset maps are presented in Figures 21 and 22. Note that some of the PSPS event areas overlap. Labels for the damage incidents represent the overall ranking for population impacts across all PSPS events. Note map scale varies for each map. The following events overlap for the areas identified in the maps.

  Figure 21

  - Area 1 is an overlap of 10/24/10 and 10/30/19 events
  - Area 2 is an overlap of 10/10/19, 10/24/19 and 10/30/19 events
  - Area 3 is an overlap of 10/10/19 and 10/28/19
  - Area 4 is an overlap of 10/10/19 and 10/30/19
  - Area 5 is an overlap of 10/10/19 and 10/30/19

  Figure 22

  - Area 1 is an overlap of 10/10/10 and 10/24/19 events
  - Area 2 is an overlap of 10/10/19 and 10/29/19 event
  - Area 3 is an overlap of 10/10/19 and 10/30/19
- The selected significant damage incidents reflect that these fires could be very intense with fast moving fires (> 50-100 chains/hr) driven by high wind speed, low fuel moisture content and grass-shrub fuel types, possibly exceeding fire suppression capabilities during initial attack. All significant incidents had an IAA high or extreme. [12]
- Five hundred and fifty five (555) fire incidents were recorded in the IRWIN system within the SCE Service Territory during the 2019 SCE PSPS events in California. This could limit the availability and effectiveness of suppression resources due to fires occurring simultaneously. However, only twenty two (22) fires are located inside the PSPS event boundaries.
- There are minimal differences between modeled wind speed data, and the nearest weather station data. This is due to a large number of weather stations in a small service

[12] 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.

territory. This has led to an accurate weather prediction model that commonly closely matches weather station observation data. Accordingly, the prediction data is very reliable to model the incident simulations, especially when considering the probabilistic simulations that incorporate weather uncertainty.

- 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 accurately predict and weather stations are sometimes far to be representative of specific locations. Nonetheless, it is important to consider probabilistic approaches to estimate the potential impact of fires in real-time operations. These are included in Appendix B for all significant incident simulations.
- The custom weather and fuel types provided in Technosylva's Wildfire Analyst™ software module allow users to modify input data based on real observations. The analysis conducted highlights the importance of these capabilities to improve and calibrate the fire simulation outputs based on integrated input data (i.e. cameras, weather station integration, IRWIN incident locations, etc.).

Figure 20. Population impacts for damage incidents.

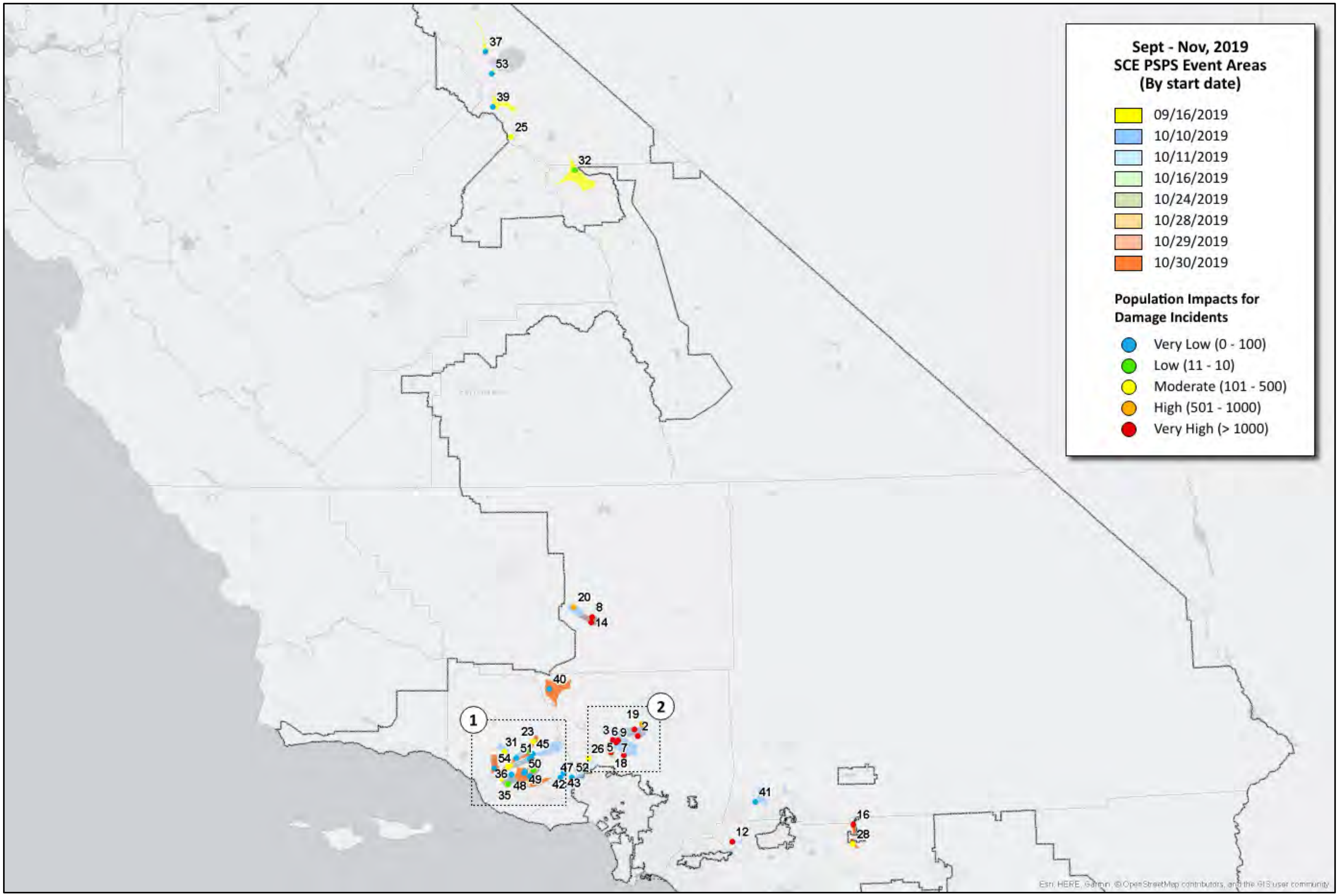


Figure 21. Detail area 1 for population impacts.

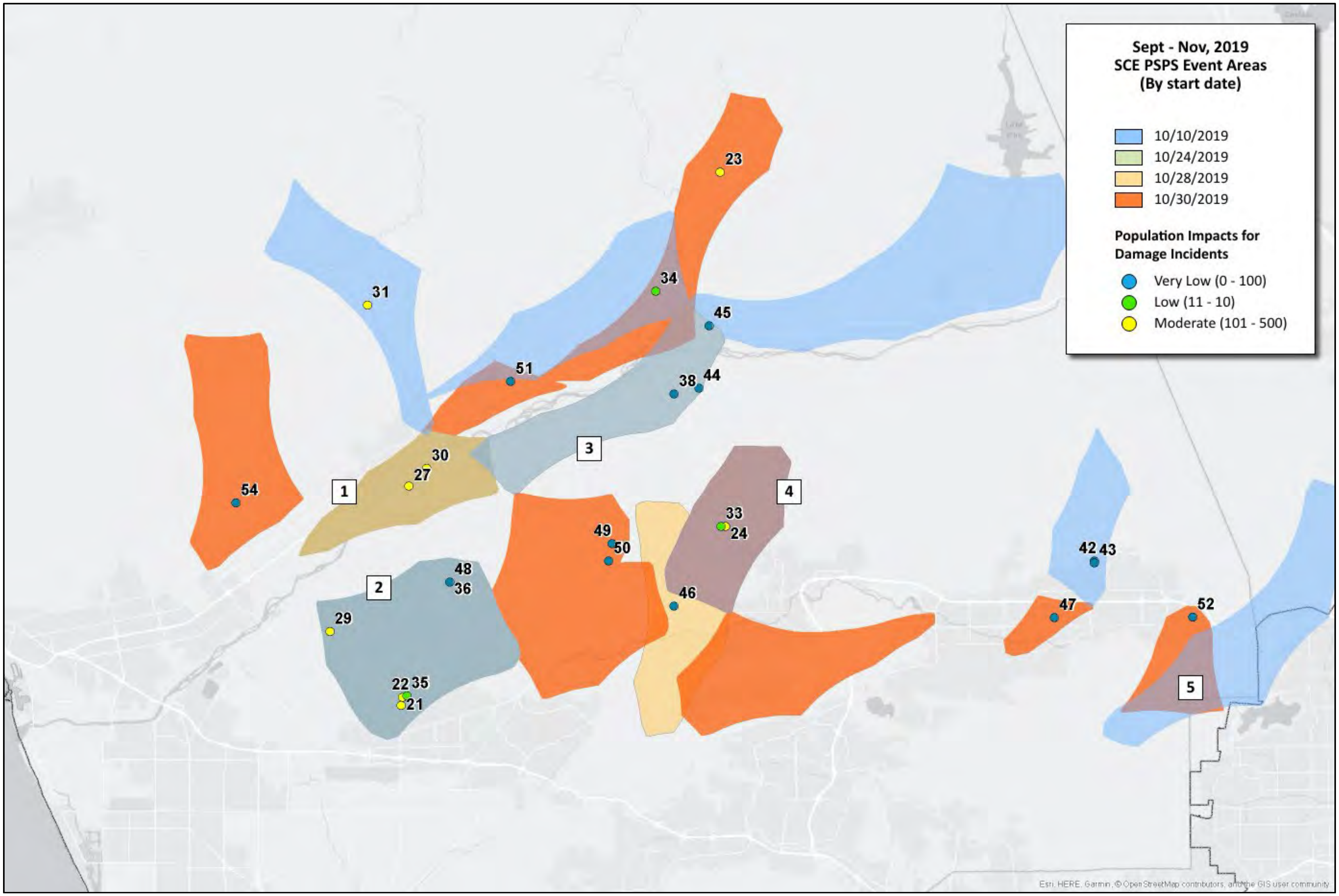
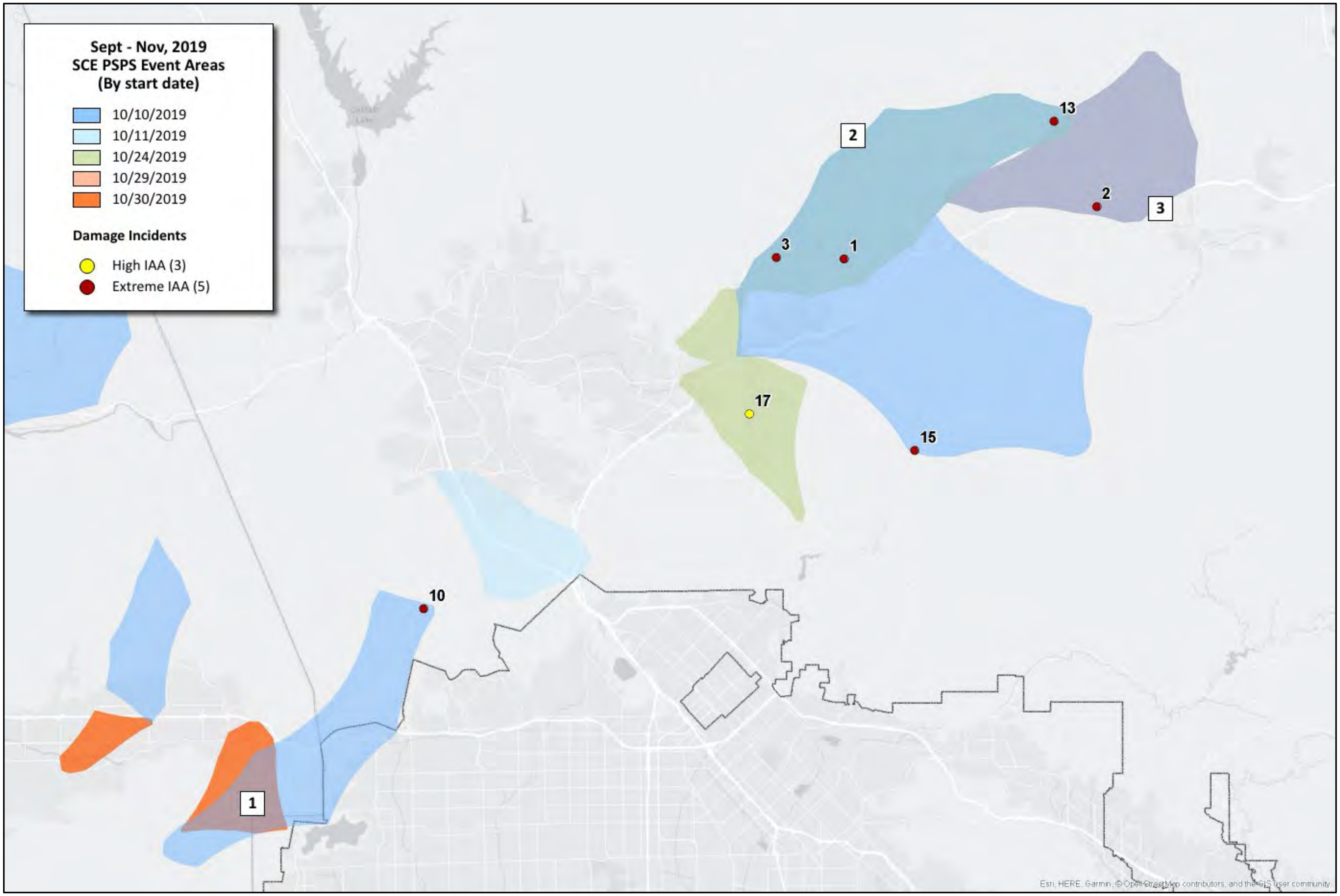


Figure 22. Detail area 2 for population impacts.



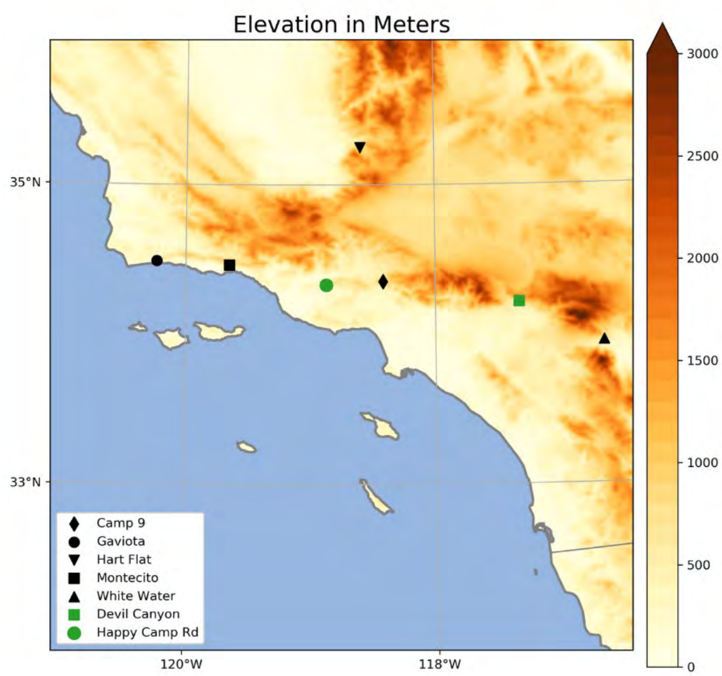
7.2 Recommendations and Opportunities for Improvement

- The analysis includes the potential impact of damage incidents on population, buildings, and acres burned if ignitions were to occur from the damage incurred to de-energized utility facilities during a PSPS event. The incidents need to be analyzed with caution due to the uncertainty of input data used 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.
- 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 SCE'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

The following investigates the weather situation during the PSPS events activated by Southern California Edison (SCE) in 2019. There are five events under review including 16 September, 10 October, 16 October, 24 October, and 28-30 October. A surface weather station near each pass, shown in Figure 20, have been selected to represent the conditions experienced in each locale. Black symbols represent RAWS stations and green symbols represent SCE stations. Hotspots for Santa Anas are monitored by Devil Canyon, Camp 9, Happy Camp Road, and White Water which represent conditions in the Cajon Pass, Newhall Pass, Soledad Canyon, and Banning Pass respectively. Hart Flat monitors the outflow from northerly winds in the central valley while Gaviota and Montecito monitor the potential for Sundowner wind events.

Figure 23. Surface weather stations that are used in this analysis.



In-Depth Case Analyses

16 September 2019

The synoptics of this event can be described by the advancement of a shortwave trough over California. Associated with this trough was a surface cold front which advanced southward across California. Ahead of this cold front, moderate southerly flow was observed followed by moderate northerly flow after the passage of the front. Aside from the synoptically induced winds, there was concern for potential convective activity ahead of this cold front. Convective activity was minimal, but the Oxnard office of the National Weather Service (NWS) observed localized lightning strikes which was noted in their area forecast discussion for 0401 UTC 16 September 2019. The strongest winds were in the Santa Barbara area with increased Northerly flow behind the cold front and the potential for Sundowner winds to develop. The Gaviota RAWS, location seen in Figure 1, observed sustained winds up to 30 knots and gusts that approached 40 knots (not shown). Camp 9 recorded elevated winds from the SSE with RH ranging from 20-50%. Happy

Camp Road and Devil Canyon recorded a consistent diurnal wind pattern with moderate RH typically above 20%.

Figure 24. Surface weather station data shown below with Devil Canyon, Camp 9, and Happy Camp Road representing conditions in the Cajon Pass, Newhall Pass, and Soledad Canyon respectively

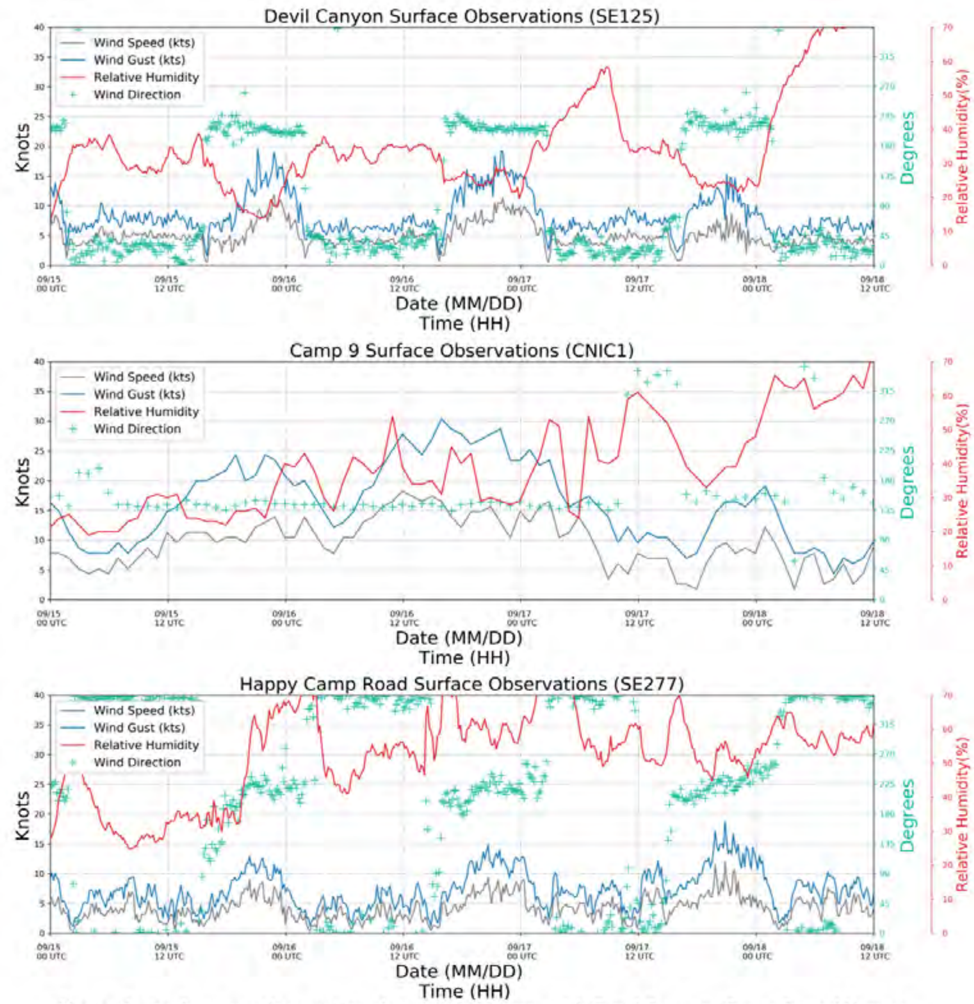
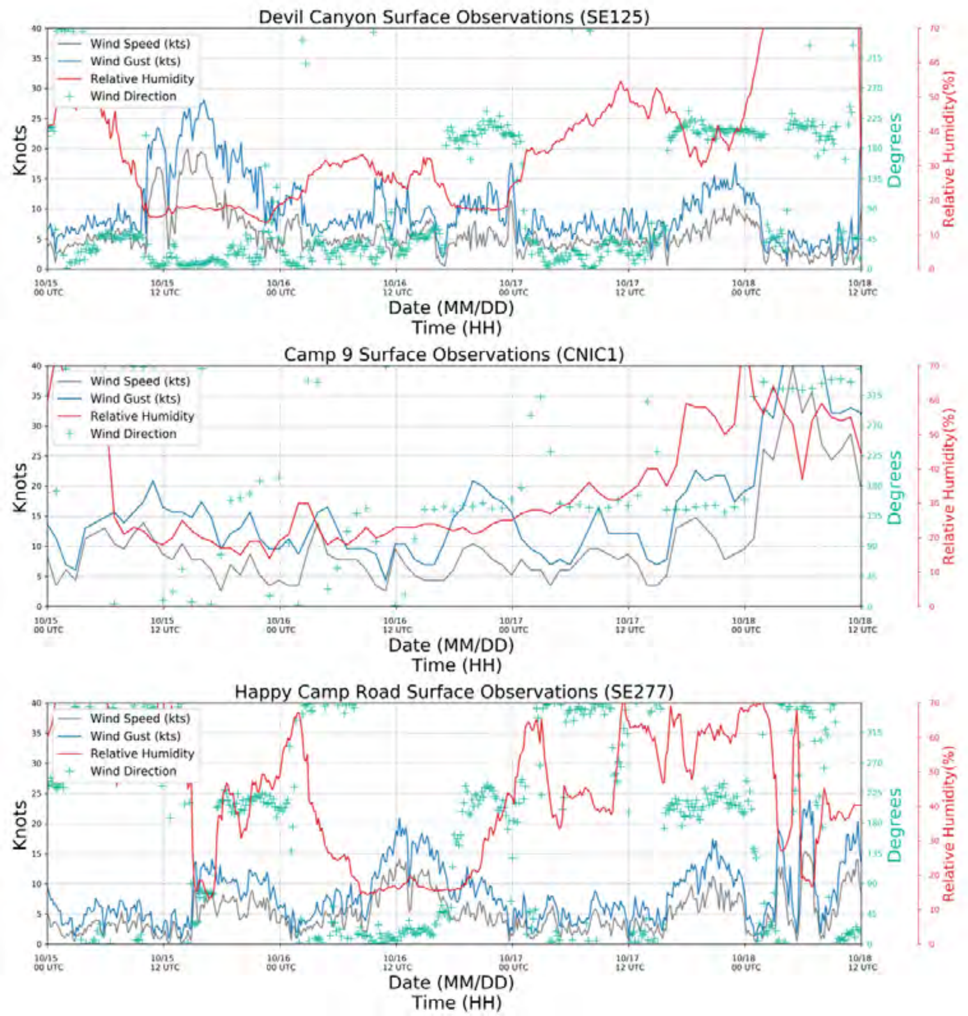


Figure 2. Surface weather station data shown above with Devil Canyon, Camp 9, and Happy Camp Road representing conditions in the Cajon Pass, Newhall Pass, and Soledad Canyon respectively.

16 October 2019

The synoptics of this event can be described by the passing of a weak shortwave trough that shifted from a positive tilted axis to a negative tilted axis as it impacted California. Significant impacts from this upper level trough were not experienced by southern California until later in the week. However, a week surface cold front did propagate south across California. Moderate southerly flow with low RH preceded this cold front. Sustained winds were generally between 10-18 knots while gusts generally ranged between 15-23 knots (Figure 12). The dry air was observed with minimum RH measurements ~ 20% in select areas and less dry elsewhere. Gaviota experienced the strongest winds, gusts over 40 knots and sustained winds over 30 knots, but the winds were associated with high RH.

Figure 25. Surface weather station data shown below with Devil Canyon, Camp 9, and Happy Camp Road representing conditions in the Cajon Pass, Newhall Pass, and Soledad Canyon respectively.



10 October 2019

The synoptics of this event can be described by an upper level shortwave trough that propagated through the Great Basin and was a primary contributor to a Santa Ana Wind event. This positively tilted trough tracked from coastal British Columbia in a southeastward direction and passed directly over the Great Basin (Figure 13). This shortwave had common surface characteristics associated with it which included a low-pressure system out ahead of it and a tight pressure gradient between the high-pressure feature that followed in the wake of the trough. Further surface analysis was performed to dissect intricacies.

Regional analyses at the surface were started using two-meter dewpoint temperatures and mean sea level pressure. Surface characteristics were carefully analyzed as the synoptic-scale meteorological conditions showed some necessary components for the development of downslope windstorms across California. Surface analysis diagnosed the existence of a strong surface pressure gradient associated with high pressure in the Great Basin and low pressure that occupied much of California. In Figure 14d, two-meter dewpoint temperatures clearly indicate that dry air advected into southern California as the strong pressure gradient sustained. Further surface analysis was needed to review the specifics related to the wind event.

Figure 26. Geopotential heights (meters9 at 500-hPa are contoured and winds are shaded in knots. Time is labeled in UTC.

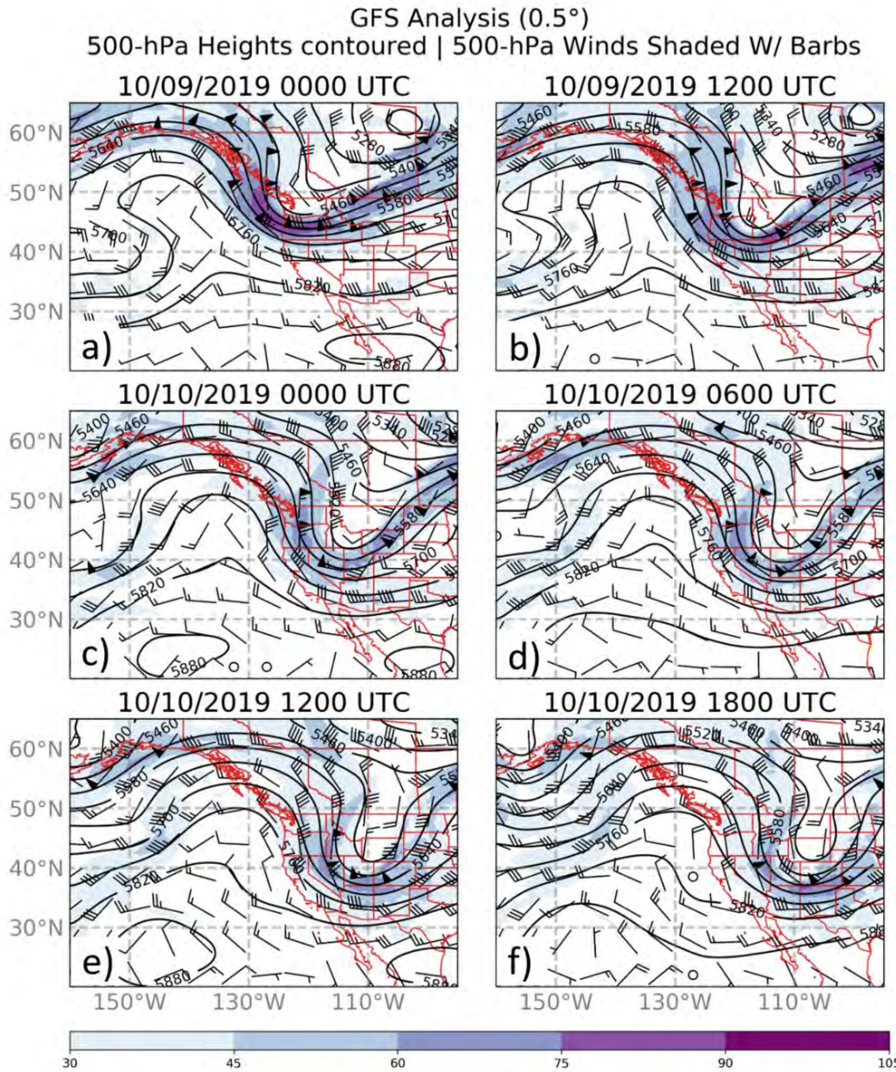
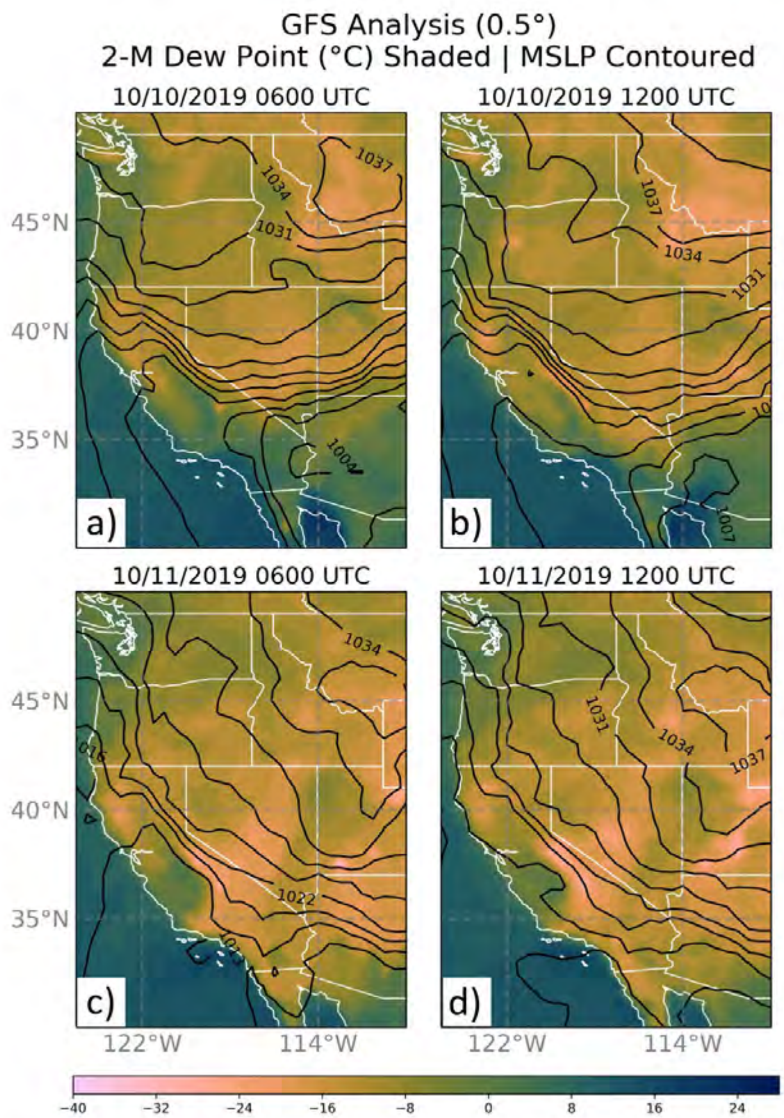
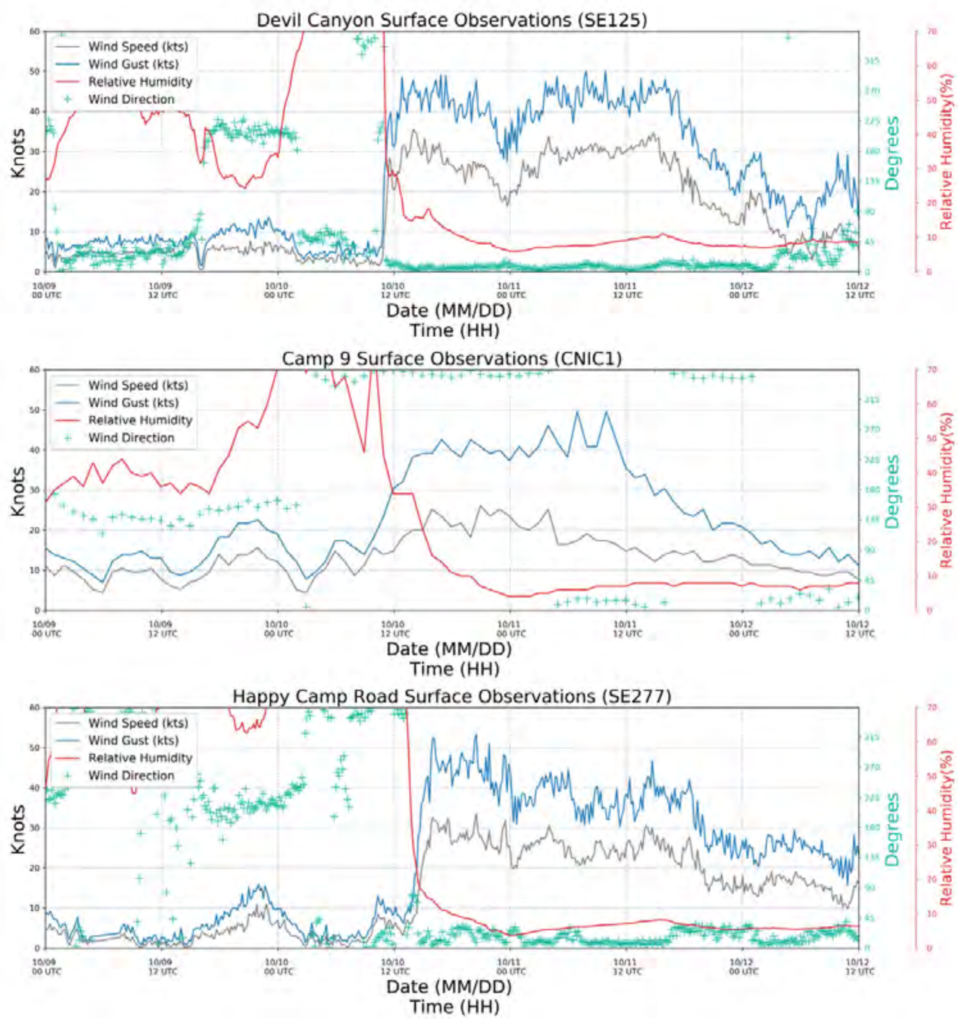


Figure 27. Dew points at two meters are shaded (Celsius) with black contours of MSLP and time is labeled in UTC.



Surface Weather stations across southern California observed dry and windy conditions. Sustained winds generally ranged from 20-30 knots while gusts generally ranged from 30-50 knots. These strong winds were concurrent with single digit RH measurements. Some locations recorded these conditions with a residence time that approached 30 hours. Devil Canyon in the Cajon Pass had some of the most impressive observations with gusts that approached 50 knots for nearly 30 hours (Figure 15).

Figure 28. Surface weather station data shown below with Devil Canyon, Camp 9, and Happy Camp Road representing conditions in the Cajon Pass, Newhall Pass, and Soledad Canyon respectively.

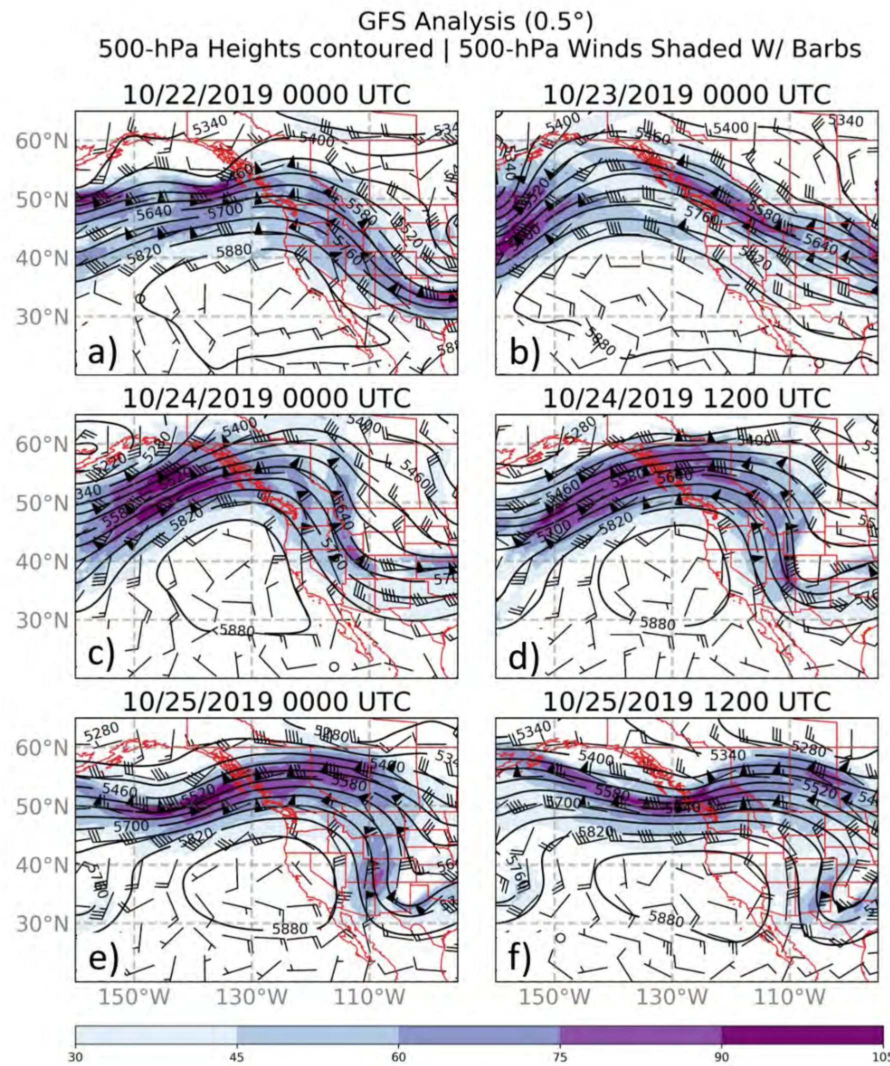


24 October 2019

The synoptics of this event can be described by an upper level shortwave that began embedded in a longwave ridge. The shortwave slowly evolved into a trough, but it had to first traverse the upper level ridge that was situated over the western US (Figure 16a). This traverse was completed twenty-four hours later at 0000 UTC 23 October 2019 and signified the start of the trough's southward propagation. As the trough propagated southward, east of California, it coincided with the amplification of the upstream ridge over the western U.S. By 1200 UTC 24 October, the trough axis was located near the Four Corners region well to the east of California.

Regional analyses at the surface were started using two-meter dewpoint temperatures and mean sea level pressure. A dry airmass entered northern California as a strong surface pressure gradient stacked along the Sierra Nevada (Figure 17a). Dewpoint temperatures of roughly -20 °C occupied the southern California region at 1800 UTC 24 October 2019. The pressure gradient subsided significantly by 0000 UTC 25 October which ended the wind event in northern California. At that time dry air continued to advect over the southern end of the Sierra Nevada and Tehachapi Mountains and into broader areas of southern California.

Figure 29. Geopotential heights (meters) at 500 hPa are countered and winds are shaded in knots. Time is labeled in UTC.



Surface weather stations across southern California observed dry and windy conditions. Sustained winds were observed with speeds of 20-40 knots while gusts were recorded with speeds upwards of 60 knots (Figure 18). The strong winds were widespread as were single digit RH observations. These conditions were persistent with residence time of more than 30 hours. The most extreme winds were observed in the Cajon Pass as well as the Soledad Canyon. In these locations, there was a bimodal pattern observed with decreased winds, even locally reversed winds, at approximately 0000 UTC 25 October 2019 (Figure 18). In both cases the second peak produced stronger winds.

Figure 30. Dew points at two meter are shaded (Celsius) with black contours of MSLP and time is labeled in UTC.

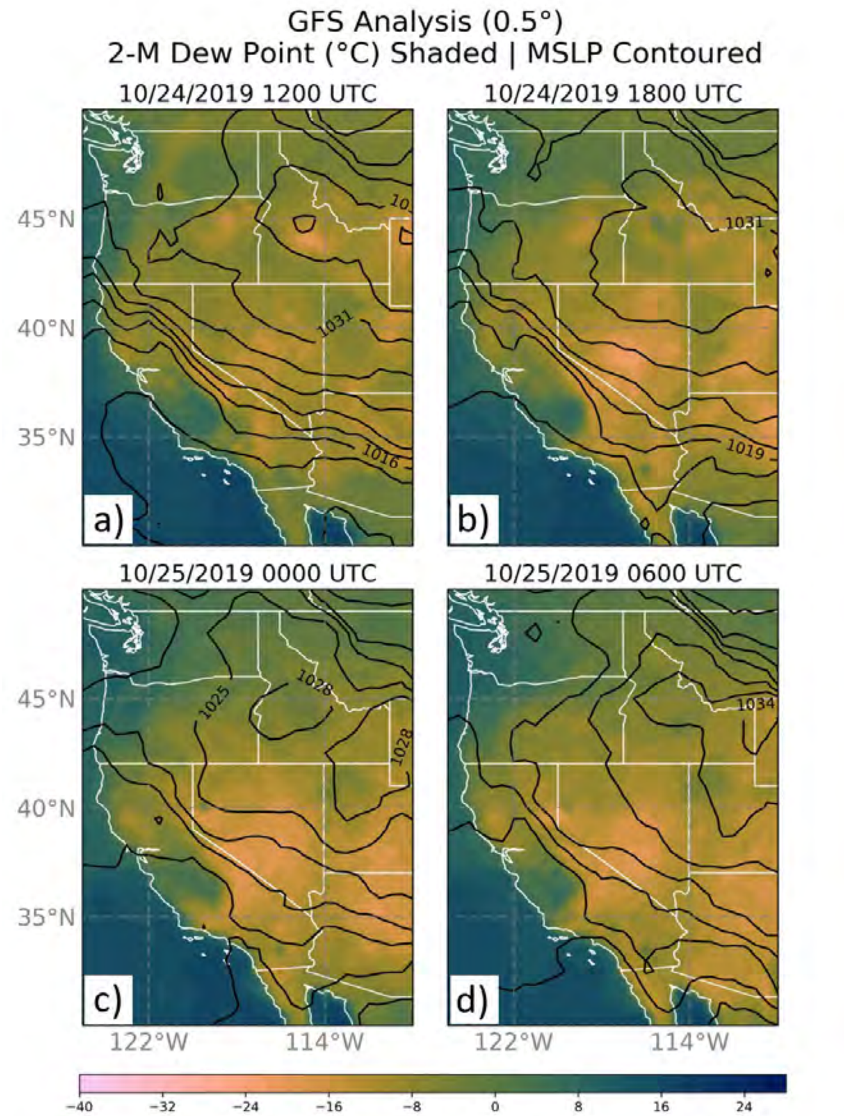
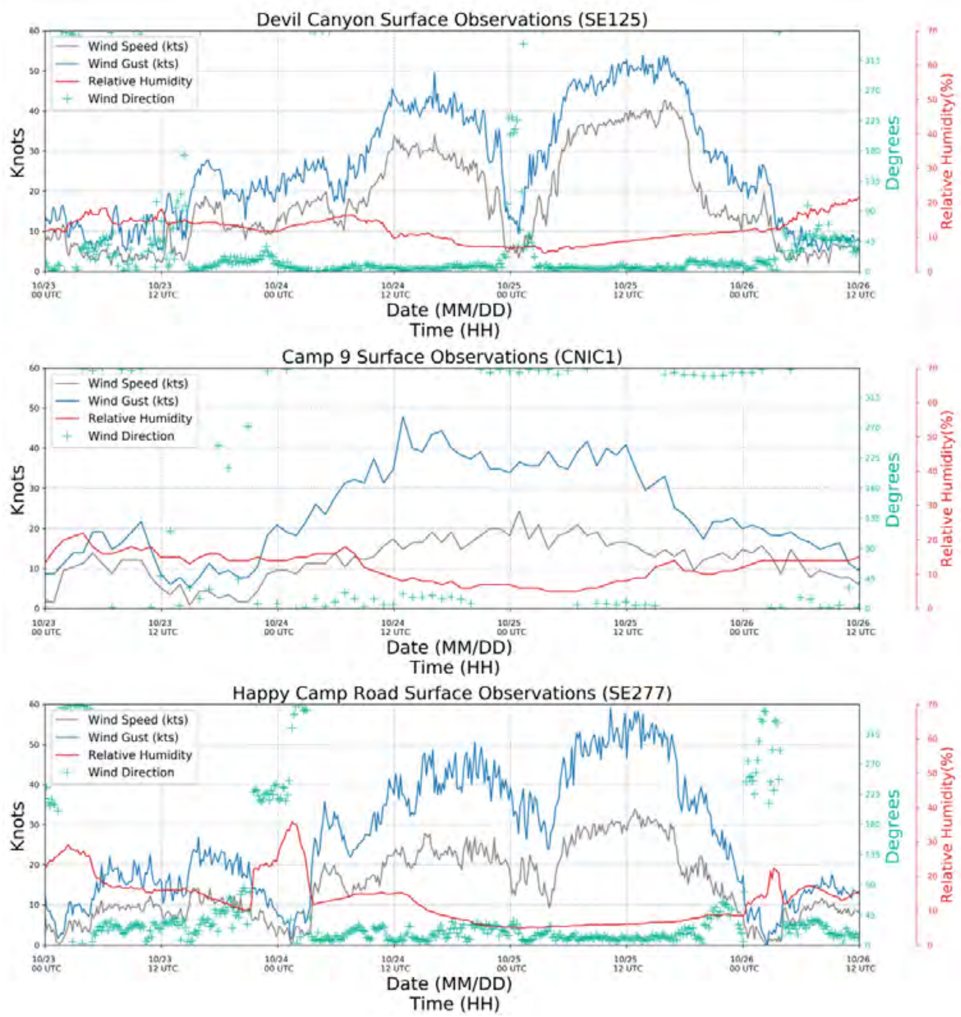


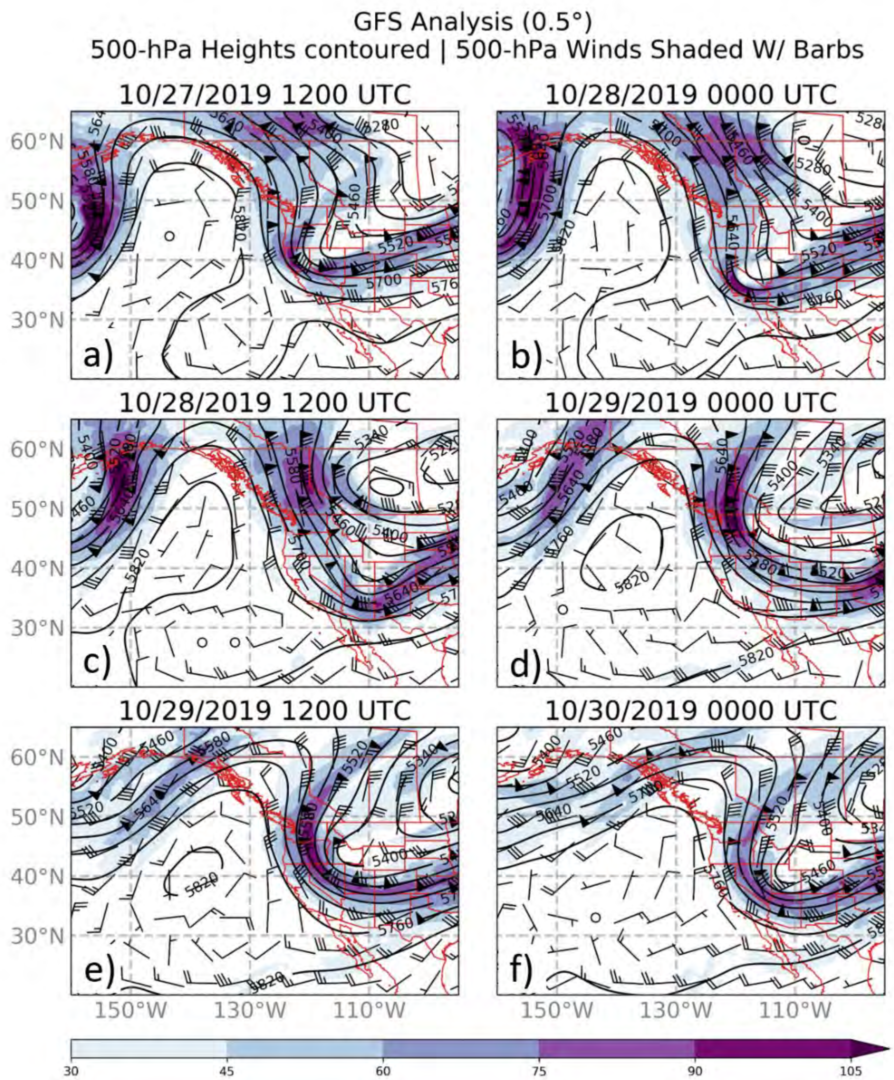
Figure 31. Surface weather station data shown below with Devil Canyon, Camp 9, and Happy Camp Road representing conditions in the Cajon Pass, Newhall Pass, and Soledad Canyon respectively.



28-30 October 2019

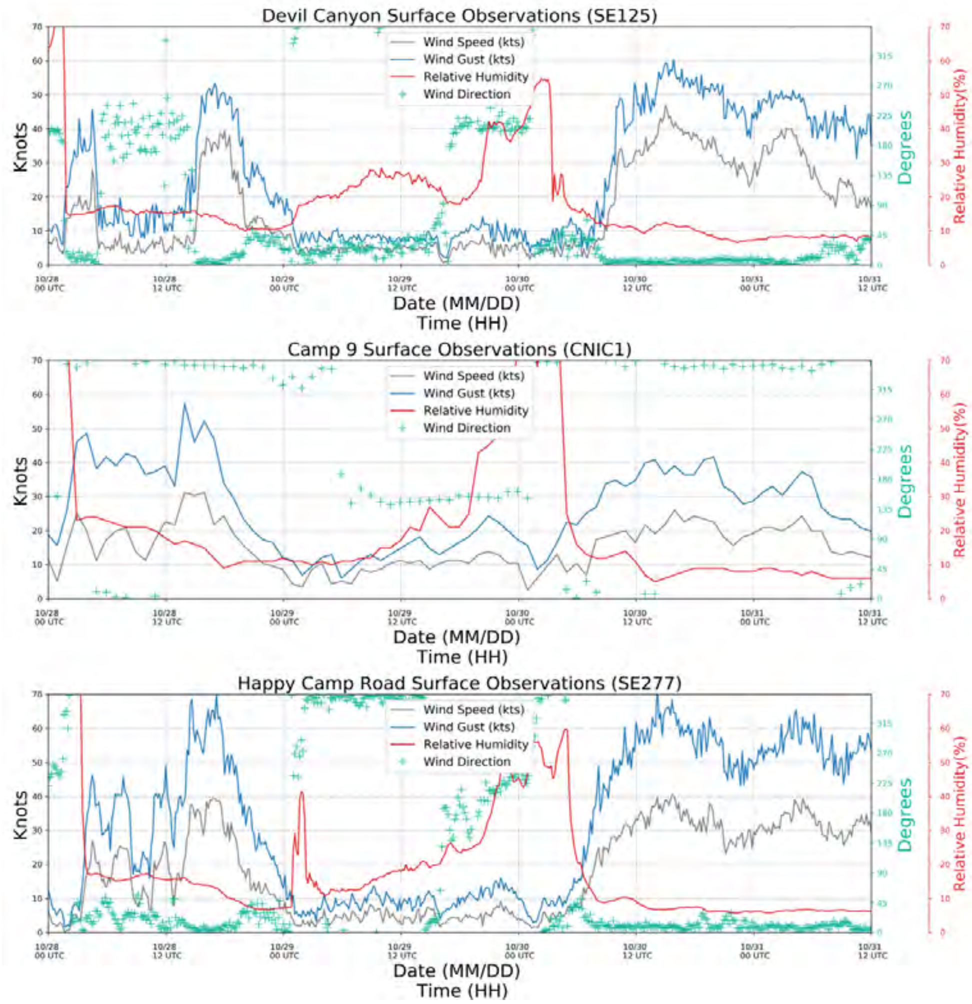
There were multiple wind events in the period of concern. This was primarily driven by multiple upper level shortwaves that propagated south along the coast of the western U.S. The original shortwave began with a very strong positive tilt which weakened as the shortwave propagated further south. At about 1200 UTC 28 October 2019, the axis of the trough was again stretched with a strong positive tilt as a secondary shortwave propagated through the long wave trough (Figure 19c). The upstream ridge built as the trough propagated further south. The trough axis of the secondary shortwave resided directly over the Great Basin at 0000 UTC 30 October.

Figure 32. Geopotential heights (meters) at 500 hPa are countered and winds are shaded in knots. Time is labeled in UTC.



Regional analyses at the surface were started using two-meter dewpoint temperatures and mean sea level pressure. The first Santa Ana event was much weaker. Weaker surface pressure gradients were apparent along the Sierra Nevada on 28 October 2019 (Figure 20a, b) as compared to 30 October (Figure 20c, d). Dewpoint temperatures also revealed a much drier airmass associated with the second Santa Ana event. Surface weather stations were used to verify wind and humidity conditions for specific locations.

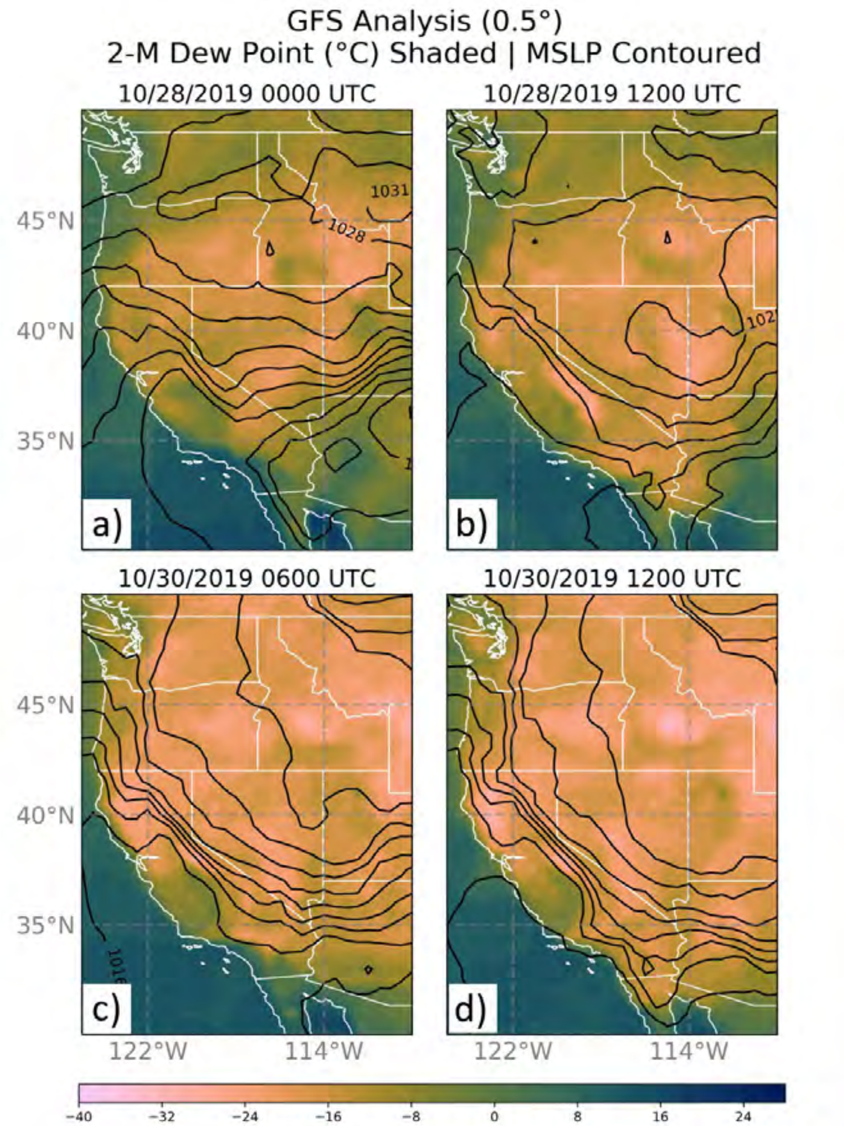
Figure 33. Surface weather station data shown below with Devil Canyon, Camp 9, and Happy Camp Road representing conditions in the Cajon Pass, Newhall Pass, and Soledad Canyon respectively.



Surface weather stations across southern California were used to analyze the specifics related to these wind events. These data verified that there were two wind events during the period of interest (Figure 21). The first wind event on 28 October 2019 was generally a weaker system. It was characterized by sustained winds 15-40 knots and gusts 30-55 knots and Happy Camp Road recorded the strongest gust of 70 knots. RH was generally between 10-20% but select locations observed brief periods of single digit RH. The first event subsided on 29 October and elevated winds were then observed in Gaviota from the NNE. This situation appeared to have characteristics of a Sundowner event with gusts over 30, sustained winds over 20, and RH between 20-50%. However, the most extensive drying in the Santa Barbara region occurred concurrent with SSE winds which were likely outflow from the Santa Anas through the Soledad Canyon pass.

The second Santa Ana event took shape on 30 October and lasted for more than 24 hours. This event was quite intense with sustained winds ranging from 25-45 knots, gusts 40-70 knots, and extensively observed single digit RH. The close temporal proximity of these events added risk associated with fire danger.

Figure 34. Dew points at two meter are shaded (Celsius) with black contours of MSLP and time is labeled in UTC.



The PSPS event that occurred October 9-12th, 2019 is currently under review. SCE released a fact sheet on this event where they identified that Sonoma County registered the highest wind gust during the event. Accordingly, the Pine Flat Road weather observation station was used as a proxy for surface winds at the peak of the event. This site, labeled in the following figure, is in the Mayacamas Mountains in the northeast of Sonoma County, California. The following figures show a time series of the sustained wind speed and gusts during the event at Pine Flat Road. The event peak occurred from 0300 UTC through 1800 UTC 10 October 2019. The time frame of the event peak is acknowledged as, sustained winds greater than 25 knots. Also note that peak gusts occurred around 1200 UTC 10 October 2019.

Figure 35. Surface observation locations with shaded terrain.

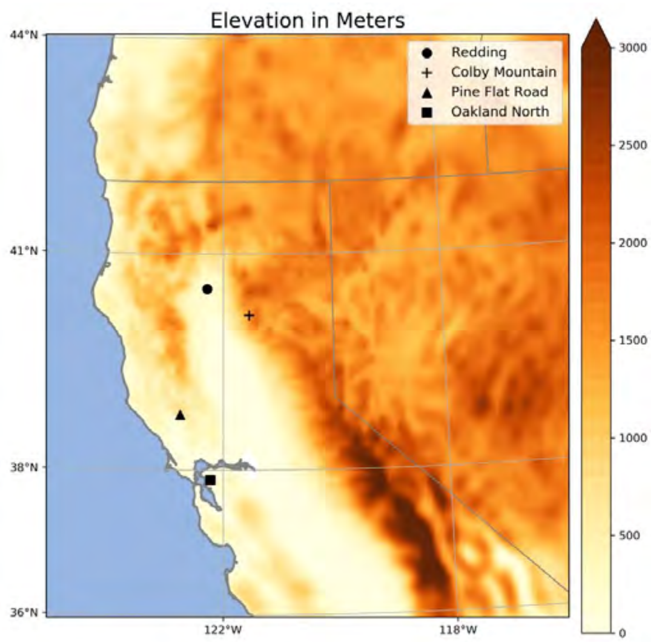
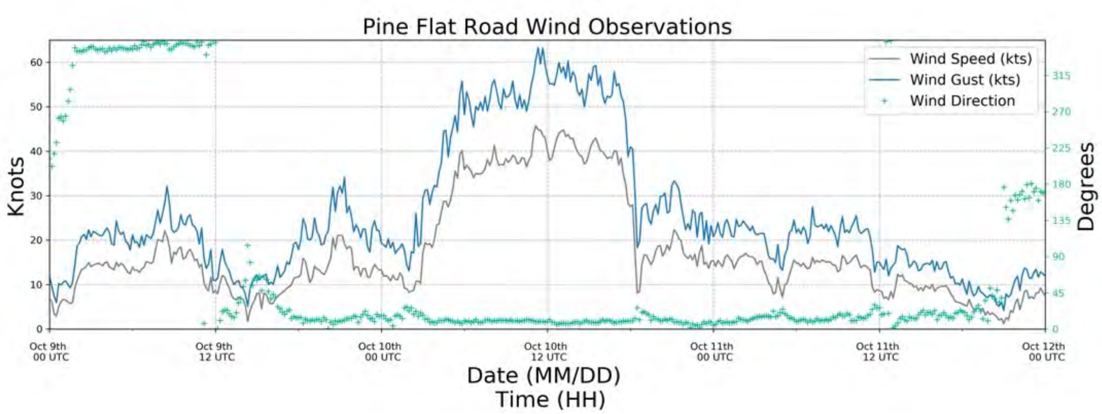


Figure 36. Surface wind observations from Pine Flat Road measured in knots.



Synoptic Scale Weather Analysis

Synoptic situations and analyses are generally viewed in a top-down format, starting with the upper level at 500 hPa. The upper-level jet in Figure 24a shows a positively tilted trough with noticeable amplification where the jet exit region was significantly weaker than the entrance region, which indicates further wave amplification will occur. Correspondingly, the trough deepens over the next twelve hours, as observed in Figure 24. At 0000 UTC 10 October 2019, three hours prior to the onset of the wind event, the jet streak entrance and exit regions have weakened. This may be indicative of the influence the upper atmosphere had on the surface features. It also shows its full development with the jet streak placement transitioning to the exit region. The jet streak regions will prove to be key in identifying the surface features that occur later in time.

Figure 24d, just three hours after the beginning of the peak event, shows the entrance region's jet streak migrates inland and encompasses the northern Great Basin. This synoptic situation allows for strong upper-level convergence and subsiding air. Under this subsiding air, high pressure is observed at the surface. Figure 24e displays the entrance jet streak migrate to the interior of the Great Basin. At this time, Pine Flat Road measured its maximum wind gusts exceeding 60 knots. It is not until 1800 UTC 10 October 2019 that the ridge to the west began to encroach onto the California Coast. The ridge continued its migration and was the dominating synoptic feature over California and the Great Basin at the end of the PSPS.

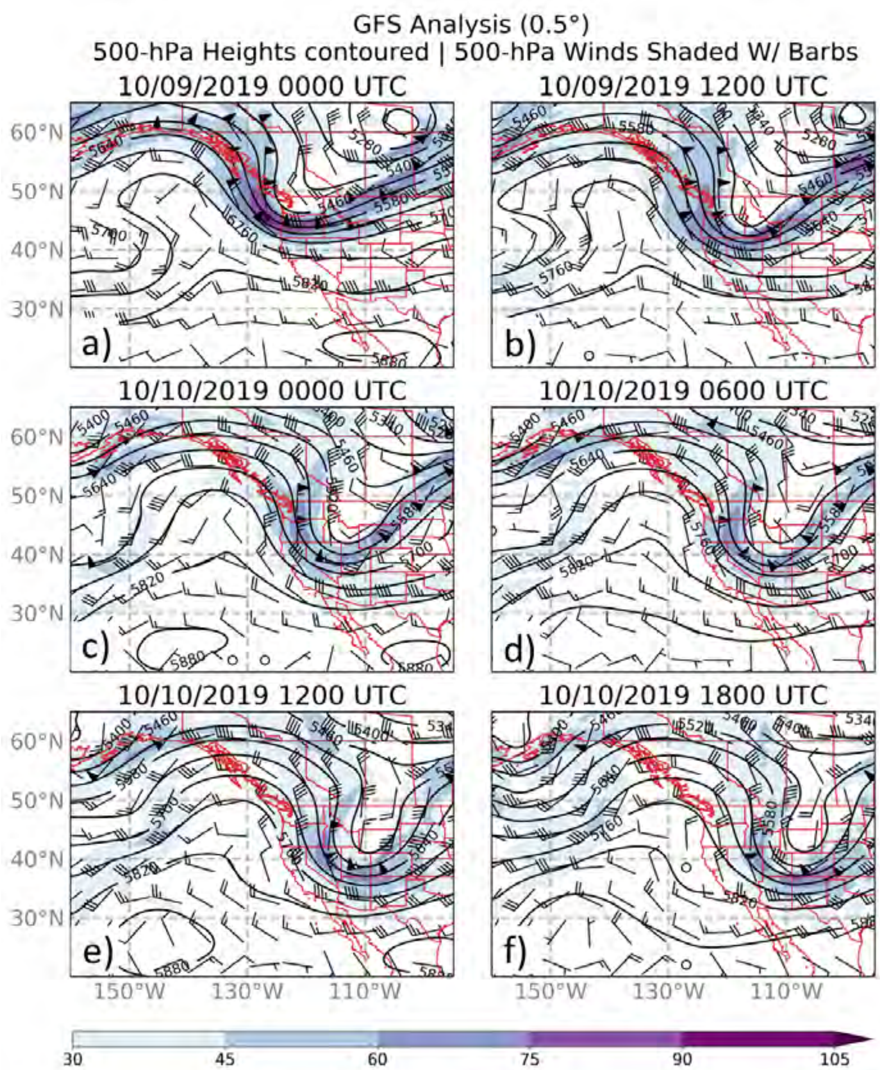


Figure 37. Geopotential heights at 500-hPa are contoured and winds are shaded in knots. Time is labeled in UTC.

Surface Analysis

Figure 25 shows the mean surface pressure evolution (hPa) and associated precipitable water (inches), which is a proxy for atmospheric moisture. The high-pressure feature, indicated by an "H" in Figure 25c, strengthened during the period (through panel f). The red isobars (pressure contours) are tracers for 1027 and 1015 hPa, and highlight the pressure gradient reaching a maximum in Figure 25e. The intense gradient from north to south produces strong and gusty winds across most of California. This gradient is defined by the tight packing of the pressure contours as shown by the red tracers.

Another important note shown in Figure 25c-f, is the presence of an inverted surface trough over coastal and southern California. The synoptically-driven surface high pressure over the Great Basin in conjunction with an inverted trough to the south is known to produce downslope winds in the California area. These downslope winds can include the Diablo Winds, Sundowners, and the Santa Ana Winds and each wind needs their own specific meteorological conditions. At a minimum, this synoptic situation warrants a closer look into the mesoscale meteorological features associated with these wind systems. In addition to the windy conditions driven by the strong surface pressure gradient, the column depth precipitable water shows that this airmass is extremely dry. Figure 25a-f, shows the advection of a dry continental polar airmass into the western US and all of California.

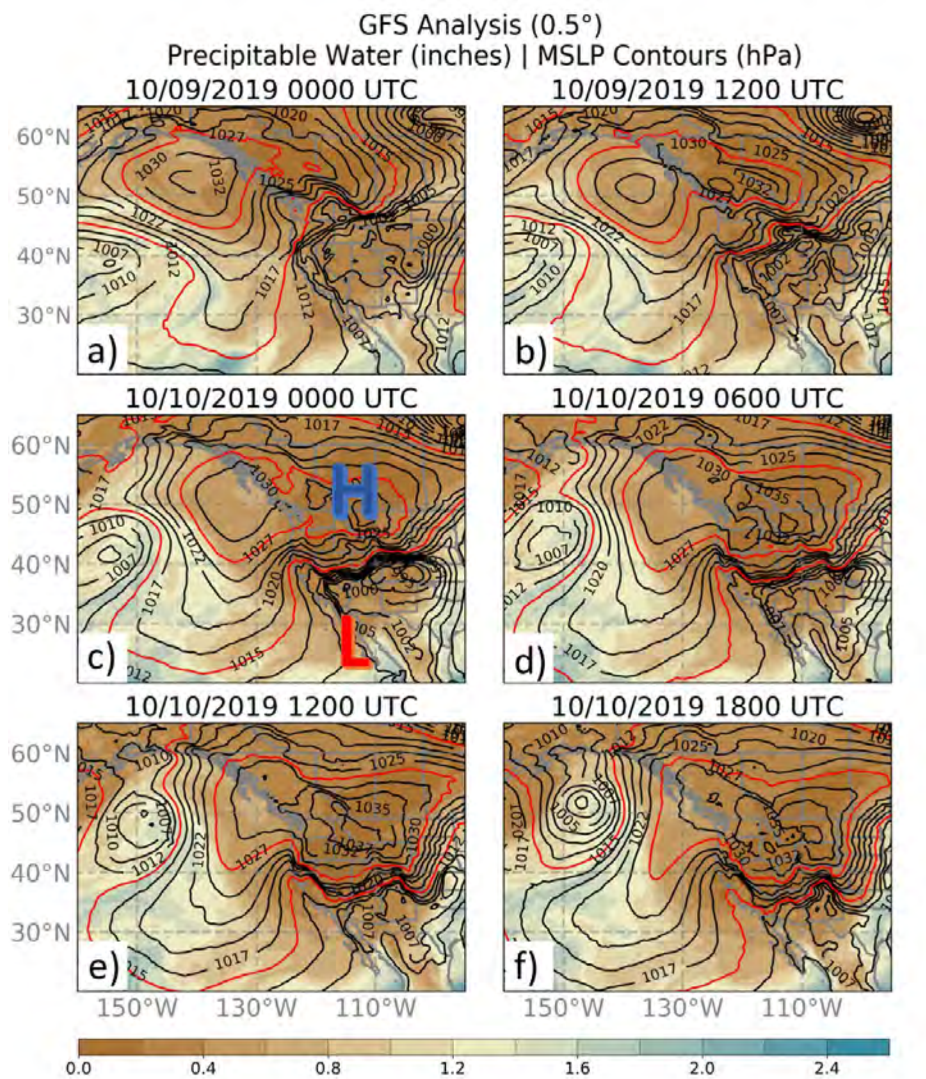
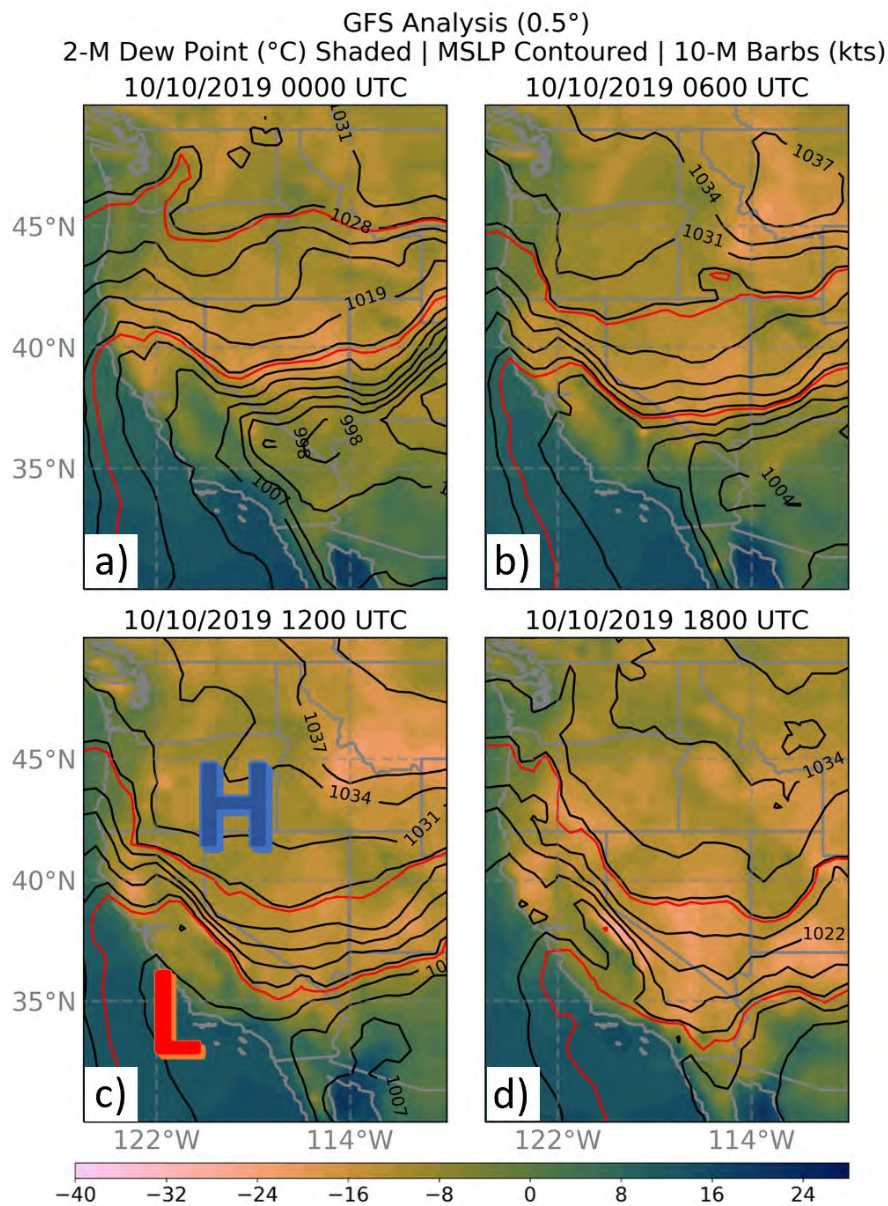


Figure 38. Precipitable water shaded (inches) with MSLP contoured in black. Red contours are tracers of MSLP at 1015 and 1027 hPa. Time is labeled in UTC.

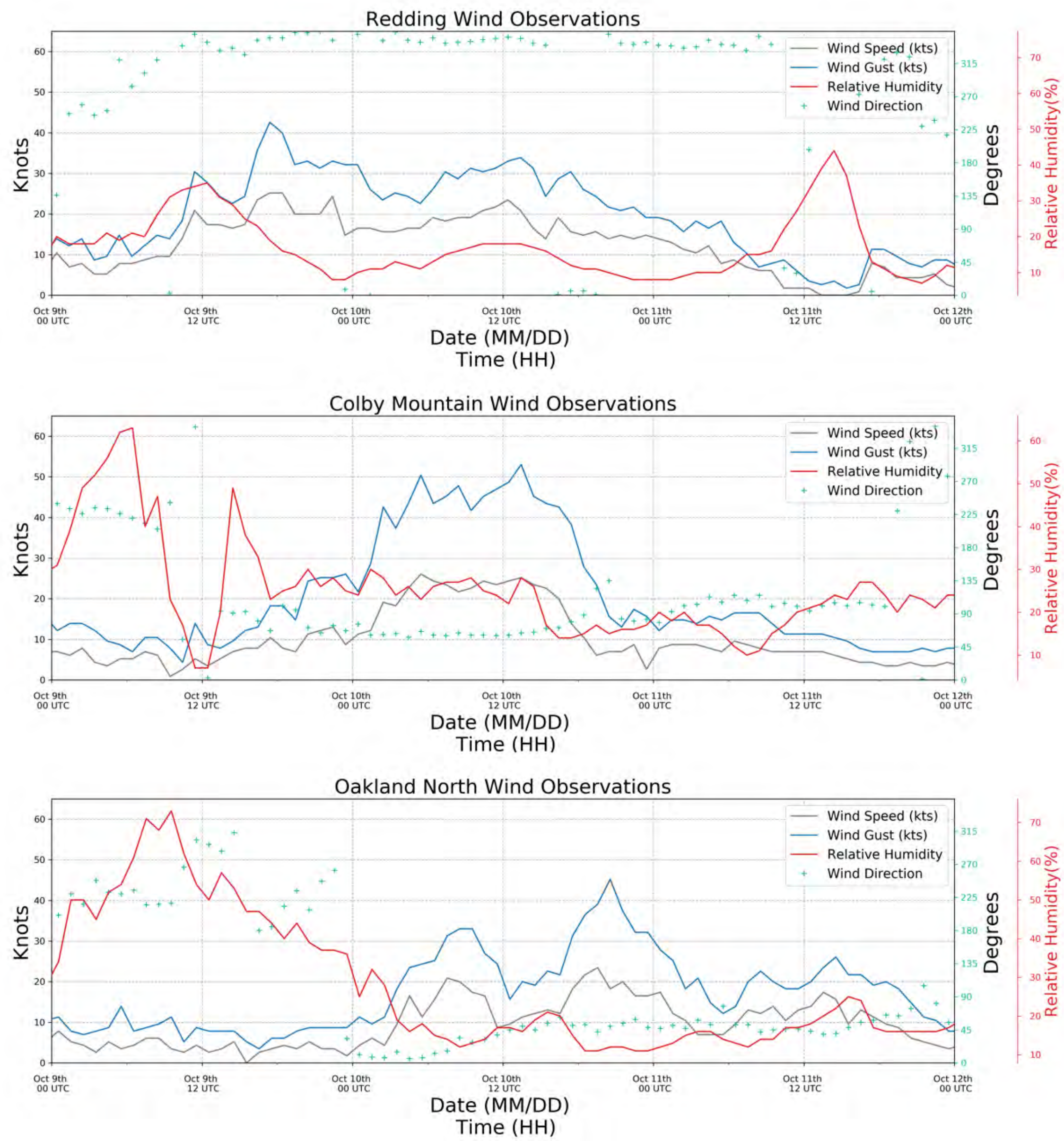
A closer look at the dry air and pressure gradient of this event is shown in Figure 26. The 2-m dew point temperatures were consistently below 0 °C across all northern California. Sonoma County was exceptionally dry during this period. This is potential evidence of strong downslope winds mixing down the drier air from aloft. The red tracers,1027 and 1015-hPa contours respectively, separate the high- and low-pressure features that are annotated in Figure 26c. Synoptic-scale meteorological conditions showed some of the components that are needed for downslope winds to occur in the area of interest such as a strong surface pressure gradient along the Sierra Nevada crest. To further determine the development and structure of downslope windstorms that may have occurred, additional analyses of mesoscale meteorology including atmospheric profiles of wind and moisture are needed.

Figure 39. Dew points at two meters are shaded (Celsius) with black contours of MSLP and red tracers at 1015 and 1027 hPa. Time is labeled in UTC.



Finally, surface wind and relative humidity observations, shown in Figure 27, confirm dry and gusty conditions across northern California. From the selected stations, it appears that Sonoma County experienced the highest wind speeds. However, all stations measured wind gusts exceeding 45 knots with sustained winds ranging from 20 to 25 knots at Redding, Colby Mountain, and Oakland North weather stations. This is evidence of widespread strong winds occurring with significant damage potential. Very dry and gusty conditions occurred with very low RH values of <10% at Redding which would warrant a NWS Red Flag Warning. In the Sierra foothills at Colby Mountain, sustained winds were ~25 knots with RH values of 25% which also warrants a Red Flag Warning. More striking are the Oakland North observations which indicate very low relative humidity values of ~10% with sustained wind speeds

Figure 40. Wind observations (kts) and relative humidity (%) from surface weather stations across Northern California. Redding (top), Colby Mountain (middle), and Oakland North (bottom) take hourly surface observations.at 23 knots. These conditions would also warrant a NWS Red Flag Warning.



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.

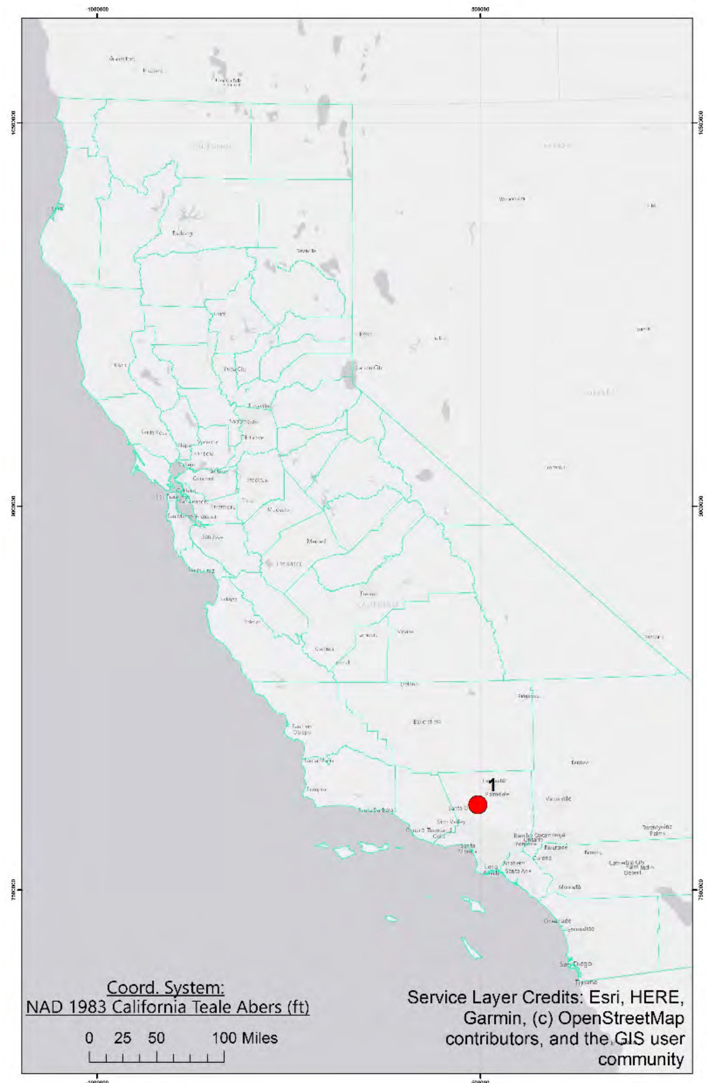
Two weather charts are included for each fire simulation, representing hourly wind direction and speed throughout the incident (i.e. 24 hours) for the nearest weather station and modeled winds for the weather station location point and the ignition location of the incident. In this sense, wind data uncertainty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

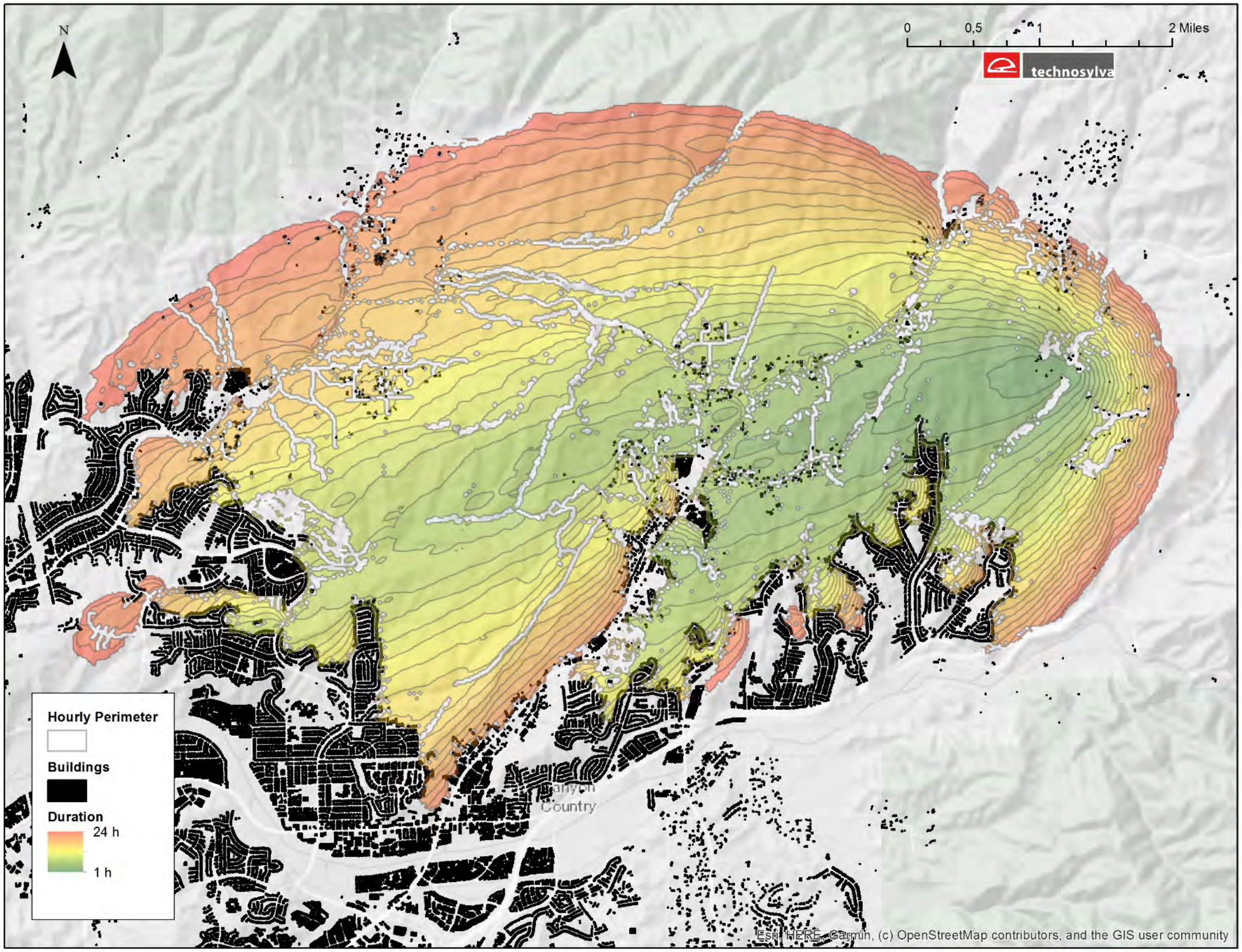
DAMAGE INCIDENT – 1

This incident is located near Mint Canyon and County Country Wildland Urban Interfaces. The fire could have started near urban areas creating the highest impact in terms of population considering all damage incidents in 2019 PSPS events for SCE (see incident summary table). Additionally, there were 6 more damage incidents near this one with similar expected fire impact. Therefore, the probability of having a significant fire in this location was high. Fire would spread very rapidly presenting high resistance to control with an IAA of 5 (Extreme) with an average wind speed of 20mi/h.

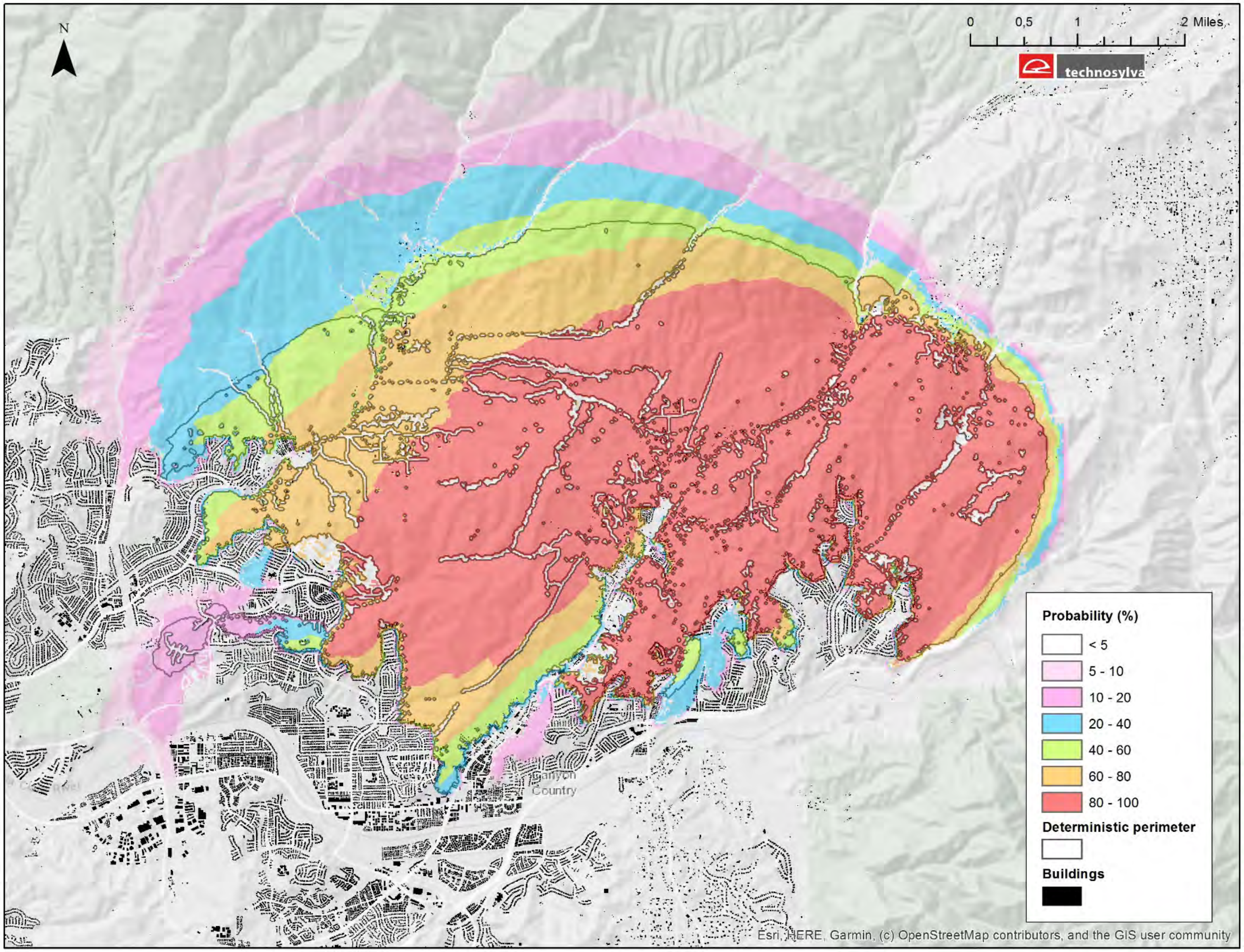
INCIDENT SUMMARY	
Start Time	10/24/2019 8:51
Duration (hrs)	24
Size (ac)	15,425
Initial Attack Assessment	5 - Extreme
No. of Buildings	2,674
Total Population	7,547
Average ROS	Very high



DAMAGE INCIDENT NO. 1 : DETERMINISTIC SIMULATION



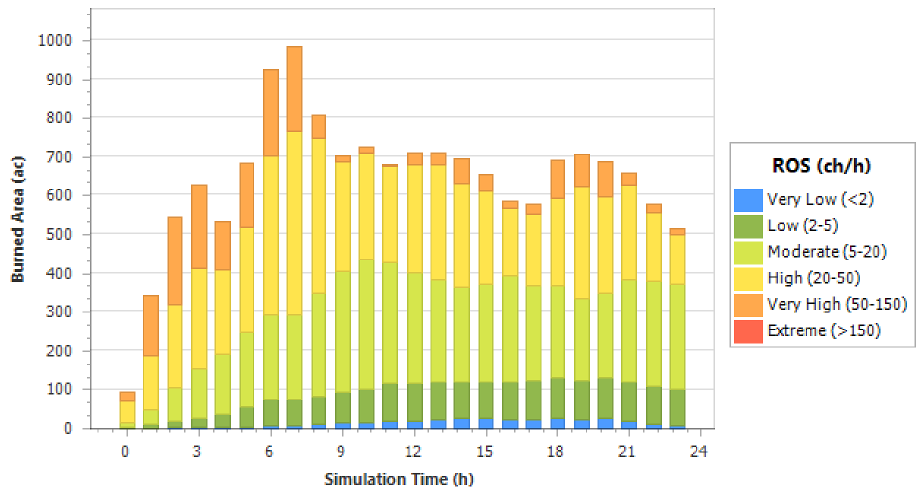
DAMAGE INCIDENT NO. 1 : PROBABILISTIC SIMULATION



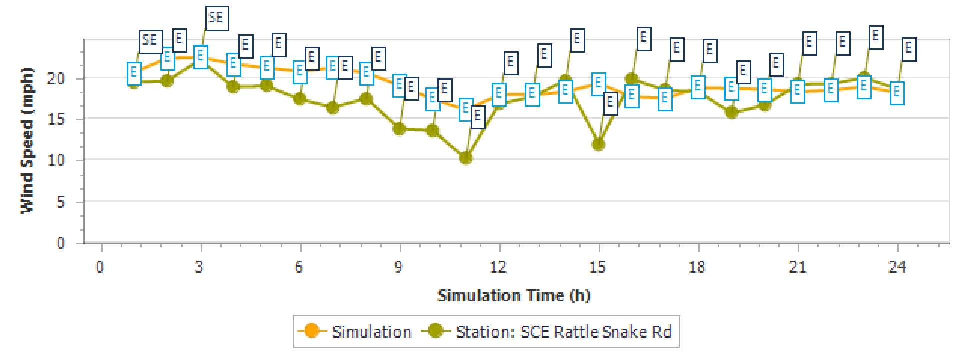
DAMAGE INCIDENT NO. 1

FIRE BEHAVIOR	WEATHER **Nearest Station:** SCE Rattle Snake Rd

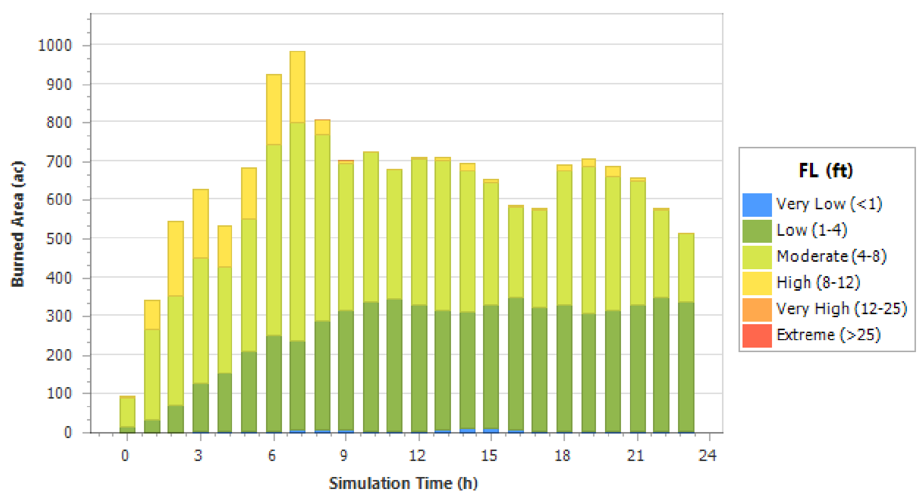
Rate of Spread

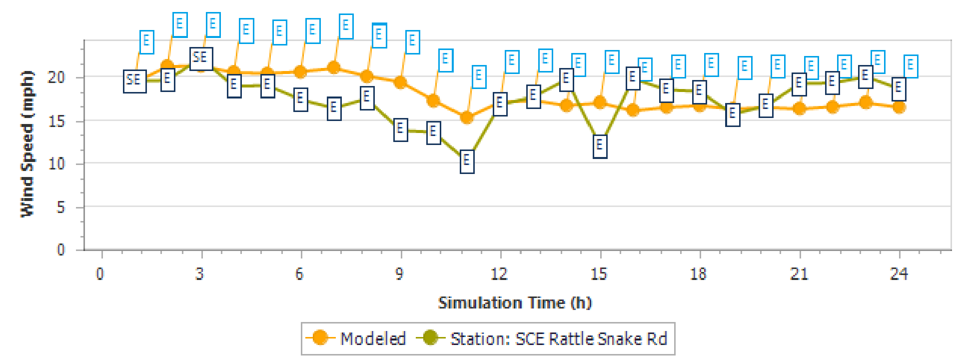


Station ID - SE130
Weather station (Wx) elevation - 2439 ft
Fire ignition point (IP) elevation - 1933 ft
Distance between Wx and IP - 0.68 mi



Flame Length

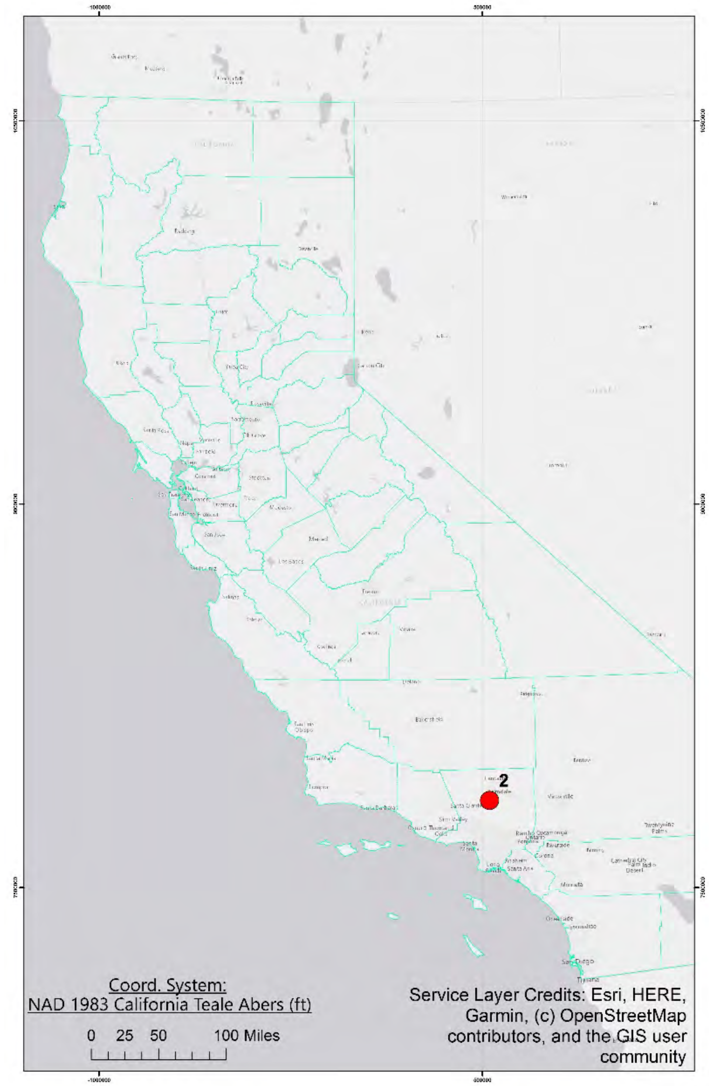




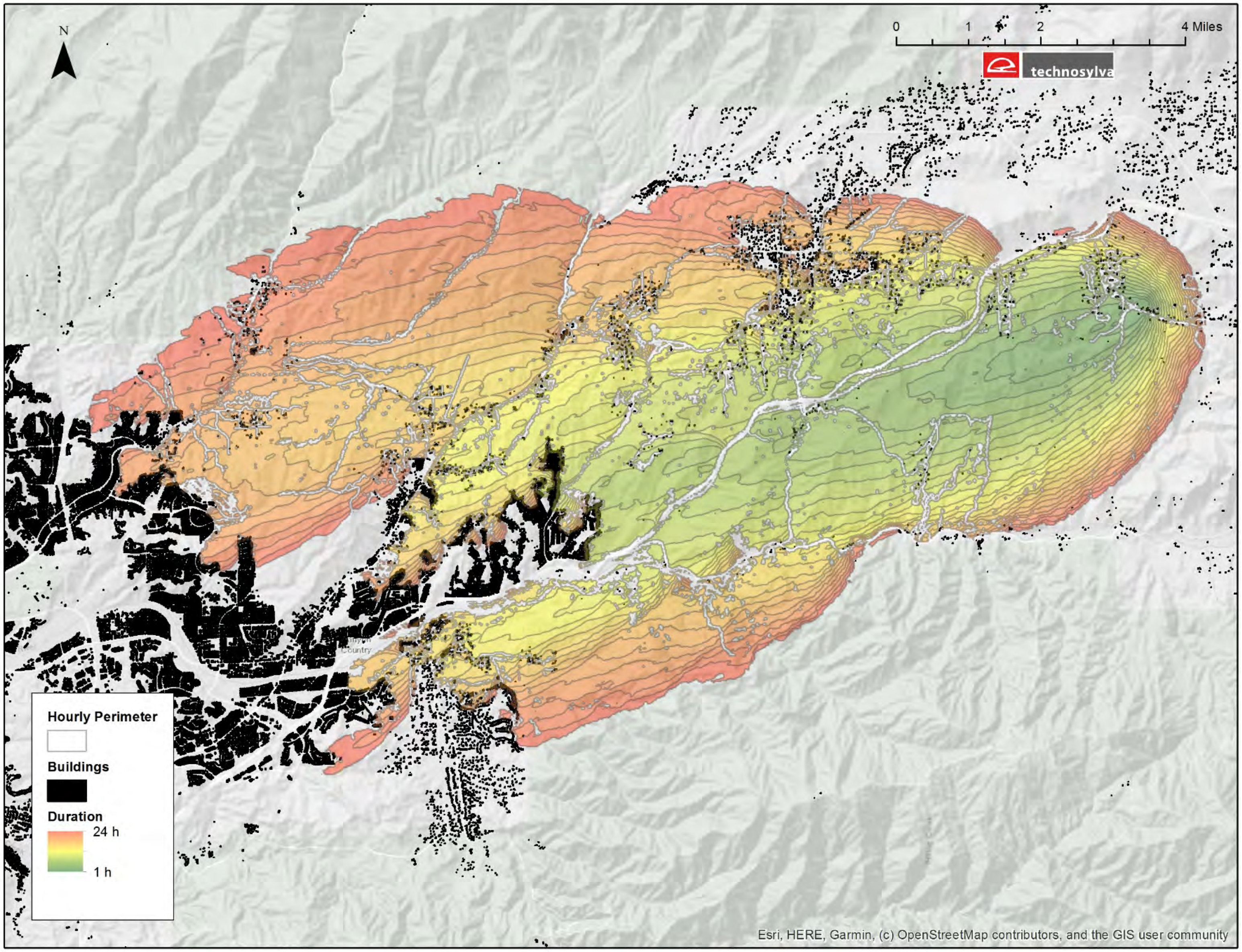
DAMAGE INCIDENT – 2

This incident is located near Mint Canyon and County Country Wildland Urban Interfaces. The fire could have started near urban areas creating the high impact in terms of population and building loss (see incident summary table). Fire would spread very rapidly presenting high resistance to control with an IAA of 5 (Extreme) with an average wind speed of 20mi/h. The fire intensity would be high in the head of the fire, potentially threatening lots of buildings. Modeled wind speed would be a slighly higher than measured at weather station.

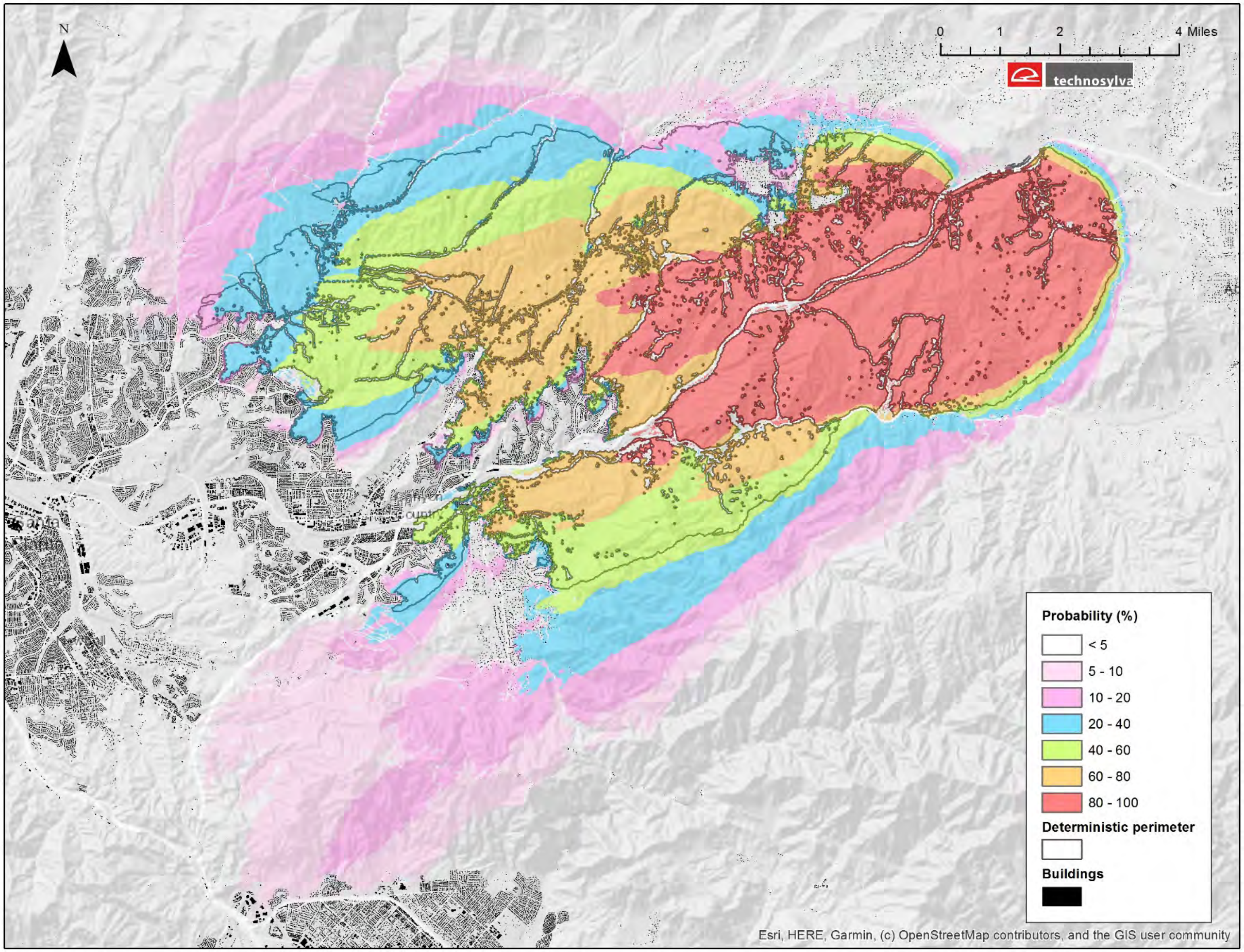
INCIDENT SUMMARY	
Start Time	10/10/2019 8:43
Duration (hrs)	24
Size (ac)	42,150
Initial Attack Assessment	5 - Extreme
No. of Buildings	3,716
Total Population	7,467
Average ROS	Very high



DAMAGE INCIDENT NO. 2 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 2 : PROBABILISTIC SIMULATION

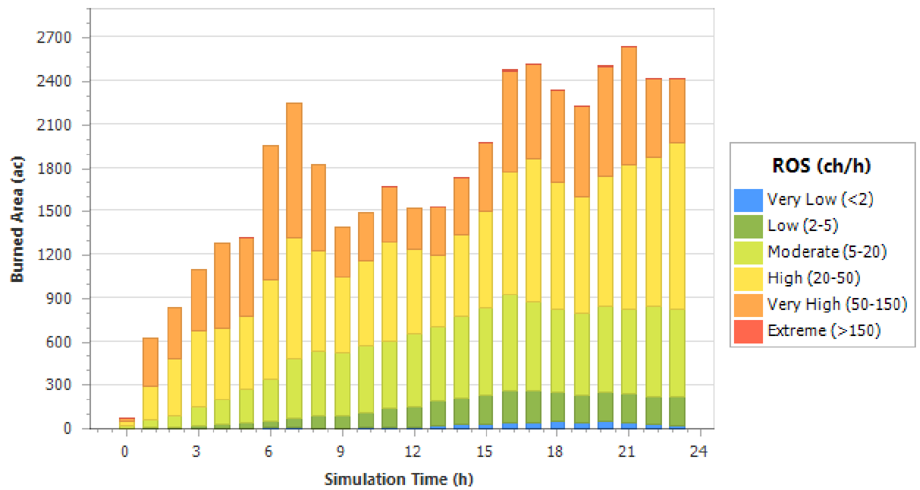


DAMAGE INCIDENT NO. 2

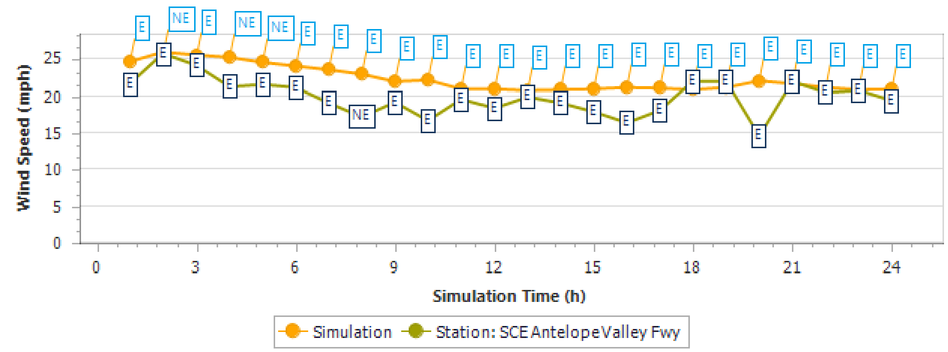
FIRE BEHAVIOR

WEATHER **Nearest Station:** SCE Antelope Valley Fwy

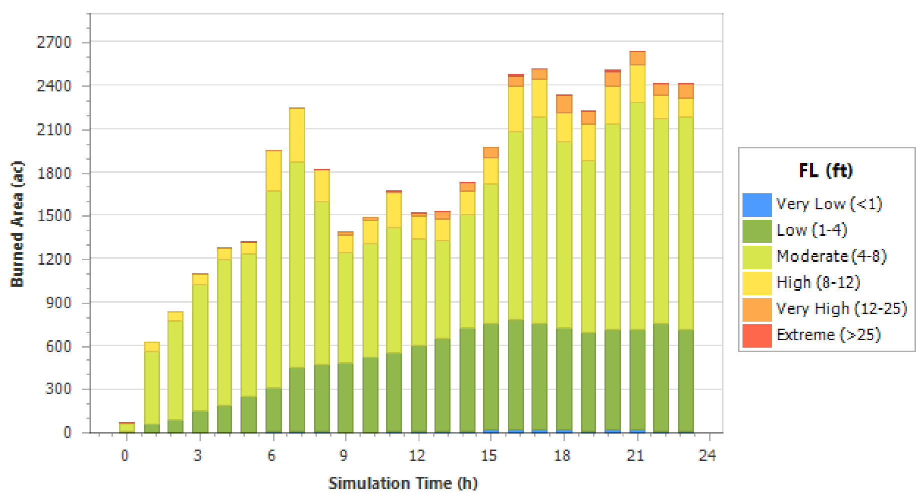
Rate of Spread

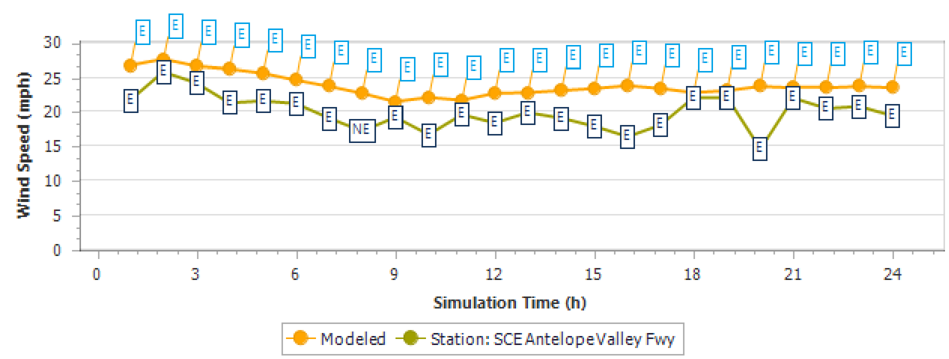


Station ID - SE062
Weather station (Wx) elevation - 2950 ft
Fire ignition point (IP) elevation - 3212 ft
Distance between Wx and IP - 1.72 mi



Flame Length

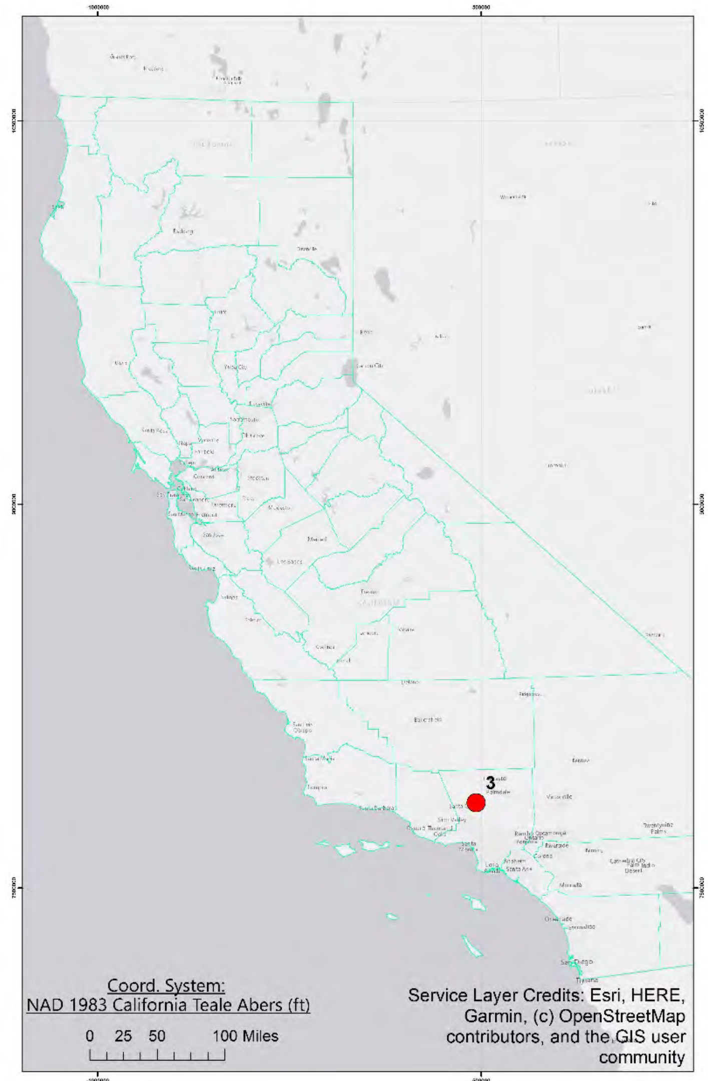




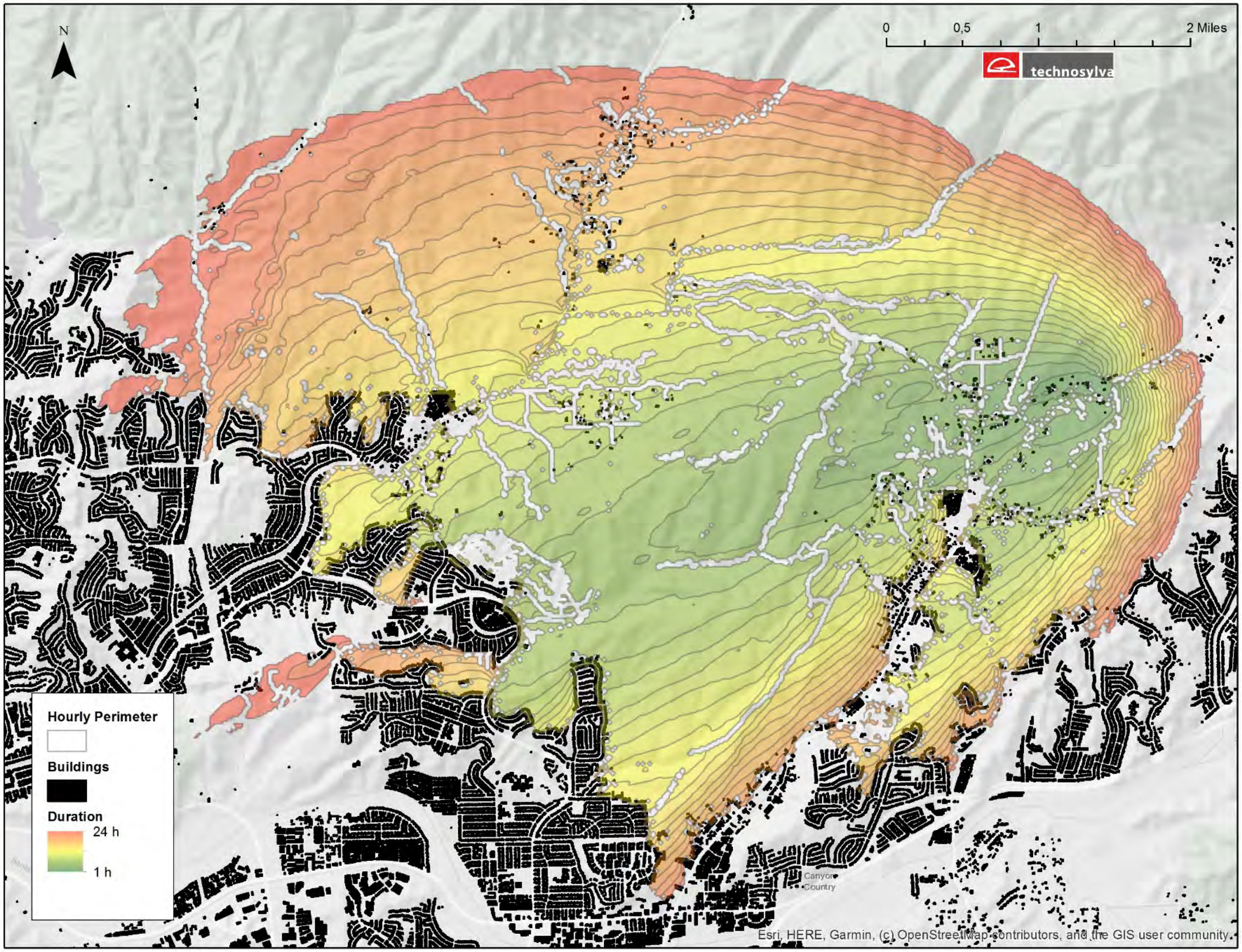
DAMAGE INCIDENT – 3

This incident is located near Mint Canyon and County Country Wildland Urban Interfaces. The fire could have started near urban areas creating the high impact in terms of population and building loss very quickly (3 hours). Lots of scattered buildings could be also impacted throughout the fire progression in addition to the dense urban areas. Fire would spread very rapidly with high intensity, presenting high resistance to control with an IAA of 5 (Extreme) with an average wind speed of 20mi/h. Modeled wind speed was similar to the weather station. Fire intensity would be high in the fire front.

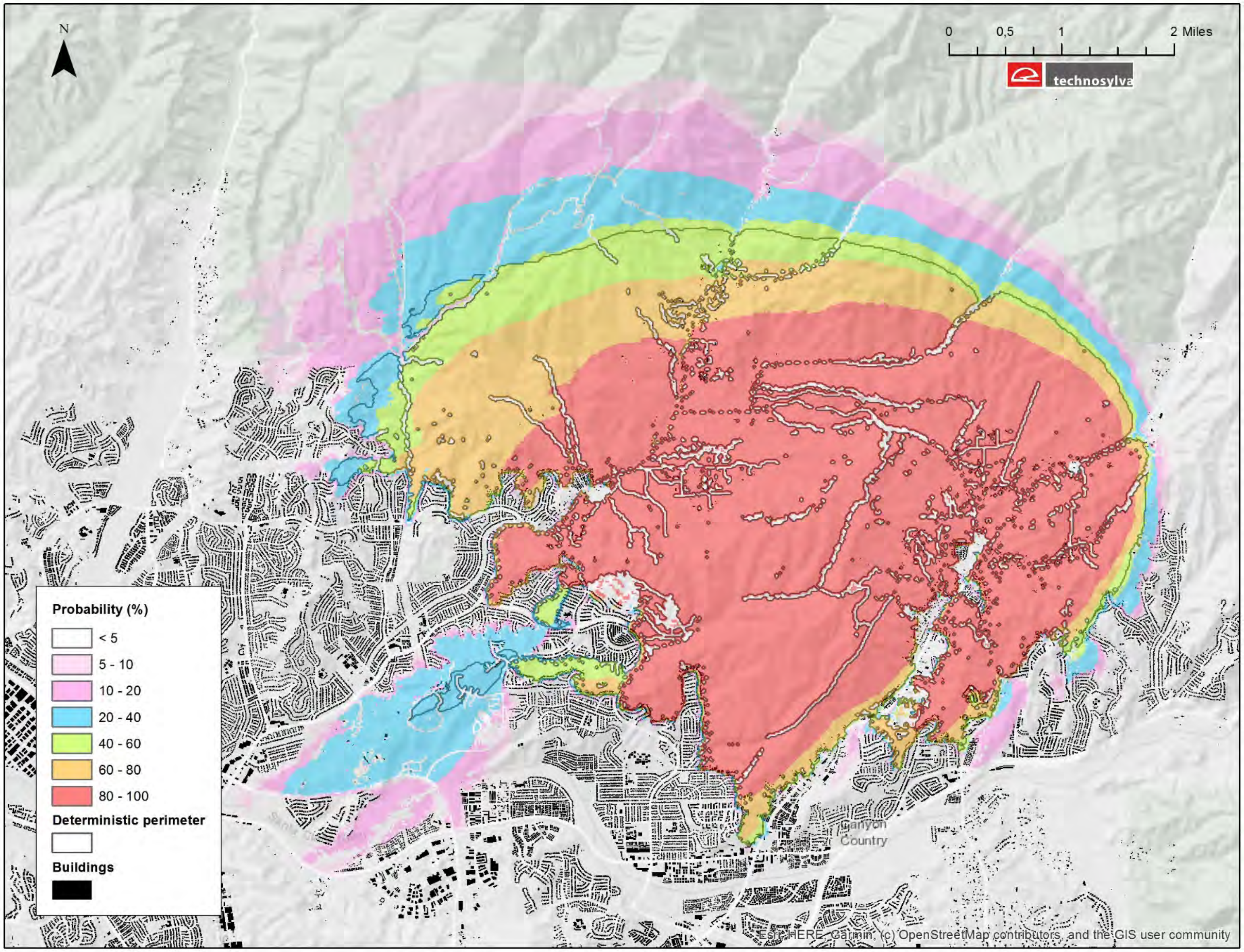
INCIDENT SUMMARY	
Start Time	10/10/2019 11:00
Duration (hrs)	24
Size (ac)	14,032
Initial Attack Assessment	5 - Extreme
No. of Buildings	2,220
Total Population	6,566
Average ROS	Very high



DAMAGE INCIDENT NO. 3 : DETERMINISTIC SIMULATION



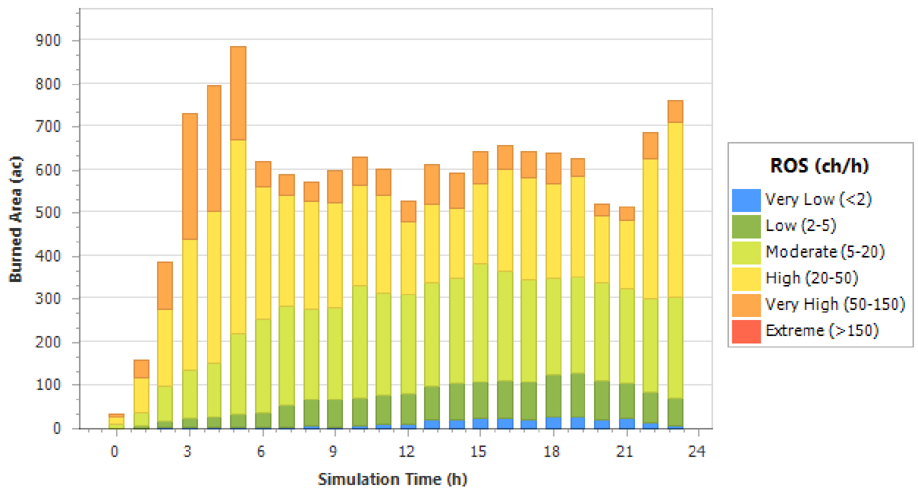
DAMAGE INCIDENT NO. 3 : PROBABILISTIC SIMULATION



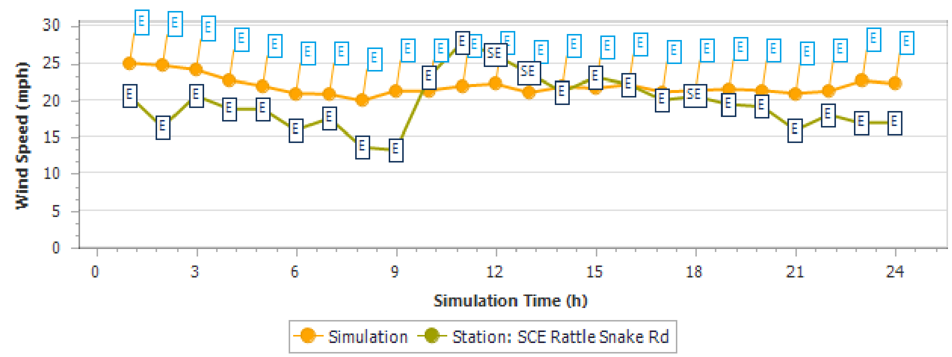
DAMAGE INCIDENT NO. 3

FIRE BEHAVIOR	WEATHER **Nearest Station:** SCE Rattle Snake Rd

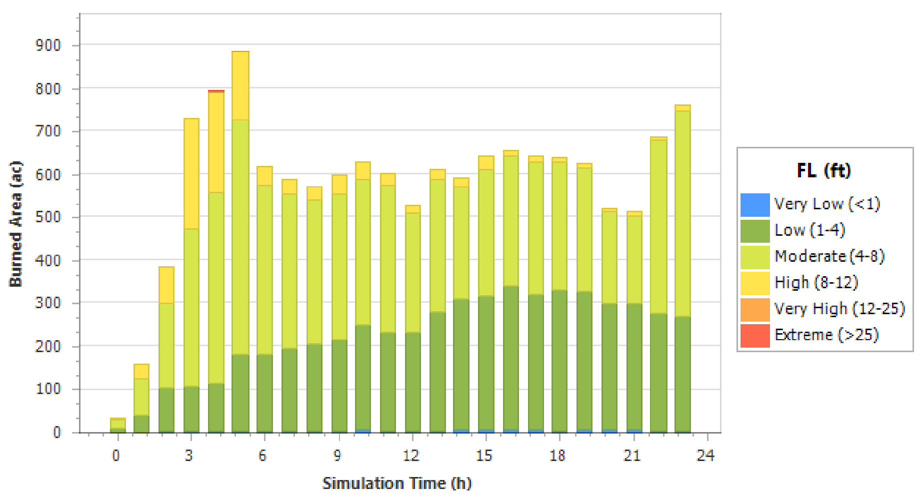
Rate of Spread

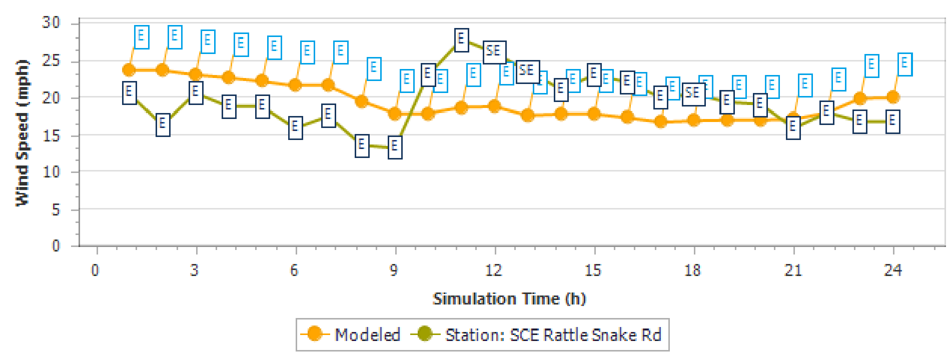


Station ID - SE130
Weather station (Wx) elevation - 2439 ft
Fire ignition point (IP) elevation - 1824 ft
Distance between Wx and IP - 2.36 mi



Flame Length

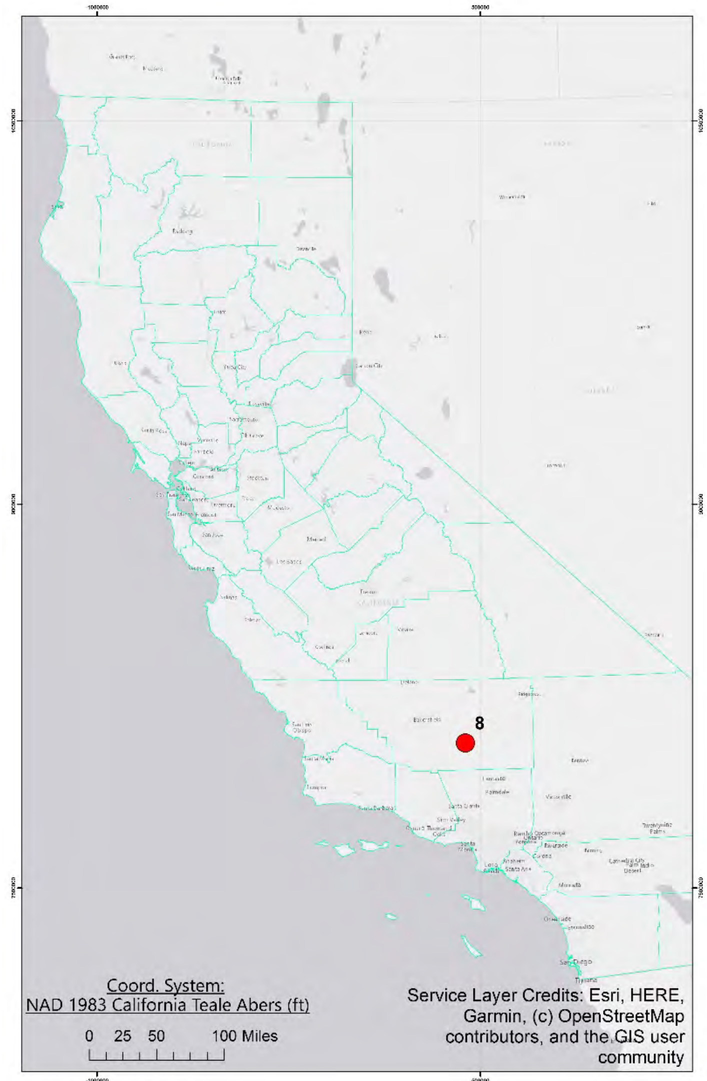




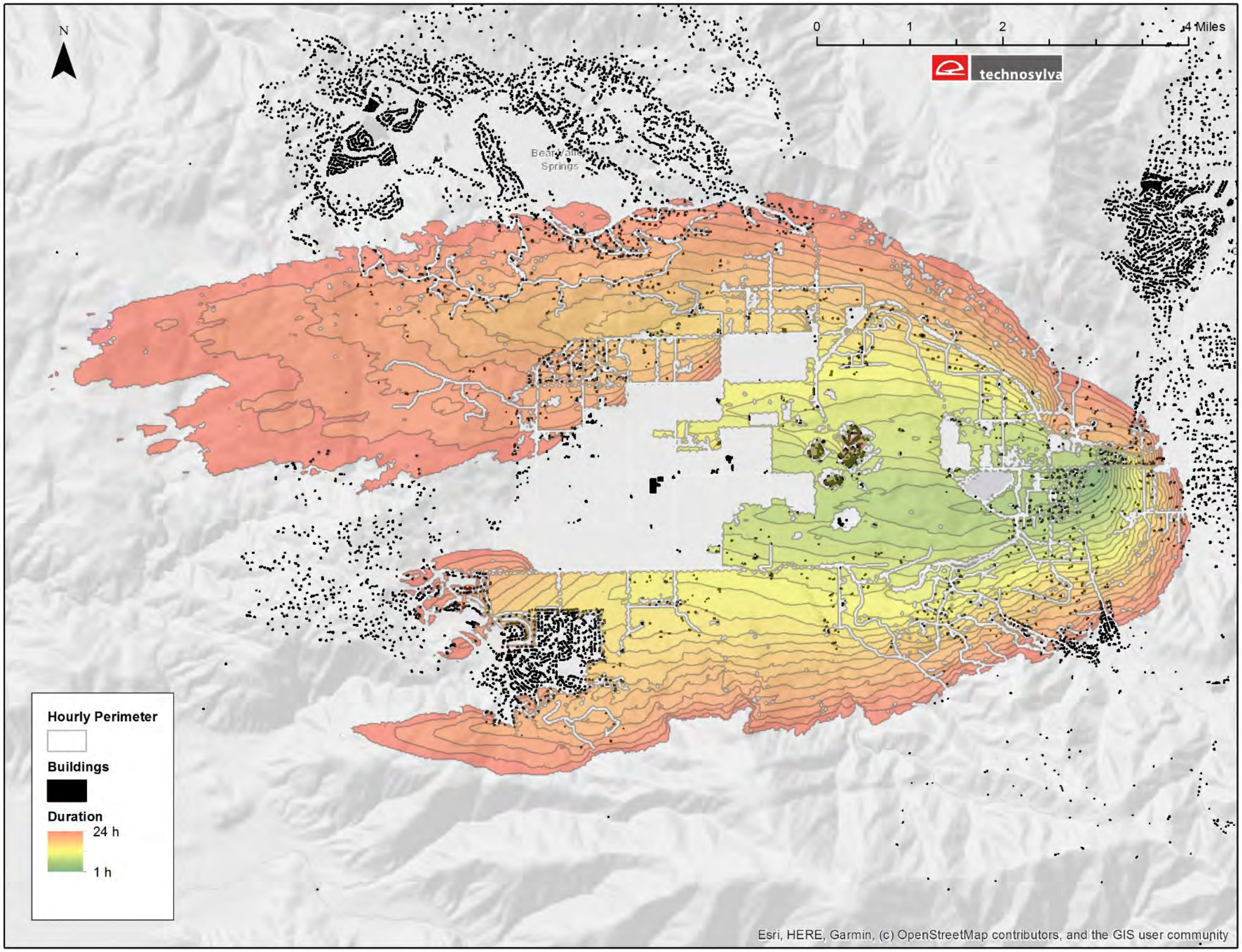
DAMAGE INCIDENT – 8

This damage incident is located near Golden Hills and Tehachapi urban areas. The fire could have impacted lots of scattered buildings in grass-shrub areas throughout the fire progression, including Bear Valley Springs and Stallion Springs urban areas. The rate of spread would very high with moderate-high intensity driven by east winds (20 mi/h). The fire containment would be very difficult although a road near the ignition location could help in suppressing the fire in the first fire run as reflected in the simulation. Finally, the fire progression would stop growing in the irrigated agricultural areas near Arvin.

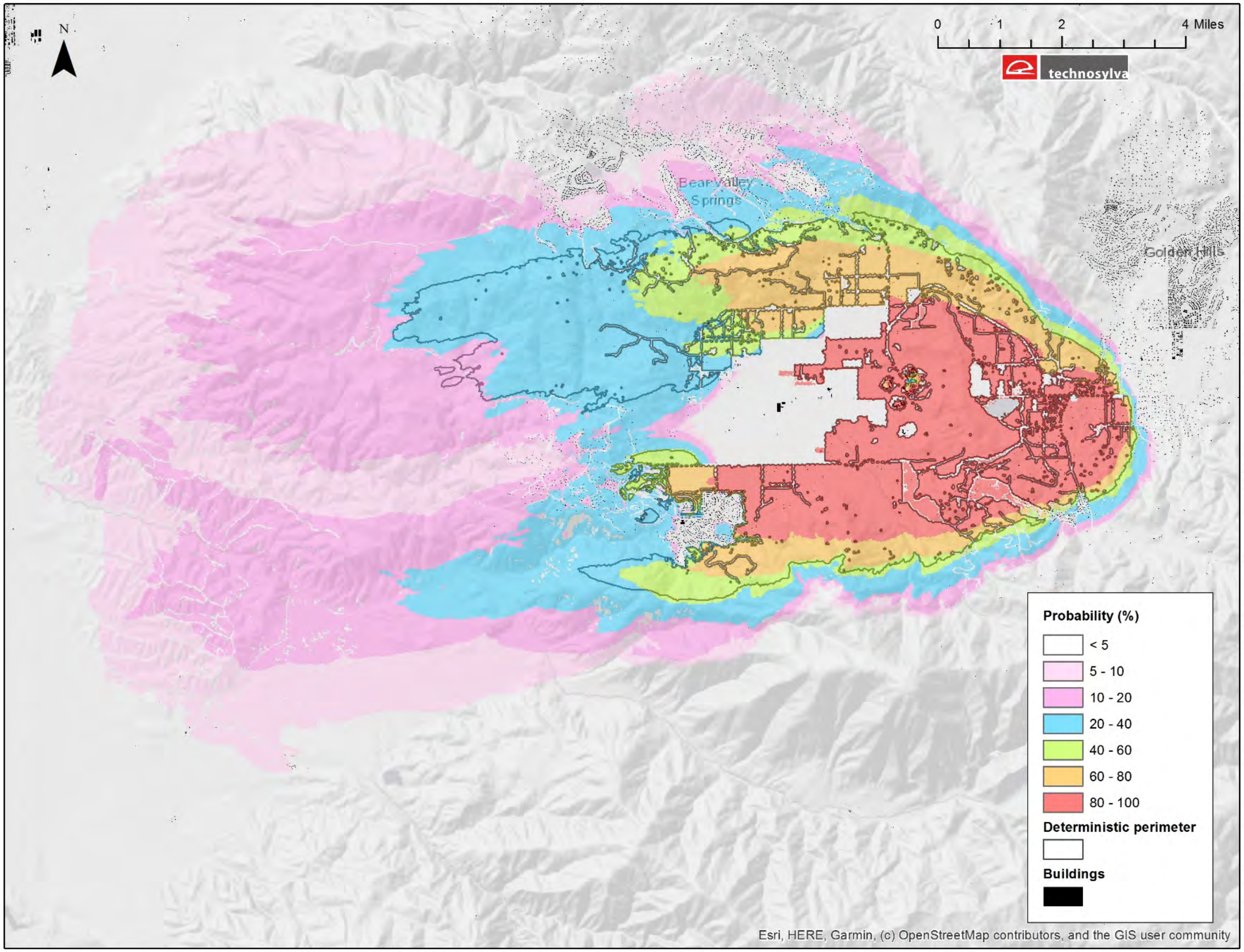
INCIDENT SUMMARY	
Start Time	10/10/2019 11:45
Duration (hrs)	24
Size (ac)	22,844
Initial Attack Assessment	3 - High
No. of Buildings	1,600
Total Population	5,515
Average ROS	High



DAMAGE INCIDENT NO. 8 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 8 : PROBABILISTIC SIMULATION



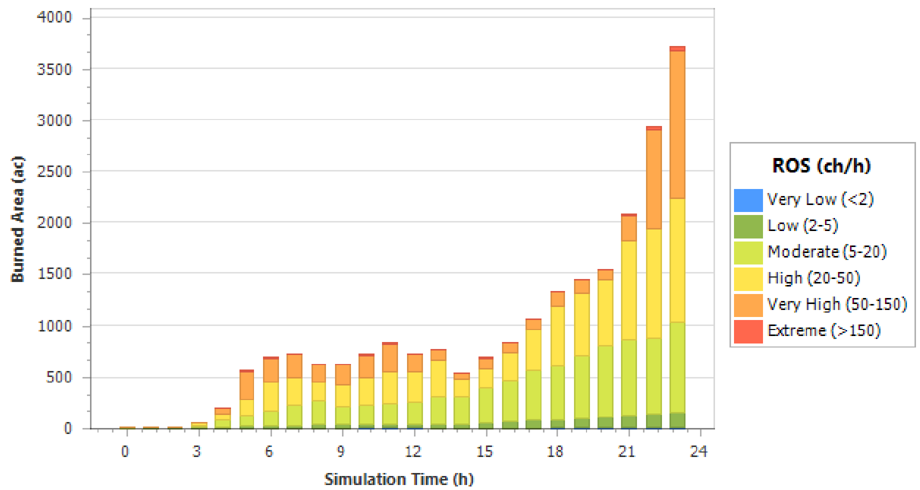
DAMAGE INCIDENT NO. 8

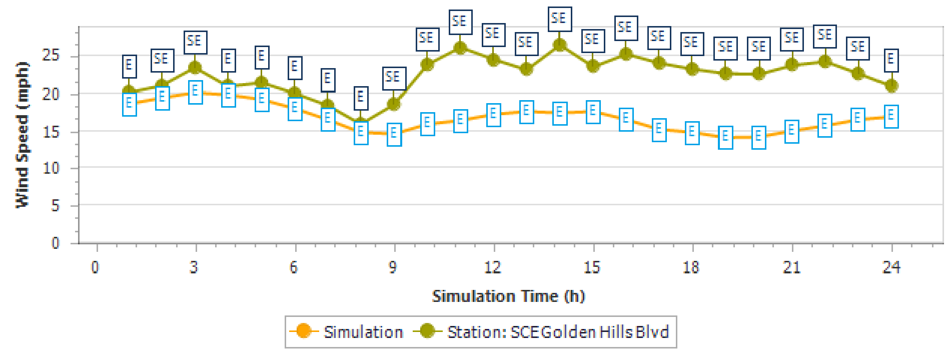
FIRE BEHAVIOR

WEATHER Nearest Station: SCE Golden Hills Blvd

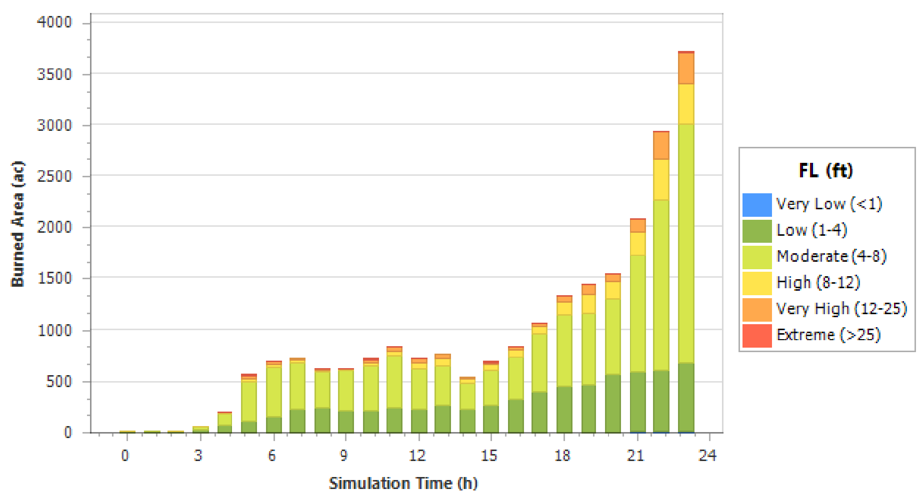
Station ID - SE467
Weather station (Wx) elevation - 4369 ft
Fire ignition point (IP) elevation - 4314 ft
Distance between Wx and IP - 1.97 mi

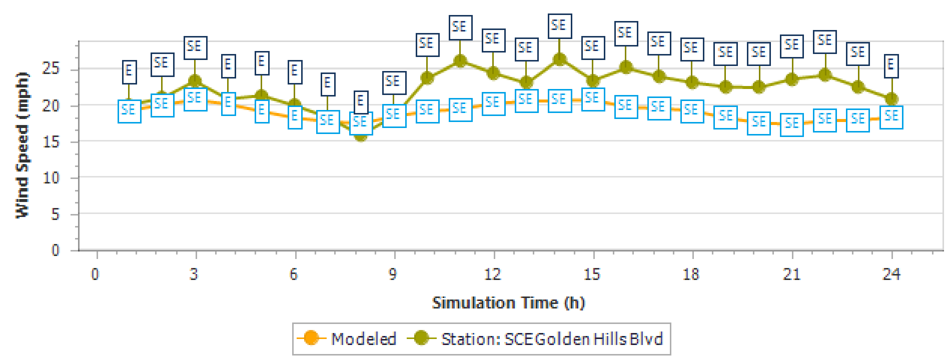
Rate of Spread





Flame Length

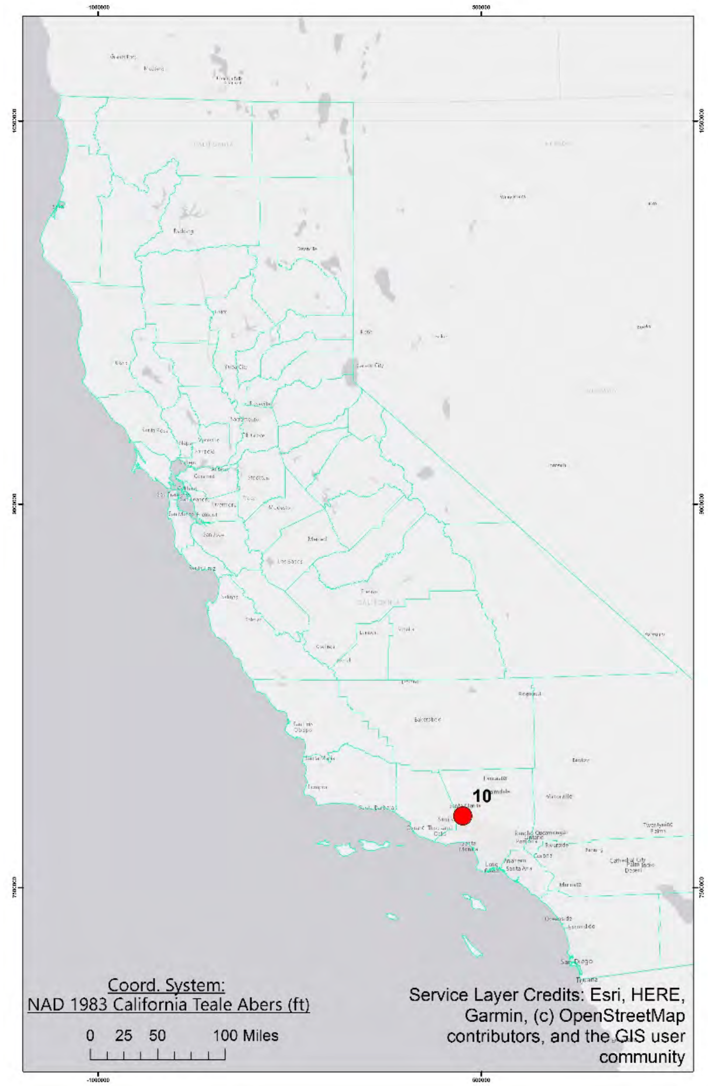




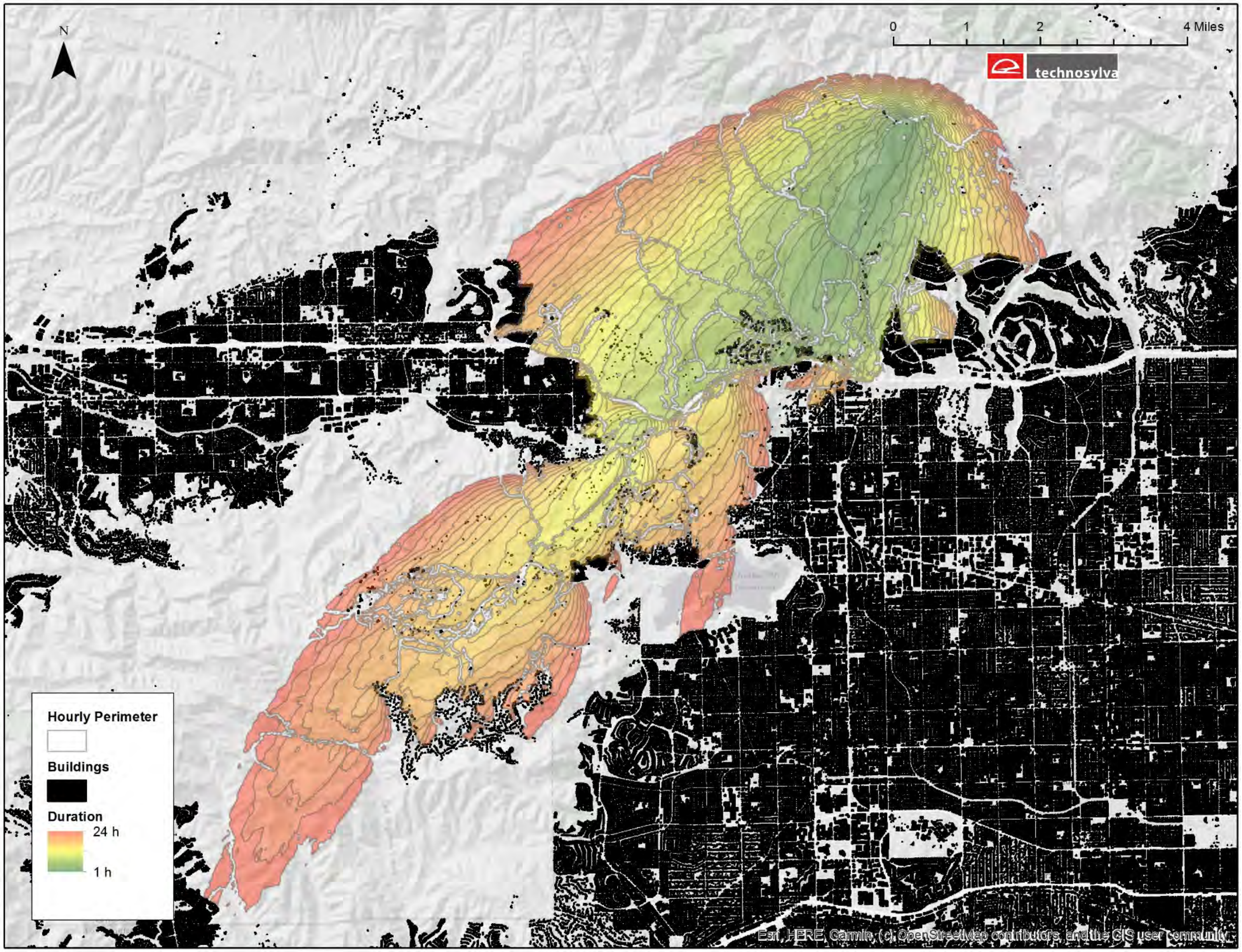
DAMAGE INCIDENT – 10

This damage incident is located in the county of Los Angeles in a fire-prone area with high historical large wildfire occurrence according to the FRAP CALFIRE dataset. It could cause a wind-driven fire with high rate of spread (50-150 ch/h) and fire intensity (> 8 ft) in the fire front, exceeding fire suppression capabilities in the initial attack (IAA = 5). Wind speeds modeled was slightly lower than recorded at weather station were similar with high winds coming from north east (25-30 mi/h). The fire could directly impact several dense urban areas during its progression potentially leading to high population and building loss.

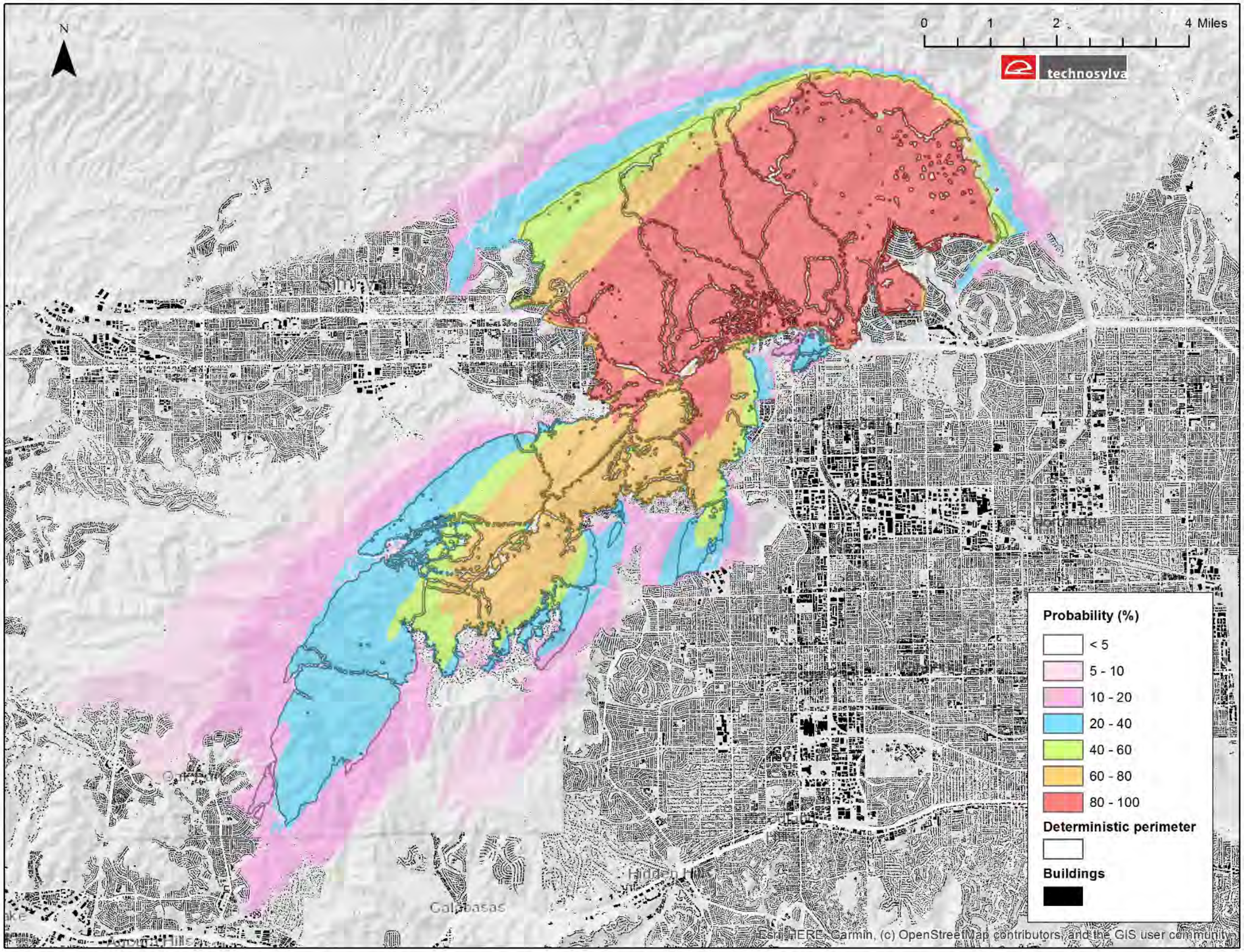
INCIDENT SUMMARY	
Start Time	10/10/2019 9:15
Duration (hrs)	24
Size (ac)	24,637
Initial Attack Assessment	5 - Extreme
No. of Buildings	2,174
Total Population	4,793
Average ROS	Very High



DAMAGE INCIDENT NO. 10 : DETERMINISTIC SIMULATION

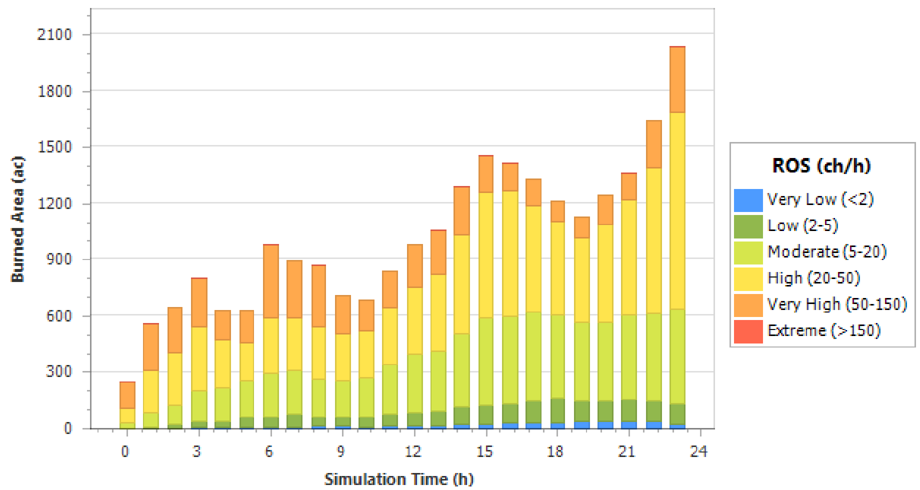


DAMAGE INCIDENT NO. 10 : PROBABILISTIC SIMULATION

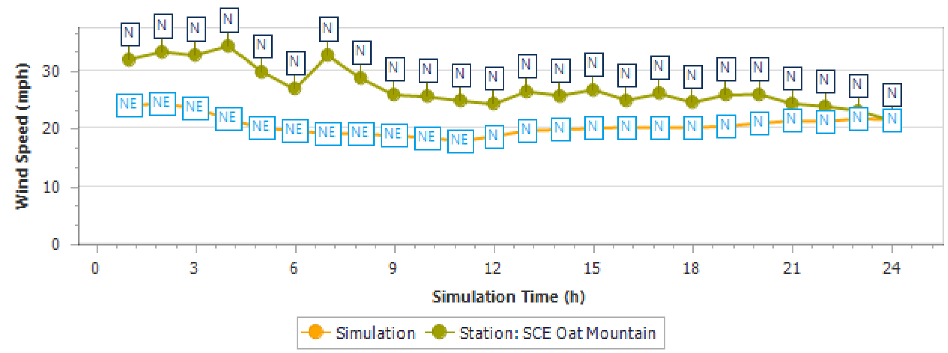


DAMAGE INCIDENT NO. 10	
FIRE BEHAVIOR	**WEATHER** **Nearest Station:** SCE Oat Mountain

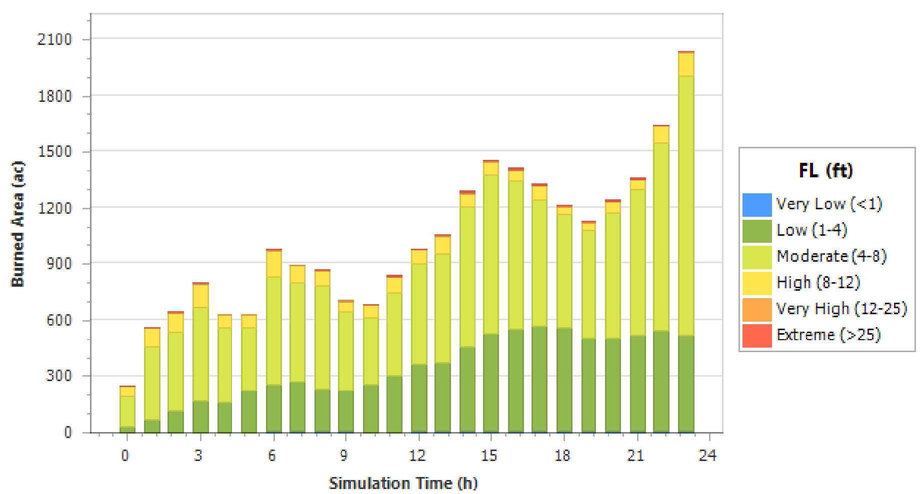
Rate of Spread

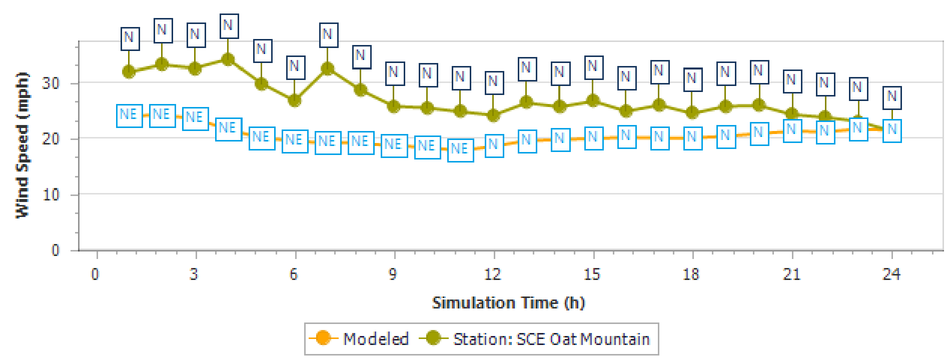


Station ID - SE079
Weather station (Wx) elevation - 3450 ft
Fire ignition point (IP) elevation - 3461 ft
Distance between Wx and IP - 0.1 mi



Flame Length

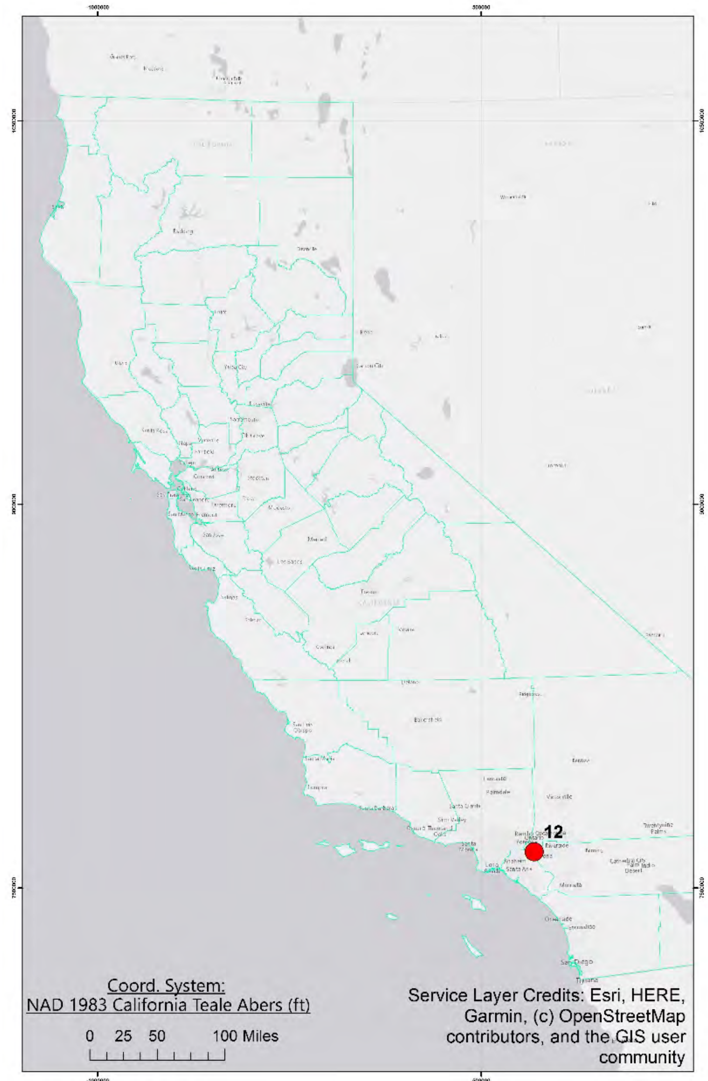




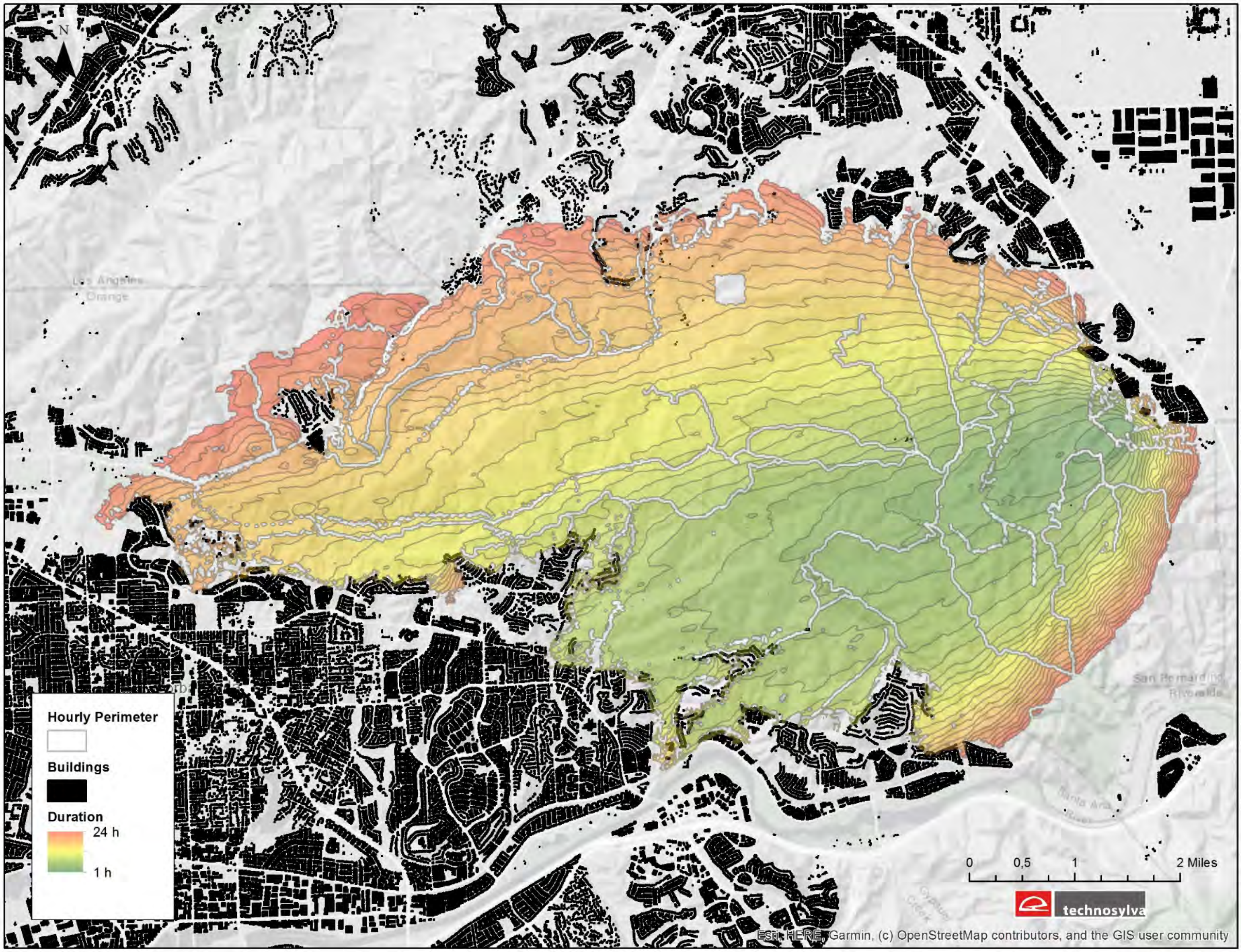
DAMAGE INCIDENT – 12

This damage incident is located in an area with lots of buildings and population. The fire could have impacted lots of scattered buildings and dense urban areas burning grass-shrub areas throughout the fire progression. The rate of spread would very high with moderate intensity driven by east winds (5-15 mi/h). Modeled wind speed was slightly higher than recorded at weather stations. The fire containment would be very difficult and could rapidly spread on the landscape, impacting lots of assets.

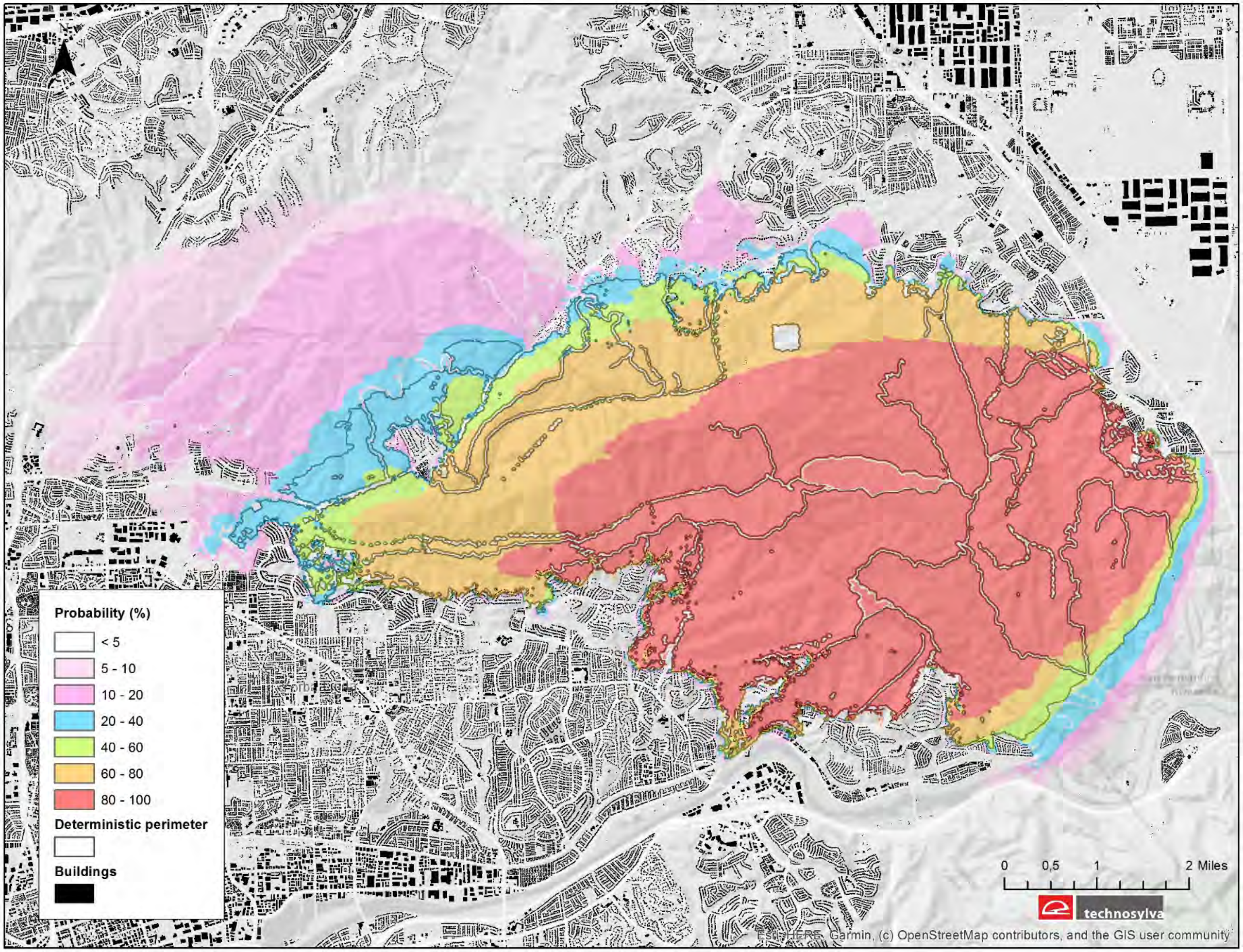
INCIDENT SUMMARY	
Start Time	10/24/2019 9:27
Duration (hrs.)	24
Size (ac)	20,357
Initial Attack Assessment	5 - Extreme
No. of Buildings	1,008
Total Population	4,235
Average ROS	Very high



DAMAGE INCIDENT NO. 12 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 12 : PROBABILISTIC SIMULATION



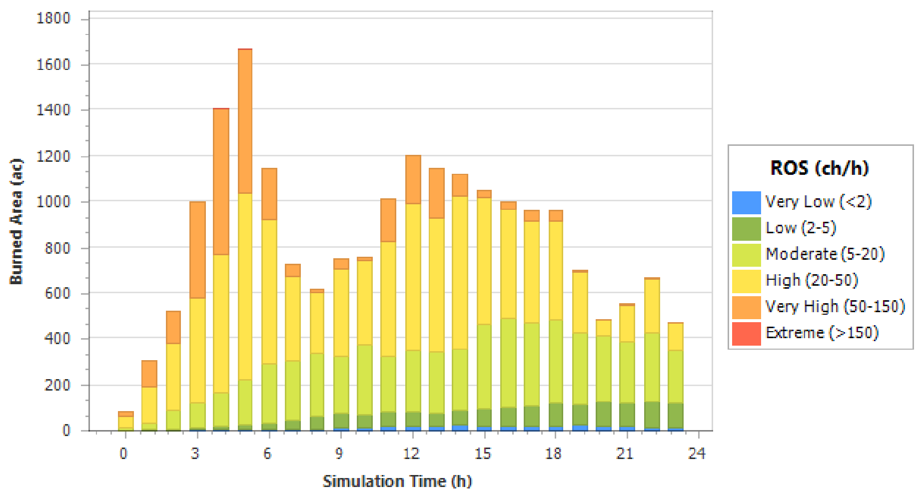
DAMAGE INCIDENT NO. 12

FIRE BEHAVIOR

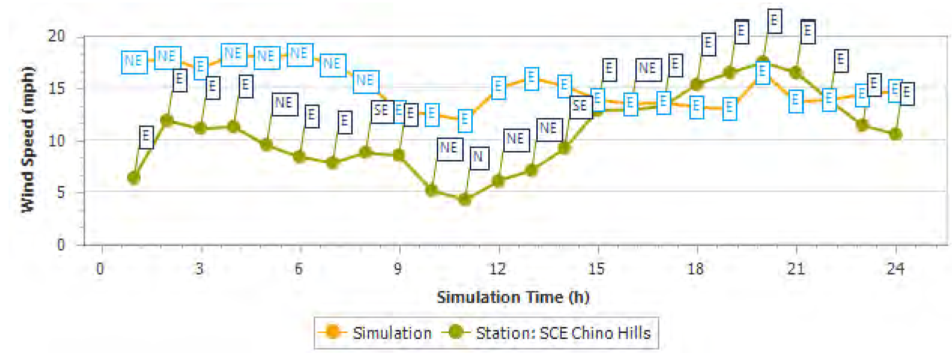
WEATHER

Nearest Station: SCE Chino Hills

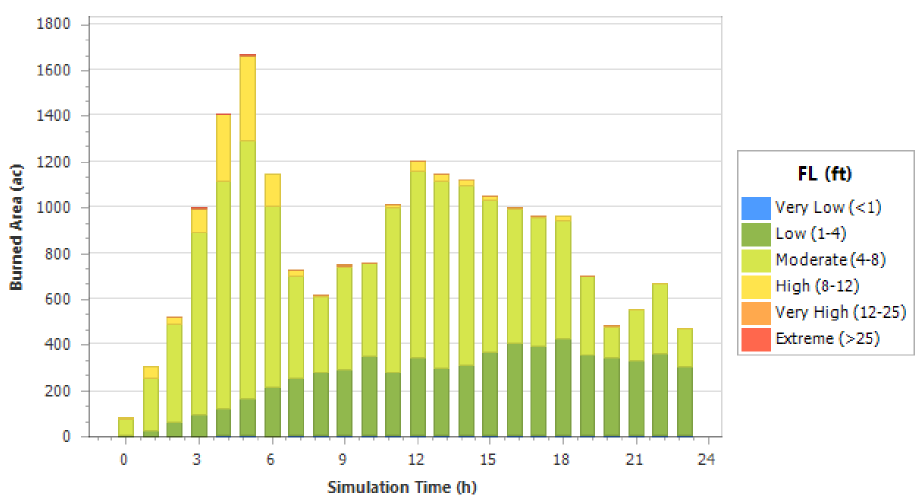
Rate of Spread

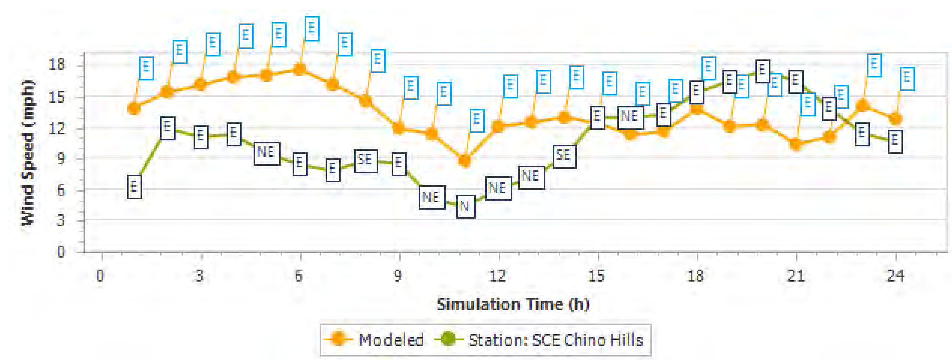


Station ID - SE132
Weather station (Wx) elevation - 1336 ft
Fire ignition point (IP) elevation - 923 ft
Distance between Wx and IP - 4.45 mi



Flame Length

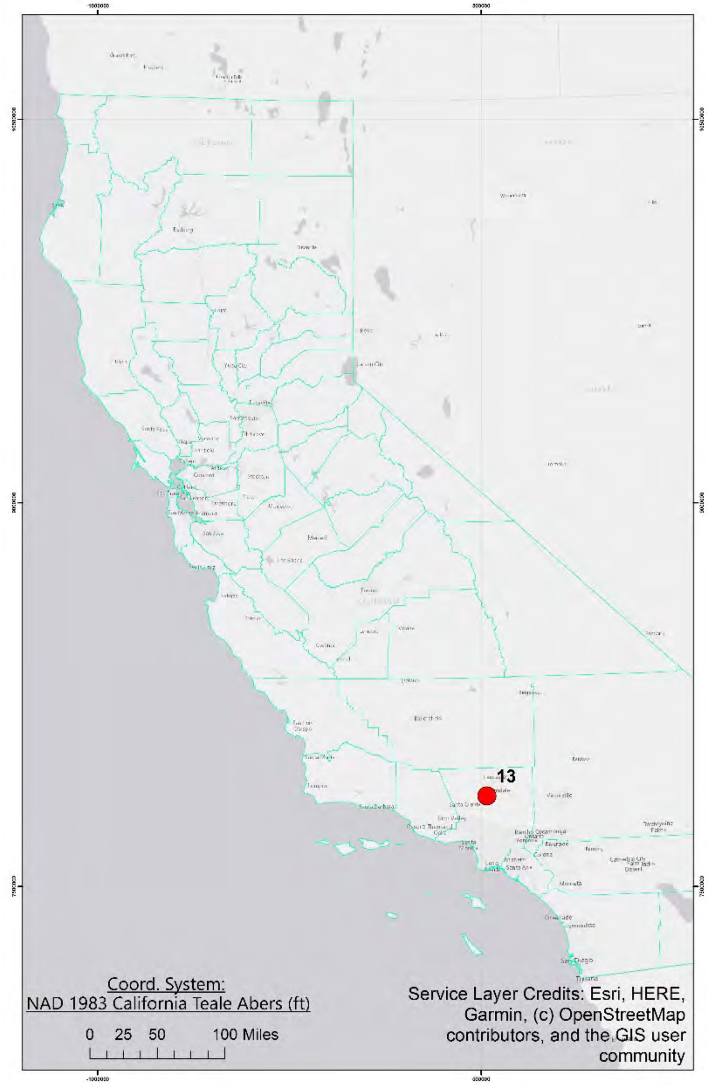




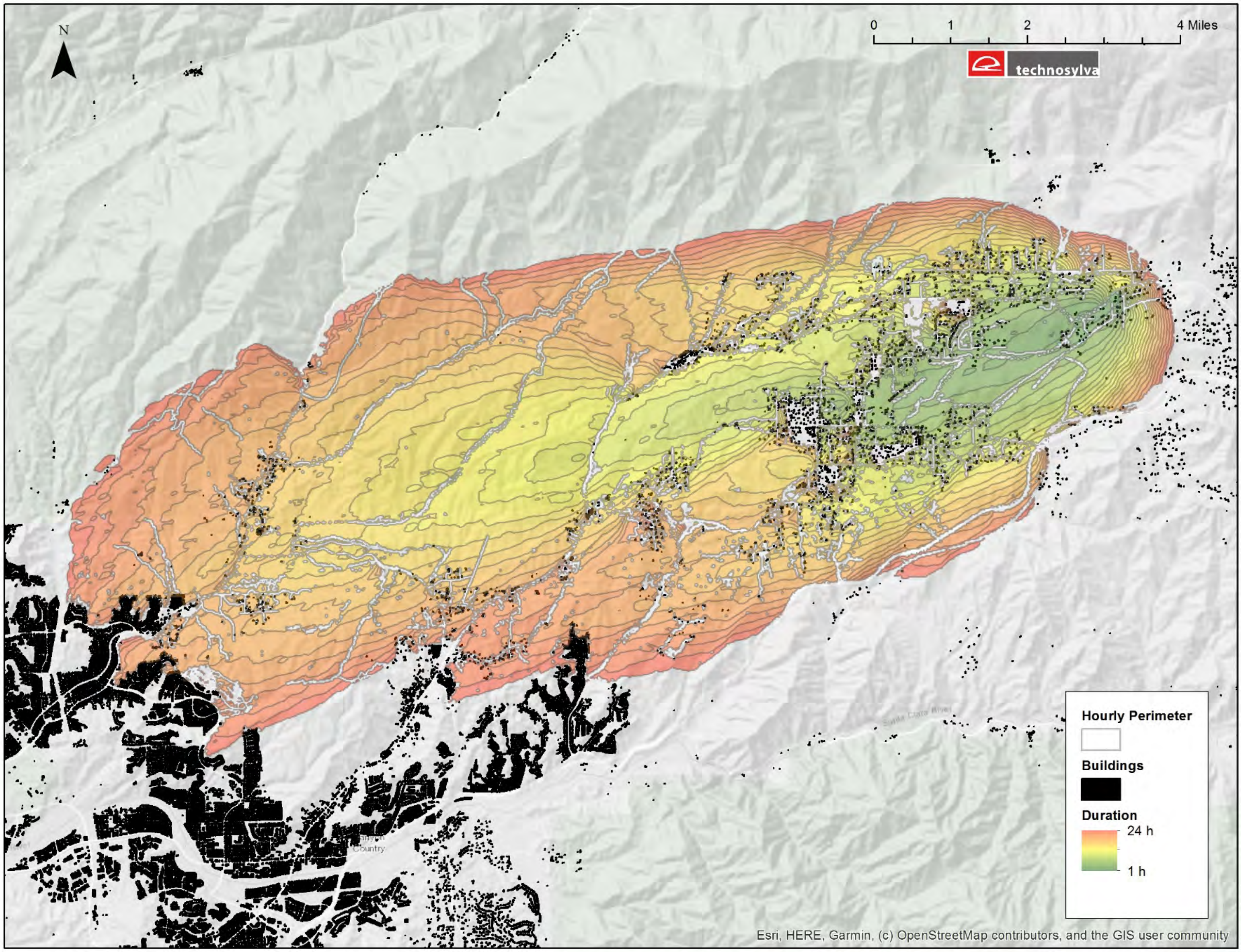
DAMAGE INCIDENT – 13

This incident is located near Mint Canyon and County Country Wildland Urban Interfaces. The fire could have started near urban areas creating the high impact in terms of population and building loss. Lots of scattered buildings could be impacted throughout the fire progression as well as dense urban areas. Fire would spread very rapidly with high intensity, presenting high resistance to control with an IAA of 5 (Extreme) with an average wind speed of 20mi/h. Modeled wind speed was higher than measured at weather station. Fire intensity would be high.

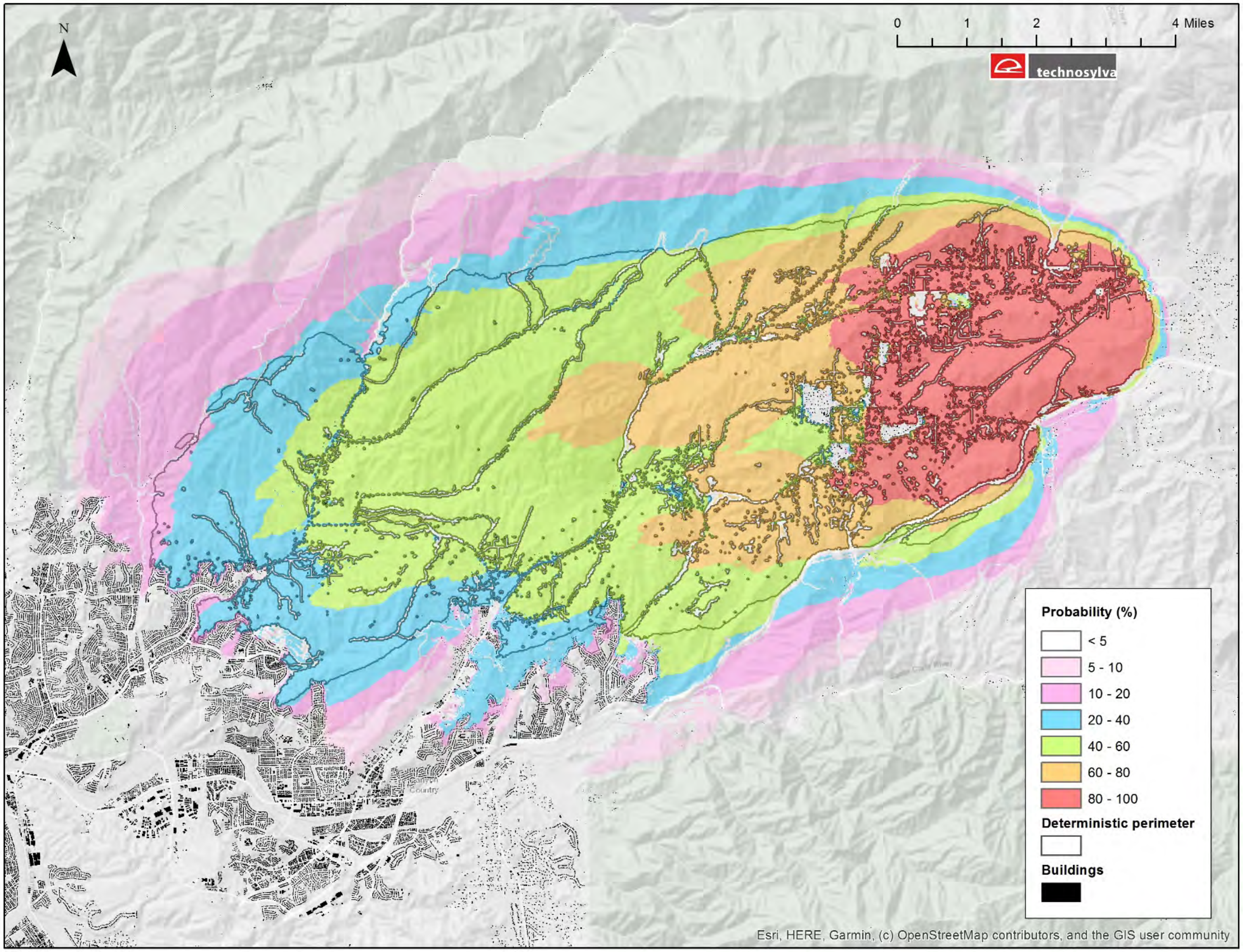
INCIDENT SUMMARY	
Start Time	10/24/2019 8:51
Duration (hrs.)	24
Size (ac)	36,898
Initial Attack Assessment	5 - Extreme
No. of Buildings	3,147
Total Population	4,135
Average ROS	High



DAMAGE INCIDENT NO. 13 : DETERMINISTIC SIMULATION

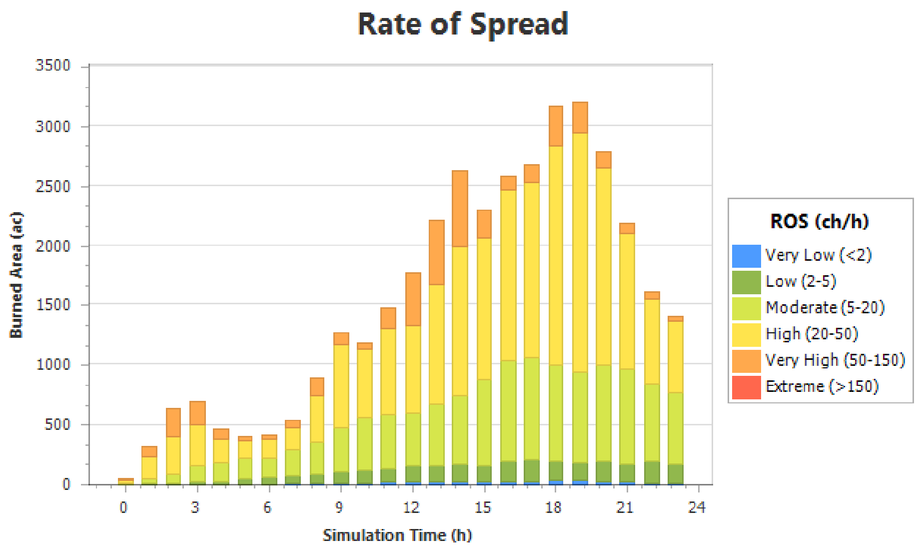


DAMAGE INCIDENT NO. 13 : PROBABILISTIC SIMULATION

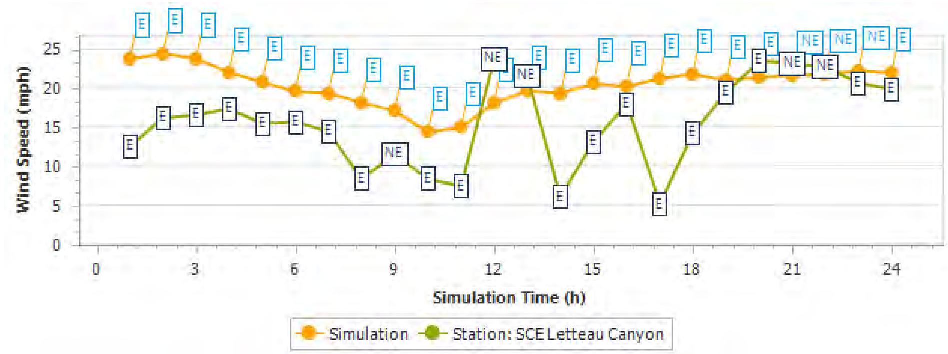


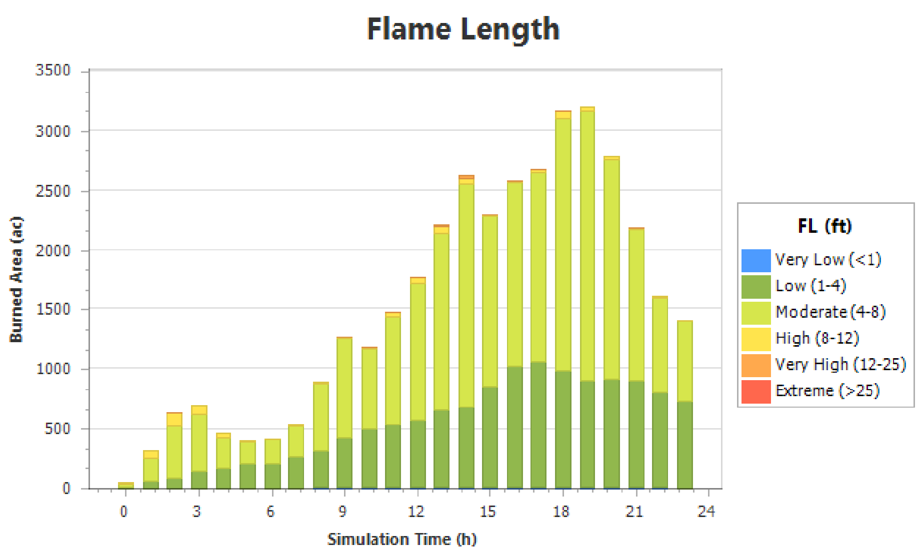
DAMAGE INCIDENT NO. 13

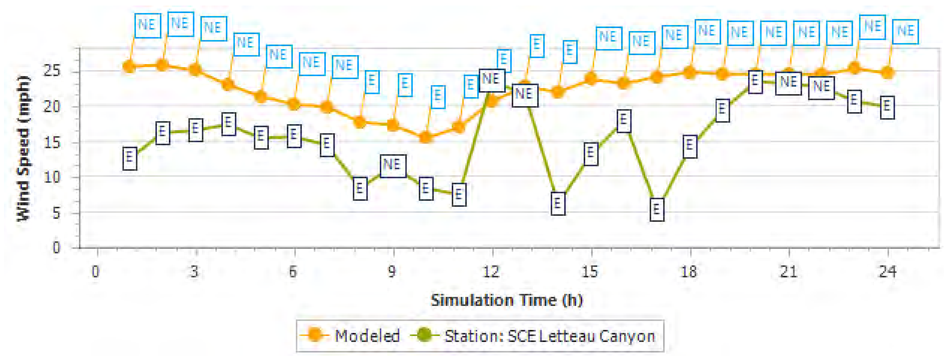
FIRE BEHAVIOR	WEATHER **Nearest Station:** SCE Letteau Canyon



Station ID - SE460
Weather station (Wx) elevation - 2928 ft
Fire ignition point (IP) elevation - 3091 ft
Distance between Wx and IP - 0.74 mi





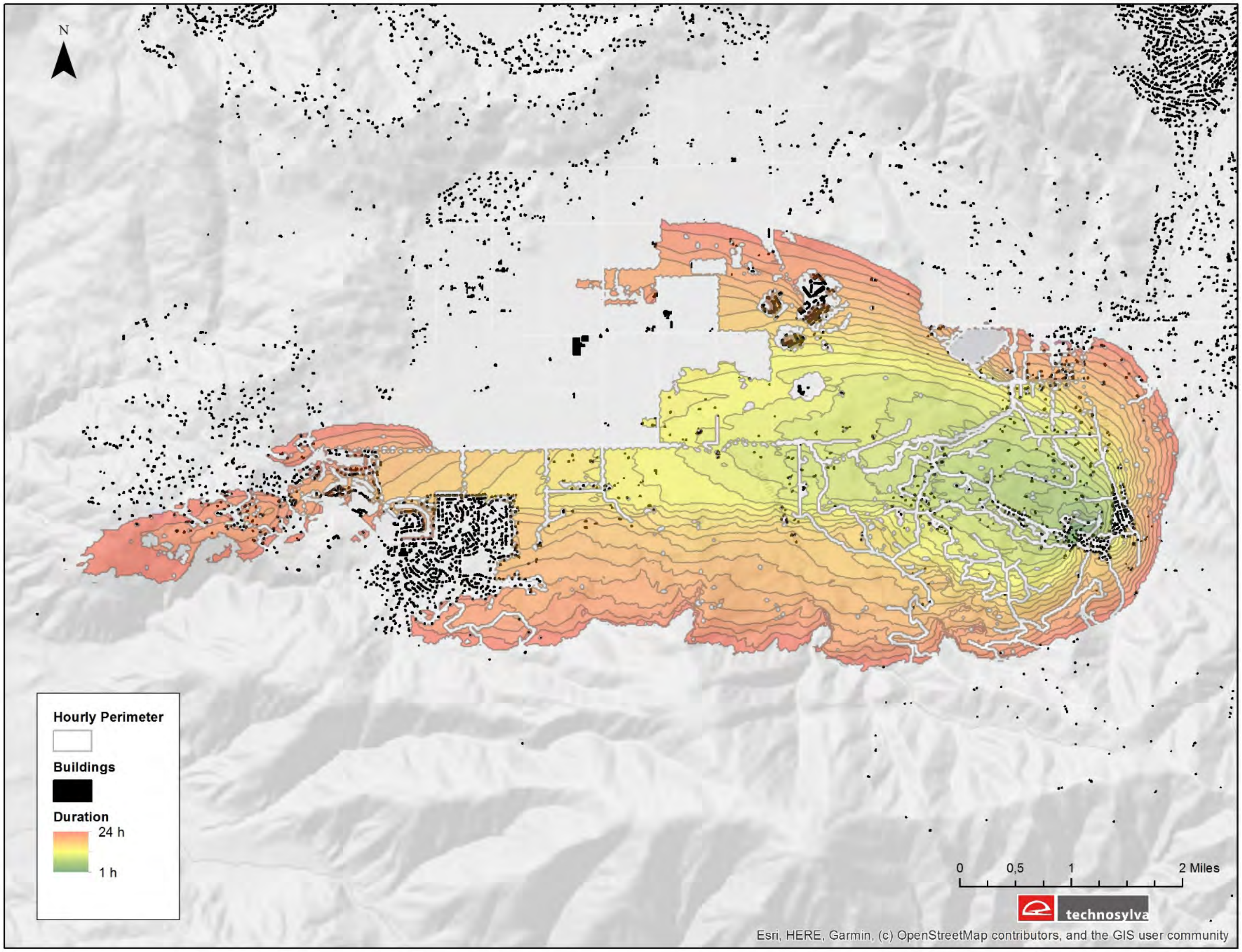


DAMAGE INCIDENT – 14

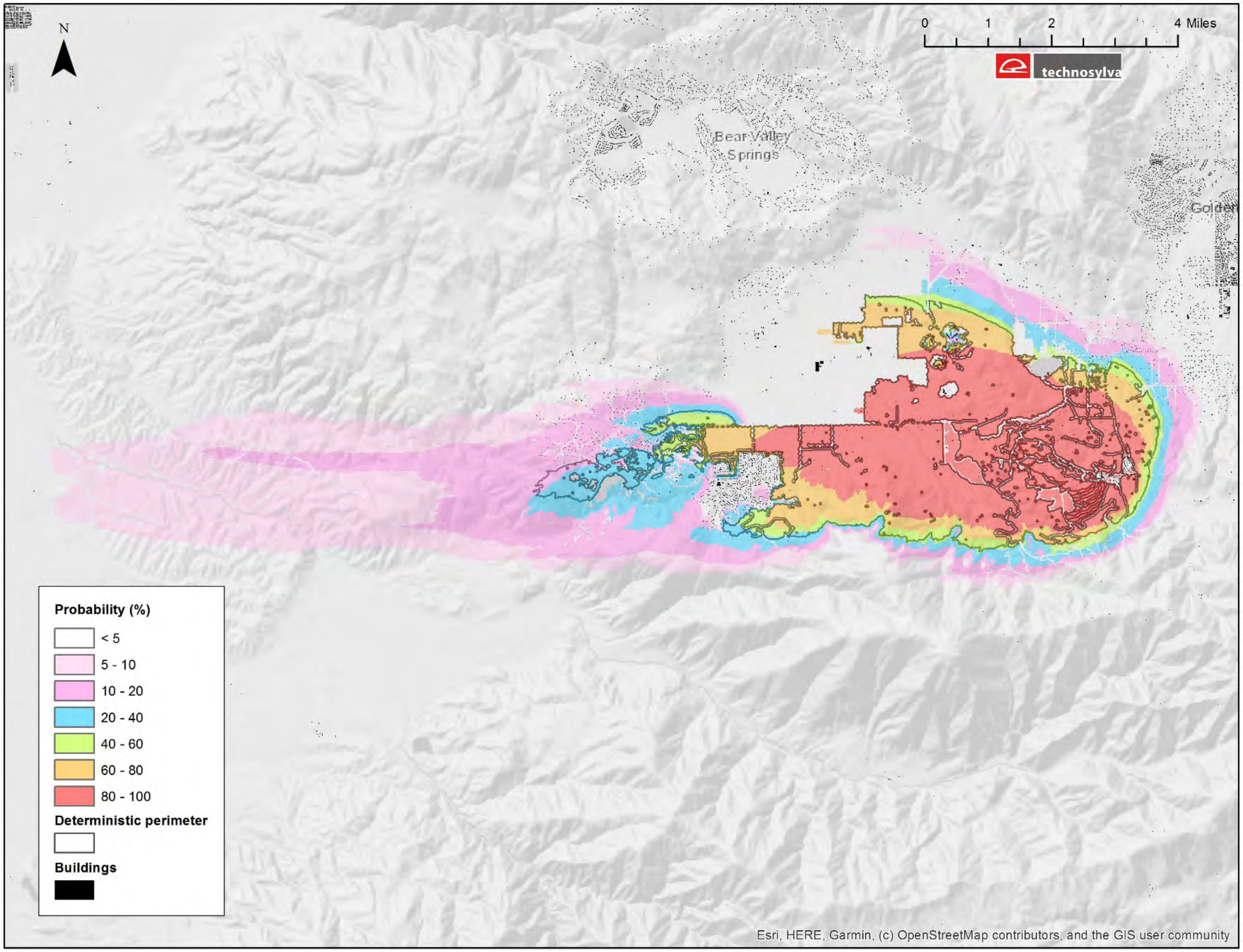
This damage incident is located in wildland urban interface area with scattered buildings between Golden Hills and Stallion Springs urban areas. The fire could have impacted lots of scattered buildings in grass-shrub areas throughout the fire progression, including Bear Valley Springs and Stallion Springs urban areas. The rate of spread would very high with moderate-high intensity driven by east winds (20 mi/h). The fire containment would be very difficult with an IAA of 3.

INCIDENT SUMMARY	
Start Time	10/30/2019 0:15
Duration (hrs)	24
Size (ac)	10,838
Initial Attack Assessment	3 – High
No. of Buildings	927
Total Population	3,953
Average ROS	High

DAMAGE INCIDENT NO. 14 : DETERMINISTIC SIMULATION



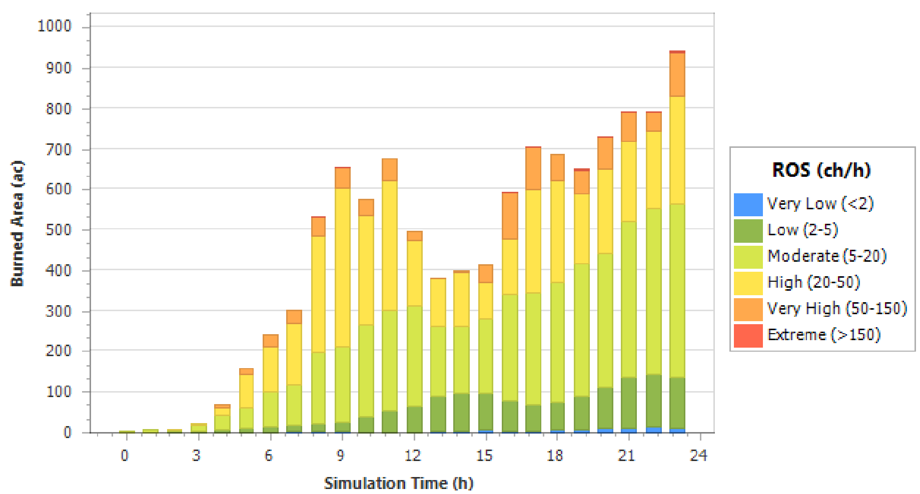
DAMAGE INCIDENT NO. 14 : PROBABILISTIC SIMULATION



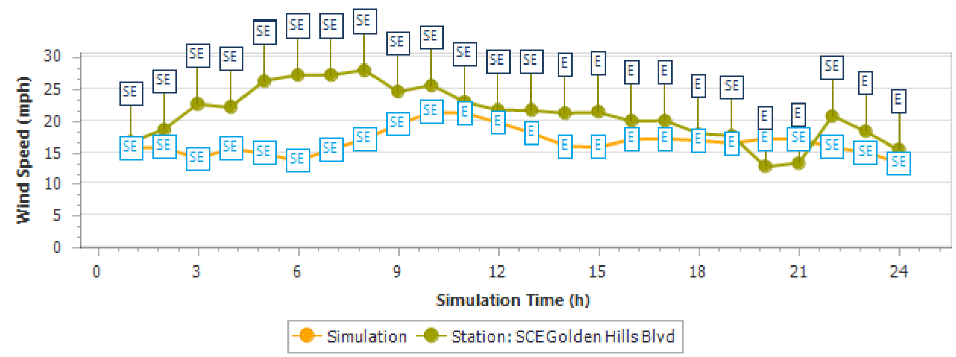
DAMAGE INCIDENT NO. 14

FIRE BEHAVIOR	WEATHER **Nearest Station:** SCE Golden Hills Blvd

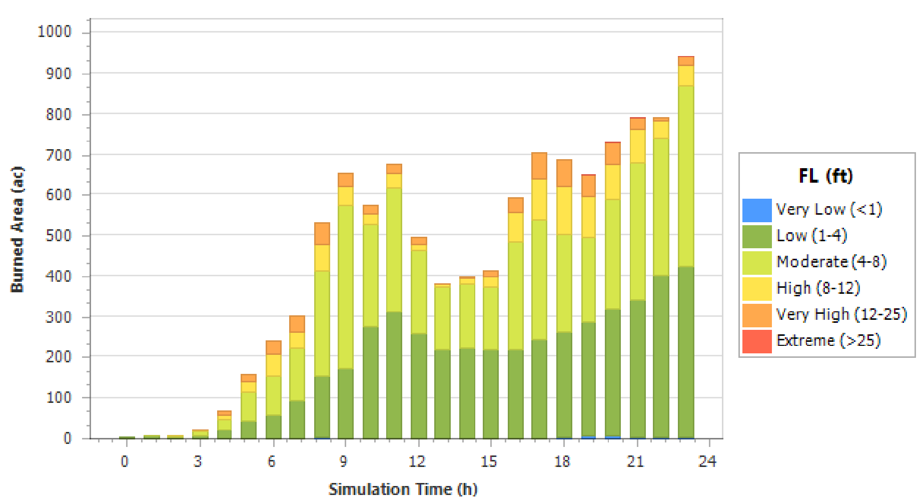
Rate of Spread

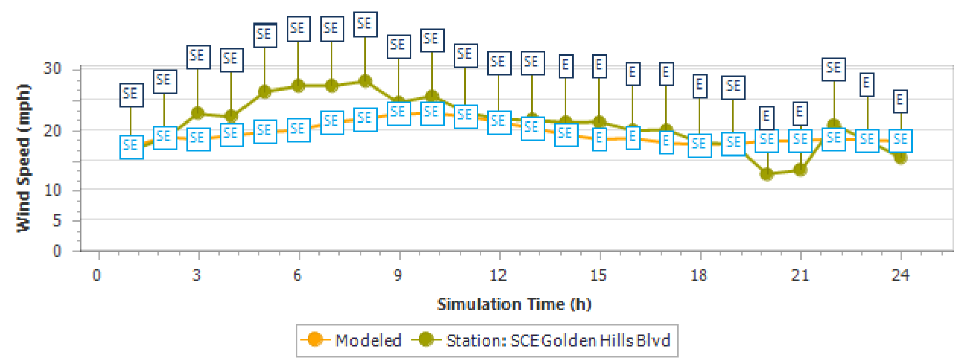


Station ID - SE467
Weather station (Wx) elevation - 4369 ft
Fire ignition point (IP) elevation - 5052 ft
Distance between Wx and IP - 2.92 mi



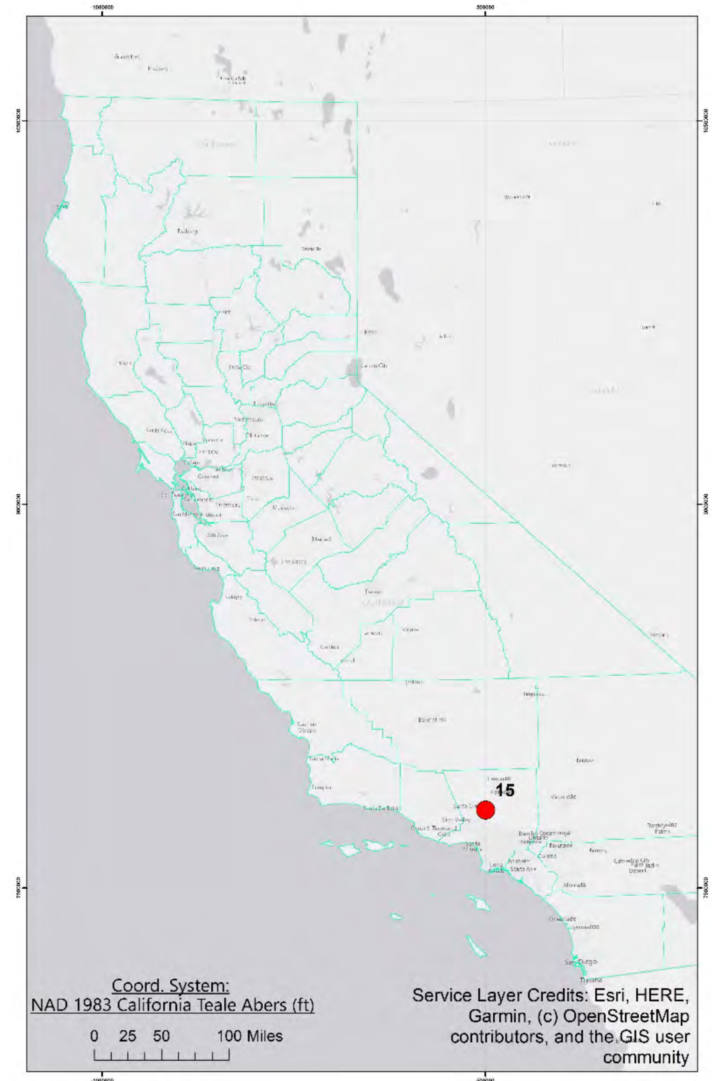
Flame Length





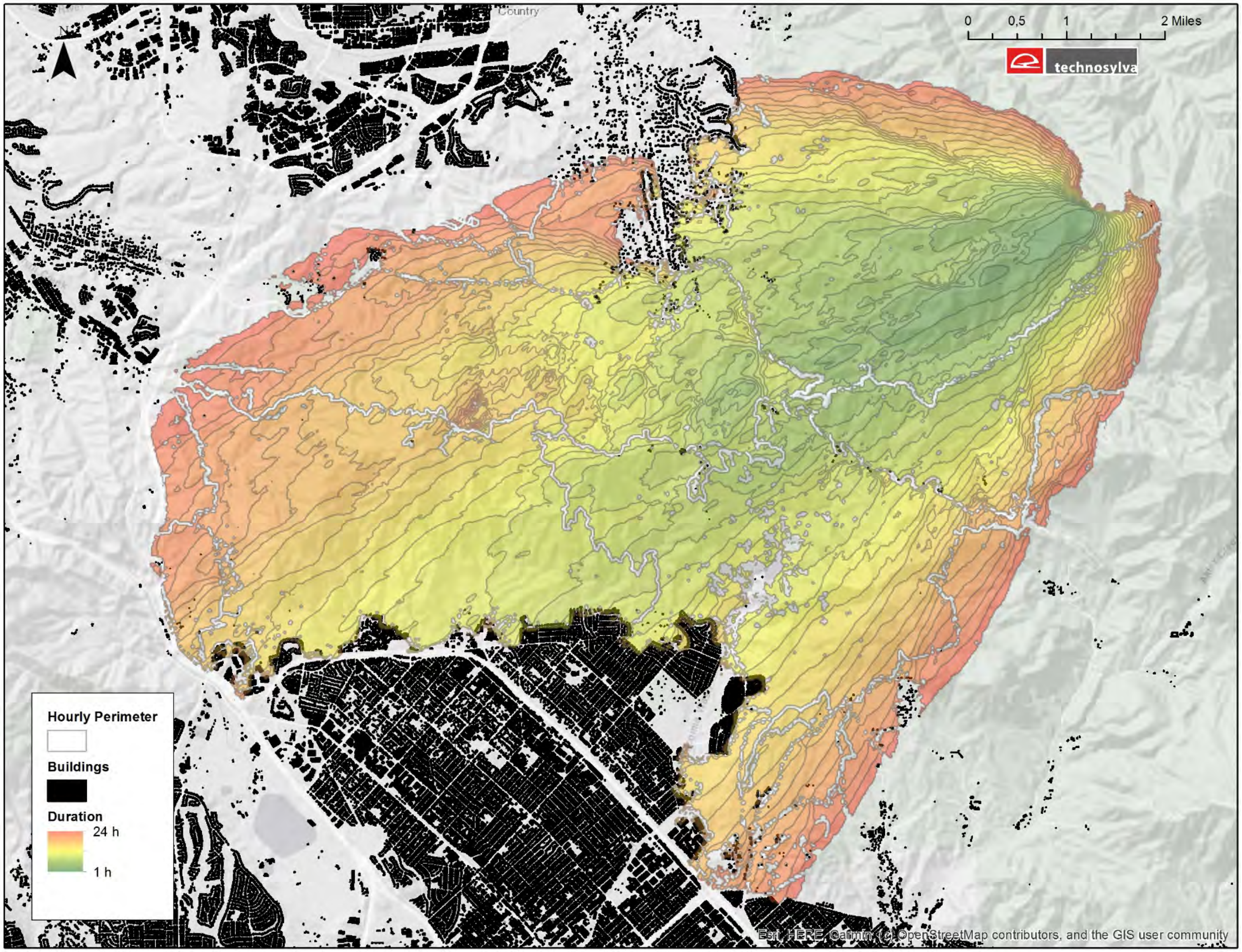
DAMAGE INCIDENT – 15

This incident could rapidly affect several Wildland Urban Interfaces throughout the fire progression, creating high impact in terms of population and building loss (see incident summary table). The fire would exceed fire suppression capabilities because the rate of spread would be very high with high fire intensity and an IAA of 5. The fire would burn grass-shrub areas driven by wind speed ranging between 15 and 25 mi/h.

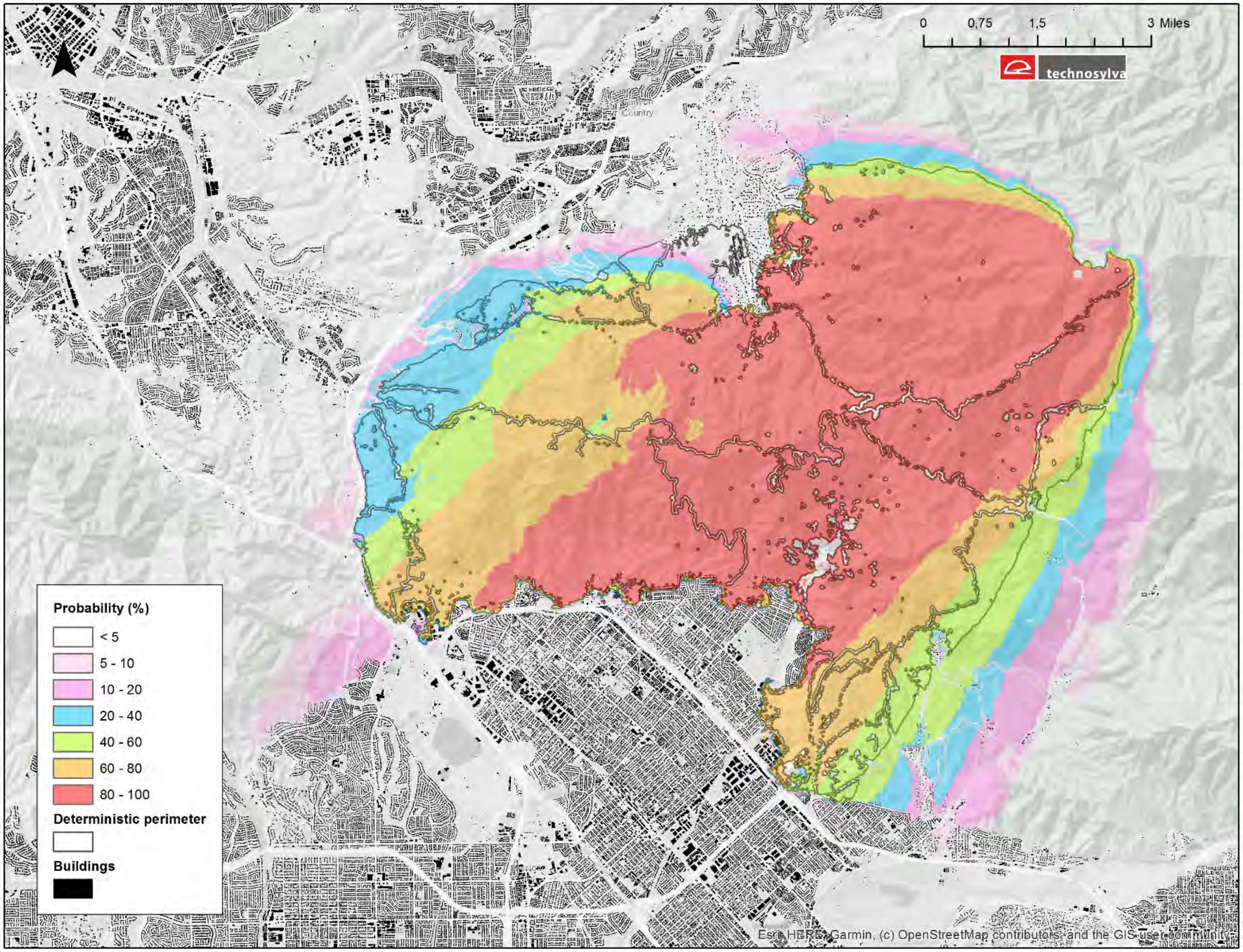


INCIDENT SUMMARY	
Start Time	10/10/2019 11:00
Duration (hrs)	24
Size (ac)	29,854
Initial Attack Assessment	5 – Extreme
No. of Buildings	1,693
Total Population	3,783
Average ROS	Very high

DAMAGE INCIDENT NO. 15 : DETERMINISTIC SIMULATION



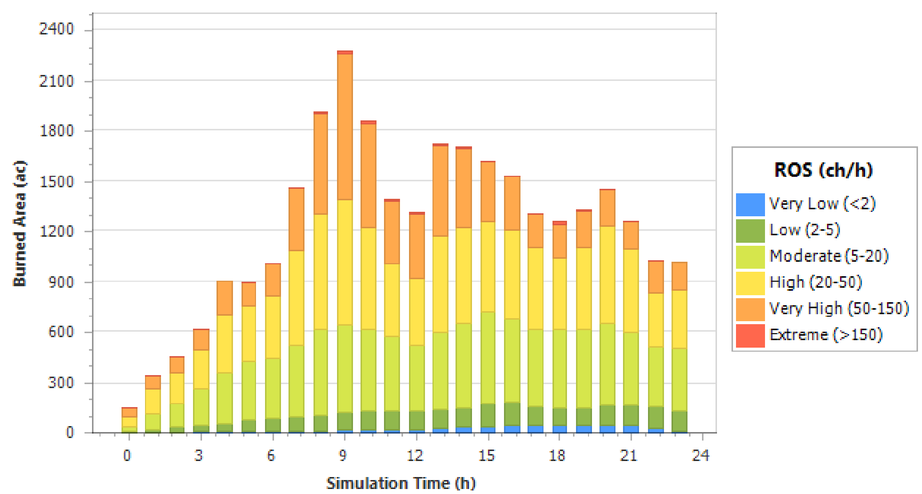
DAMAGE INCIDENT NO. 15 : PROBABILISTIC SIMULATION



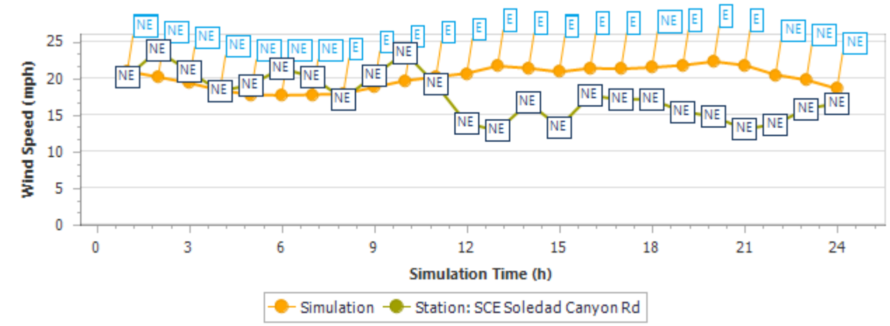
DAMAGE INCIDENT NO. 15

FIRE BEHAVIOR	WEATHER **Nearest Station:** SCE Soledad Canyon Rd

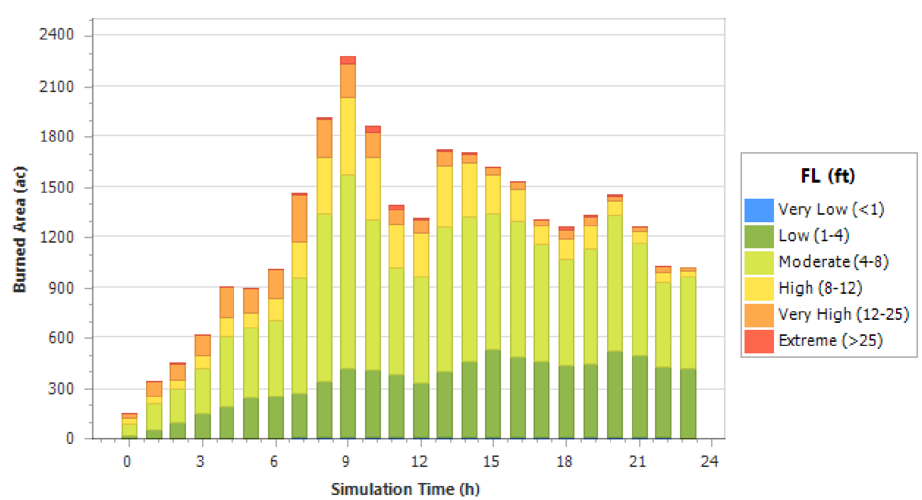
Rate of Spread

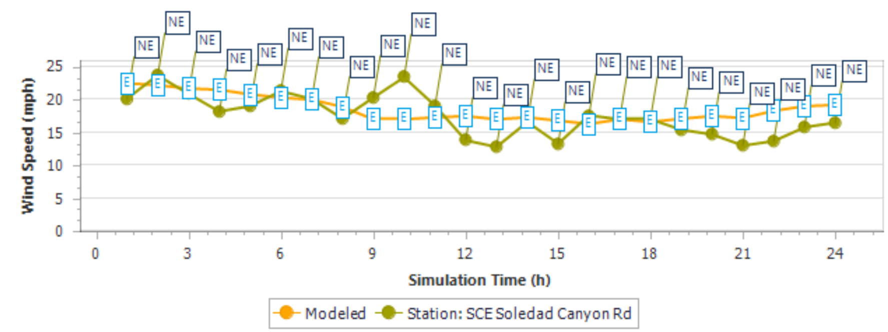


Station ID - SE273
Weather station (Wx) elevation - 1936 ft
Fire ignition point (IP) elevation - 4440 ft
Distance between Wx and IP - 3.45 mi



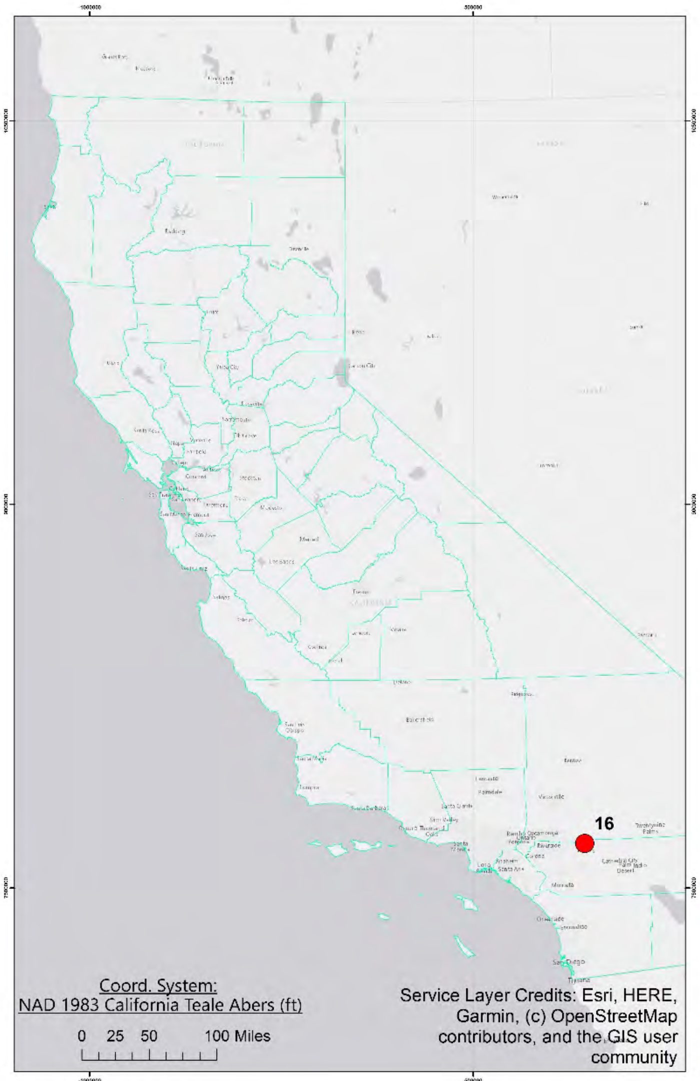
Flame Length





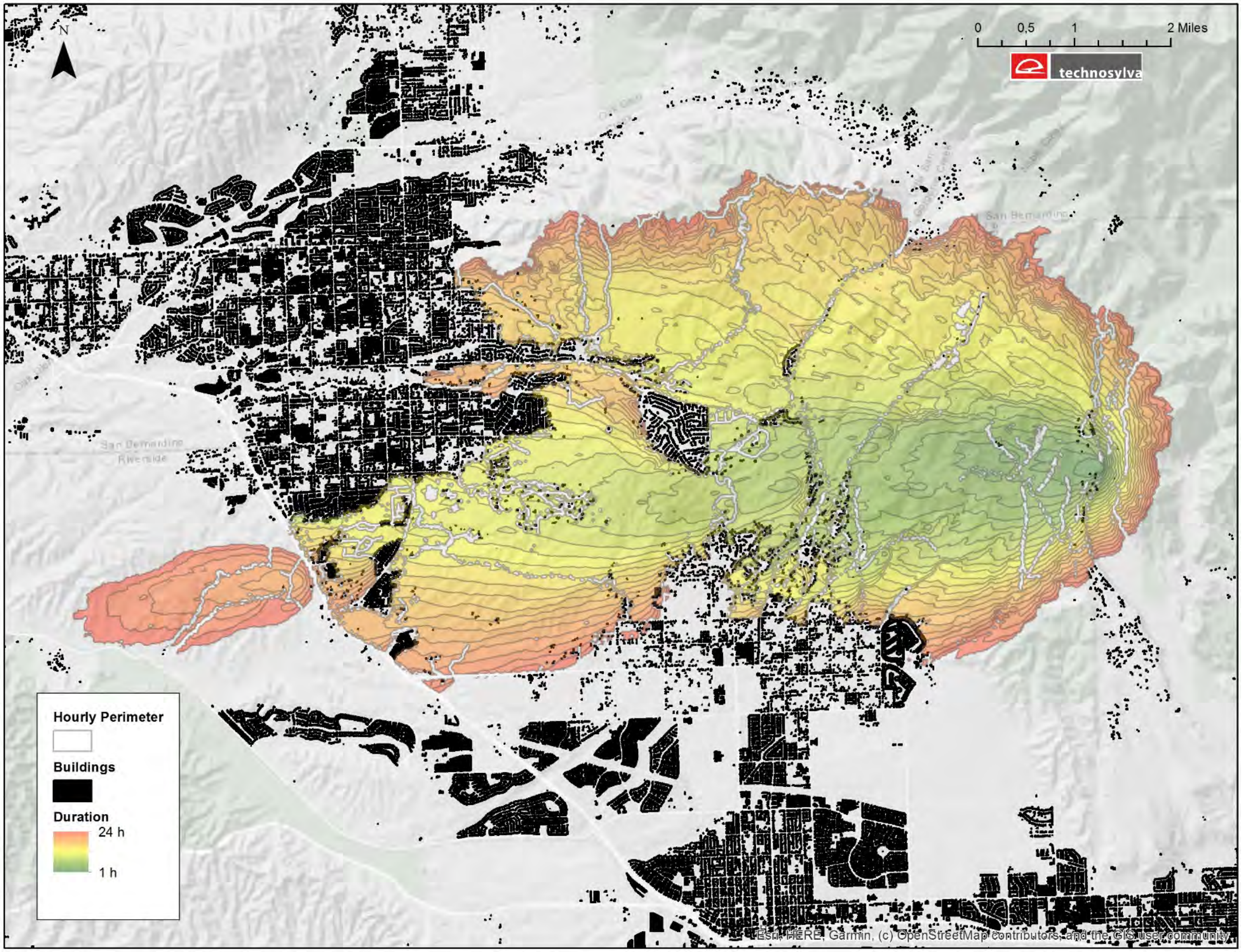
DAMAGE INCIDENT – 16

This incident damage was located near an area with lots of buildings. The fire would start burning grass-shrub fuel types and impacting a dense wildland urban interface area in 2-3 hours after the fire start. The fire would be difficult to contain due to a very high IAA (4), The fire could further spread on forest areas very quickly driven by winds from east ranging between 10 and 30 mi/hr. Modeled wind speed was lower than measured at weather station.

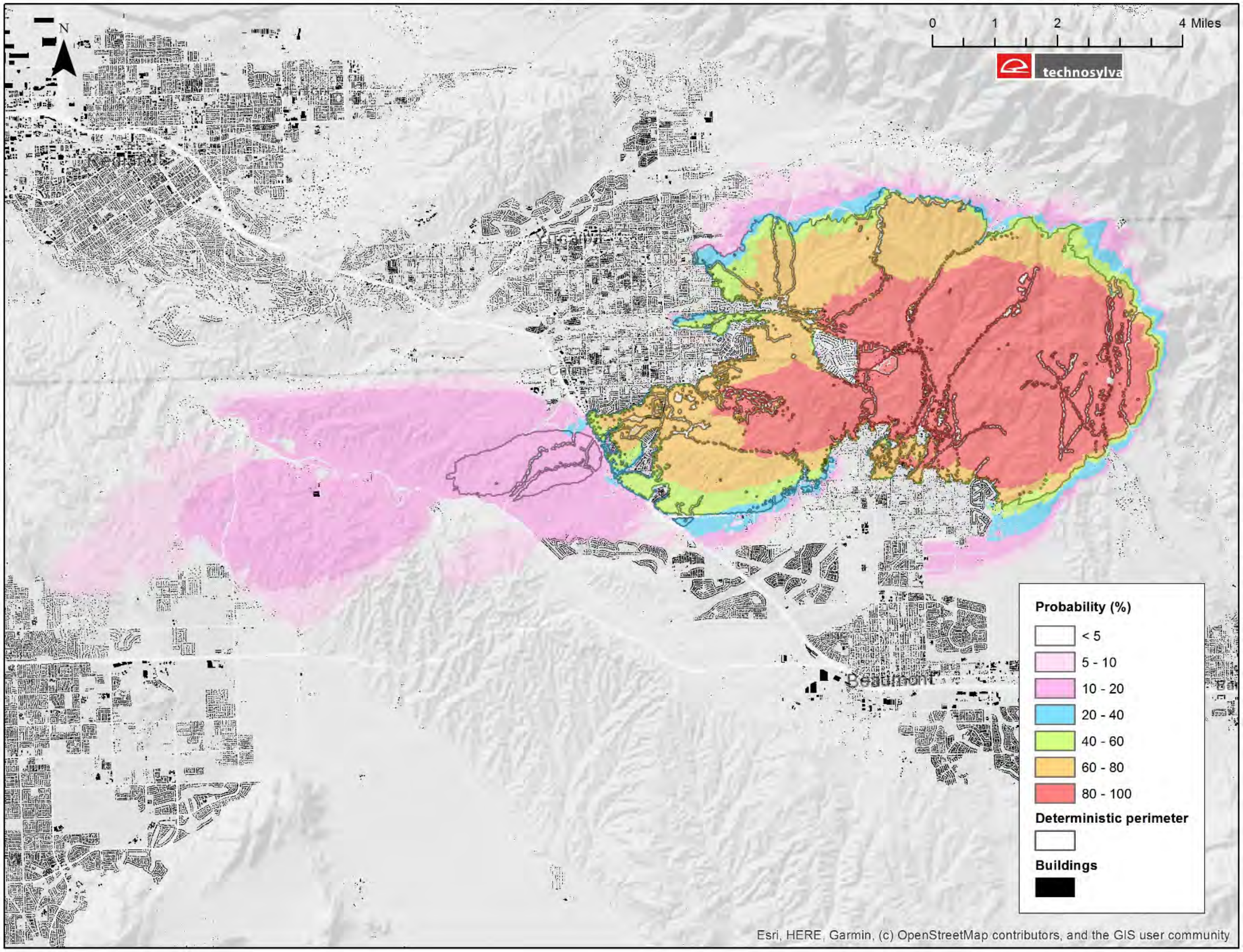


INCIDENT SUMMARY	
Start Time	10/30/2019 8:51
Duration (hrs)	24
Size (ac)	19,377
Initial Attack Assessment	4 – Very High
No. of Buildings	2,163
Total Population	2,967
Average ROS	High

DAMAGE INCIDENT NO. 16 : DETERMINISTIC SIMULATION

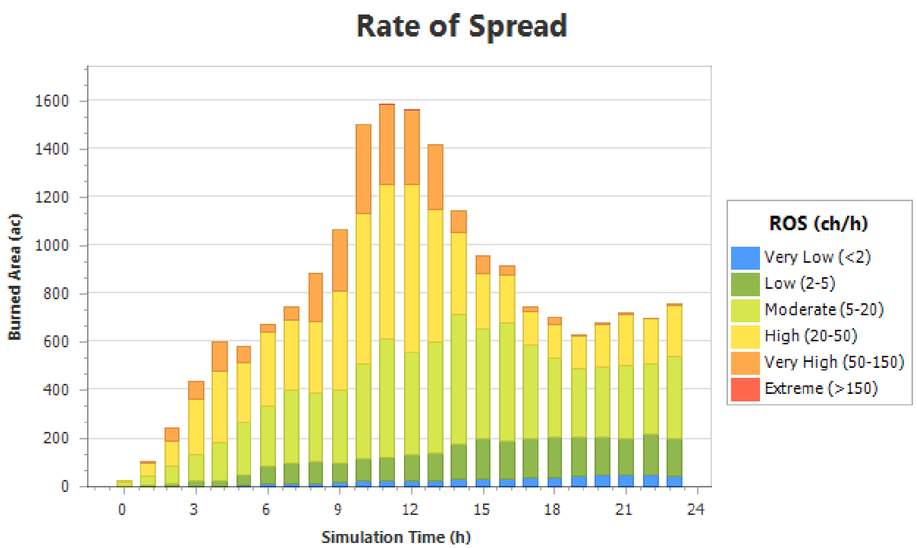


DAMAGE INCIDENT NO. 16 : PROBABILISTIC SIMULATION

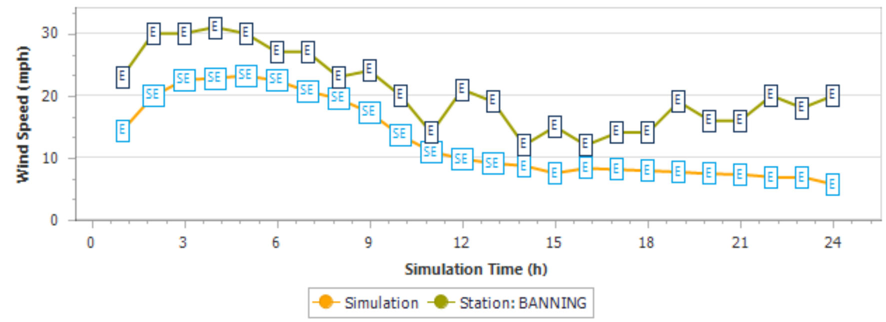


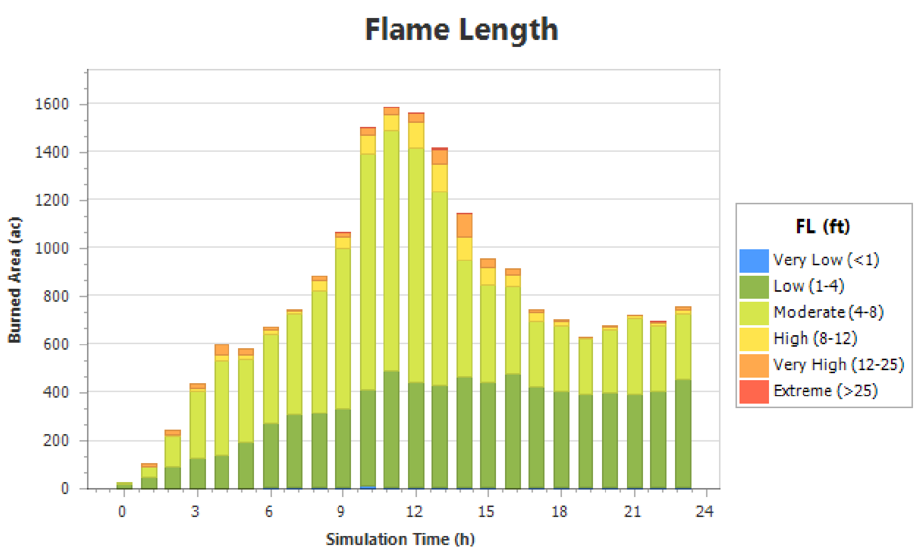
DAMAGE INCIDENT NO. 16

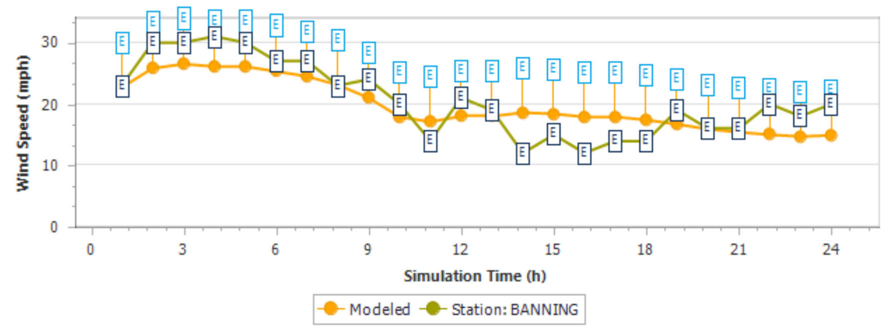
FIRE BEHAVIOR	WEATHER — **Nearest Station:** BANNING



Station ID - BNJC1
Weather station (Wx) elevation - 3607 ft
Fire ignition point (IP) elevation - 4009 ft
Distance between Wx and IP - 1.62 mi





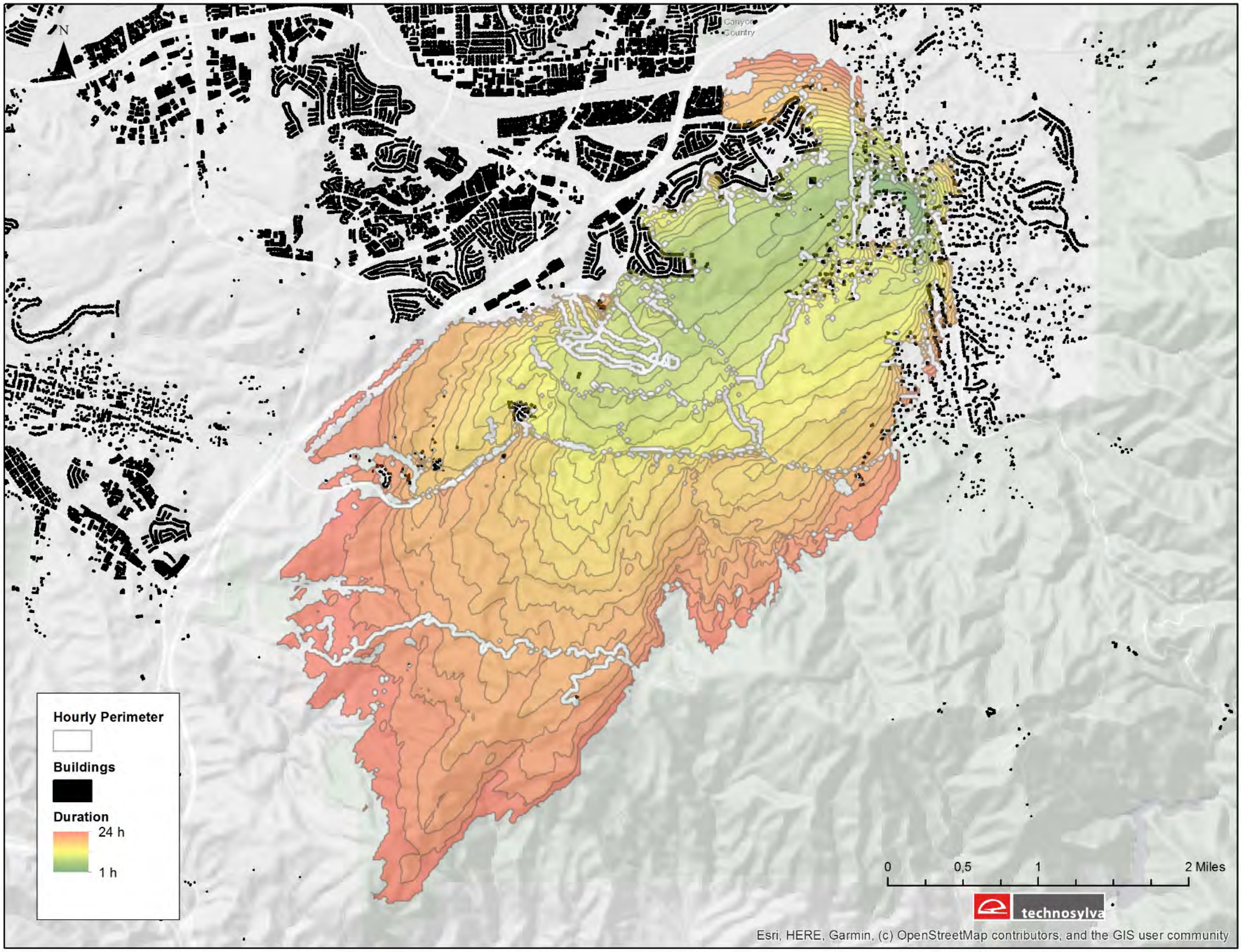


DAMAGE INCIDENT – 17

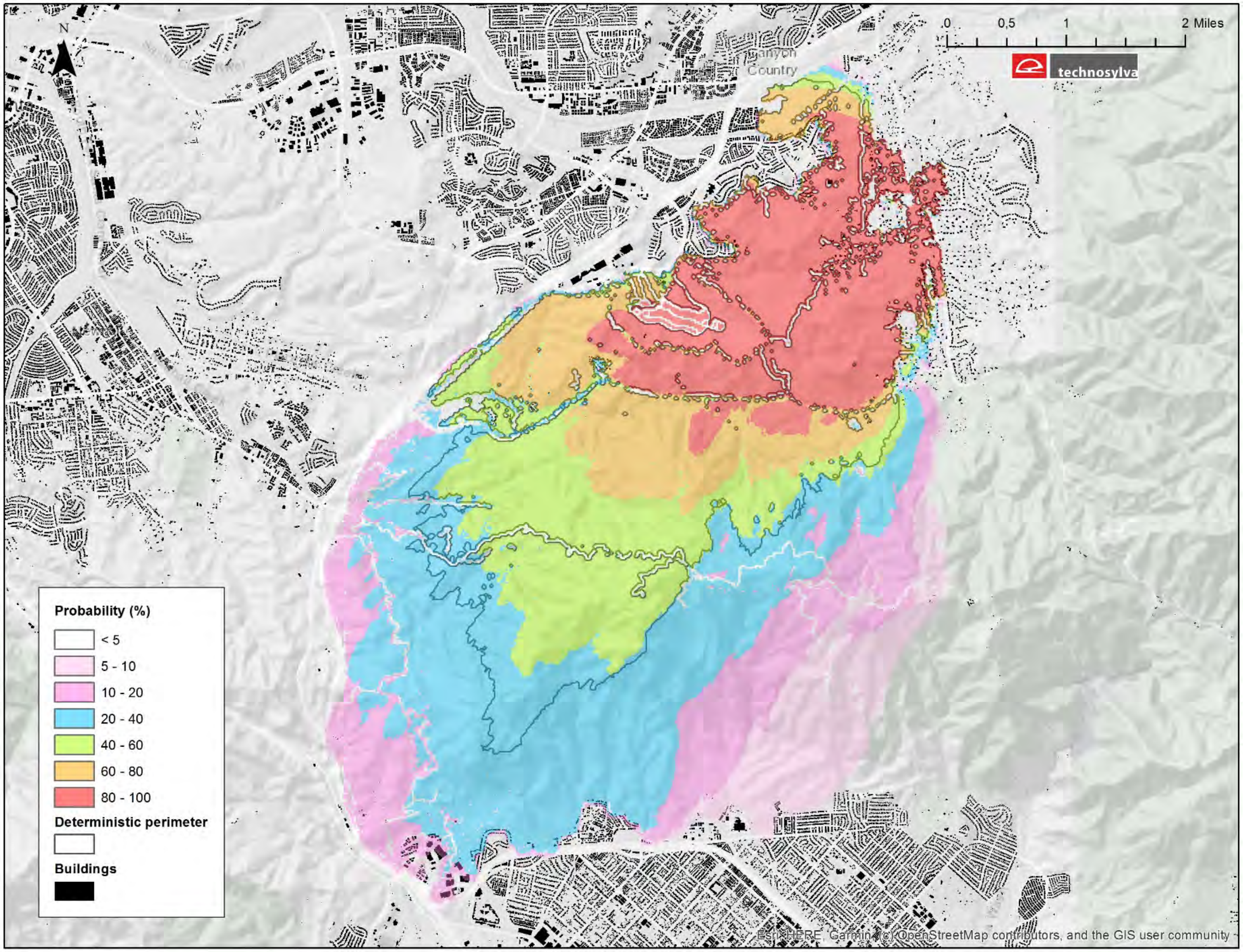
This incident is located in a wildland urban interface in Santa Clarita. The fire would start burning grass patches and impacting scattered buildings. The fire would be difficult to contain due to a high IAA (3), high winds ranging between 10 and 20 mi/hr, and the proximity of buildings that would limit the fire suppression activities. The fire could further spread on forest areas very quickly driven by winds, threatening a large amount of people and buildings. Modeled wind speed was slighly higher than measured at weather station.

INCIDENT SUMMARY	
Start Time	10/24/2019 10:35
Duration (hrs)	24
Size (ac)	7,299
Initial Attack Assessment	3 – High
No. of Buildings	608
Total Population	1,458
Average ROS	Very High

DAMAGE INCIDENT NO. 17 : DETERMINISTIC SIMULATION



DAMAGE INCIDENT NO. 17 : PROBABILISTIC SIMULATION

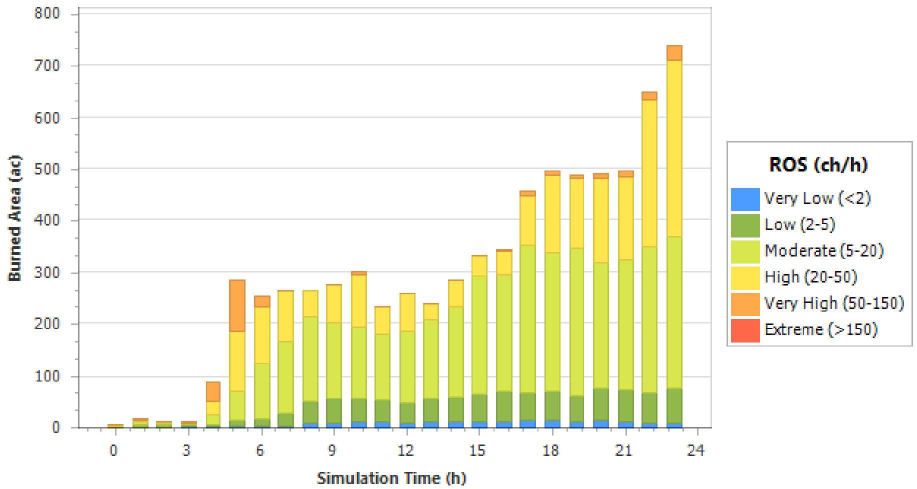


DAMAGE INCIDENT NO. 17

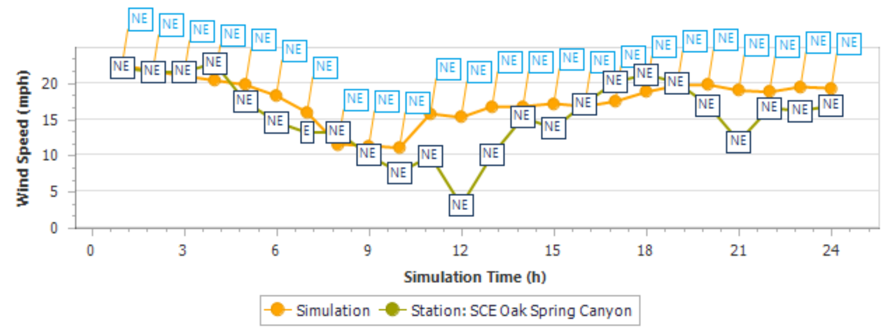
Nearest Station: SCE Oak Spring Canyon

FIRE BEHAVIOR	WEATHER

Rate of Spread



Station ID - SE042
Weather station (Wx) elevation - 1575 ft
Fire ignition point (IP) elevation - 1663 ft
Distance between Wx and IP - 1.51 mi



Flame Length