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Burnover events identified during the 2018 Camp Fire

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Abstract

The most destructive and deadly wildland-urban interface (WUI) fire in California history burned through communities in Butte County, California on November 8, 2018. Characterized by strong winds, dry fuel conditions, and steep terrain, the fire spread more than 12 km in the first 2 hours after ignition, triggering mass evacuations. The fire destroyed over 18 000 structures and caused 85 fatalities, mostly within the first 12 hours of the incident. Extensive data collection was conducted after the fire, gathering detailed first-hand account information from technical discussions with 157 first responders, photos and videos, emergency call recordings, and first responder radio logs, among other data to support an in-depth case study of the incident. Subsequent analysis and data integration yielded a complete timeline reconstruction of the first 24 hours of the event, as well as additional observations of the fire behavior. This report presents novel findings related to 23 identified life-threatening entrapment/burnover events, in which fire trapped or overtook people and compromised escape routes. These events affected the safety of hundreds of civilians and dozens of first responders, and occurred throughout the fire area. Many entrapments/burnovers impacted civilians evacuating in heavy traffic on major artery roadways or otherwise blocked evacuation routes and first responder access. Some resulted in injuries and fatalities. As the frequency of fast-moving fires requiring last-minute large-scale evacuations increases, the risk of similar events is high, particularly in intermix communities where the presence of primarily wildland vegetation along evacuation routes and some secondary roadways, likely amplified by local topography and wind, can result in significant entrapments/burnovers.

1. Introduction

1.1. The 2018 Camp Fire

The Camp Fire, which occurred in Butte County in northern California in 2018, was the most destructive and deadly fire in California history (CAL FIRE 2022). The fire first ignited shortly before dawn on November 8, 2018 near Camp Creek Road (for which the fire is named), in the community of Pulga, located in the Feather River Canyon (CAL FIRE 2019a). Dry fuel conditions, a strong wind event, and steep wind-aligned topography presented conditions conducive to rapid fire spread. By 07:30, just over one hour after ignition, high winds up to 22 m/s had driven the fire from the origin, over a ridge, and into the community of Concow 6.4 km to the southwest. By 08:00, numerous spot fires were igniting throughout the eastern portion of the town of Paradise an additional 6 km southwest of Concow. Structures in Paradise were burning by 08:30 as thousands of civilians began evacuating. The rapid fire spread led to 85 fatalities (Butte County Sheriff 2019; CAL FIRE 2019b; Butte County District Attorney 2020), and within 12 hours a majority of the structures in Paradise had burned. Ultimately, over 18 000 structures were destroyed and over 700 structures were damaged by the fire (Wallingford 2018; CAL FIRE 2022). Figure 1 depicts the location of Butte County within the state of California with the final fire perimeter shown in red.

After a preliminary reconnaissance (Maranghides *et al.* 2020a; Maranghides *et al.* 2020b), it was determined that an in-depth case study of the incident was feasible due to the data available and would provide scientific merit. Subsequent data collection and data integration were conducted to reconstruct a detailed timeline of the fire to provide a foundation for additional data analysis (Maranghides *et al.* 2021). The results presented here constitute findings related to the numerous life-threatening burnover events that were identified during the case study (Maranghides *et al.* 2021; Maranghides *et al.* 2022). The interested reader is encouraged to study (Maranghides *et al.* 2021) for the most detailed fire progression data available. While over 2200 data points

were included, the spatial resolution and detail required to provide accurate temporal contours is incredibly high and is not possible at this scale without consistent widespread aerial measurement. An animation of the analyzed fire observation data showing the fire progression is available from (National Institute of Standards and Technology 2021) which provides a non-interpolated view of fire progression.

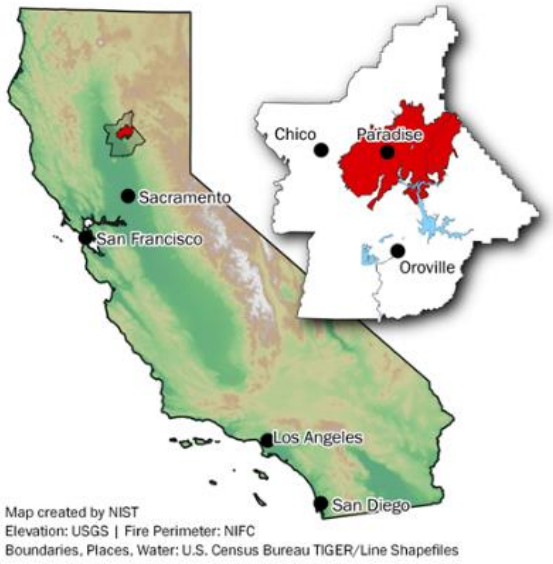

Figure 1 – Location of Butte County in California and the Camp Fire (red).

1.2. Entrapments and Burnovers

Entrapments in wildland fires are defined by the National Wildfire Coordinating Group (NWCG) as "a situation where personnel are unexpectedly caught in a fire behavior-related, life-threatening position where planned escape routes or safety zones are absent, inadequate, or compromised. An entrapment may or may not include deployment of a fire shelter for its intended purpose. These situations may or may not result in injury. They include 'near misses.'" (Page and Freeborn 2019; National Wildfire Coordinating Group n.d.-a). A burnover is further defined as an entrapment in which "fire moves through a location or overtakes personnel or equipment…often resulting in personal injury or equipment" (Page and Freeborn 2019; National Wildfire Coordinating Group n.d.-b). A recent report by Page et al. (Page *et al.* 2019), considering a comprehensive database of firefighter entrapments in the US, indicates entrapment rates have been steady at about 9 incidents per year.

In the US, most entrapment documentation is related to firefighters during operations, rather than civilians. Internationally, there are few studies about burnover events involving civilians unless they are focused on fatalities (Blanchi *et al.* 2014; Diakakis *et al.* 2016; Haynes *et al.* 2019; Molina-Terrén *et al.* 2019). In general, the number of entrapments or burnover events involving civilians is likely undercounted because they are not widely publicized, reported, or studied. As more fires burn rapidly into WUI areas with little time to evacuate, the potential for burnovers is increasing. Recent events with civilian fatalities while attempting evacuation have been documented in Portugal (Viegas *et al.* 2017; Viegas *et al.* 2019) and Greece (Horowitz 2018; Xanthopoulos and Athanasiou 2019).

During the Camp Fire, numerous events occurred where fire temporarily restricted through-access on a major traffic artery or a secondary road, or trapped civilians or first responders amid dangerous conditions. The events varied in intensity and duration. Some impacted civilian evacuation while others impacted first responders only. Some burnovers resulted in civilian fatalities, civilian and first responder injuries, and destruction and damage of civilian and first responder vehicles. In many cases, burnovers did not result in fatalities, injuries, or damage. These were instances in which fire blocked the road and civilians caught in traffic and/or first responders attempting to access the scene either waited for conditions to improve or opted to take another route, if available. These events could be interpreted as entrapments or "near misses" with respect to the NWCG definitions but are included in this report as they have significant impact on civilian and first responder life safety. All identified

events were grouped and labeled as burnovers in this report for simplicity, acknowledging the uncertainty in the data regarding exact extent and accounting for all potential people in the event.

Specifically understanding the fire development and progression associated with individual burnover events will require in-depth spatial and temporal (pre-, during, and post-fire) data collection of local fuels, weather, and topography. This detailed data was beyond the scope of the current work, which identified the prevalence of these types of events during the Camp Fire.

2. Identified Burnovers

The fire progression timeline report (Maranghides *et al.* 2021) includes 23 technical findings related to fire progression and fire behavior. Four of the findings relate to the burnover events that were identified during the case study data analysis. The findings were:

F15. Multiple burnovers occurred during the Camp Fire.

F16. Burnovers adversely affected pre-planned evacuation routes and led to use of Temporary Refuge Areas (TRAs).

F17. Intense vegetation and structure fires occurred along roadways and resulted in multiple road closures which adversely impacted response and evacuation activities.

F18. Fire resulted in downed utility poles along roadways and throughout the communities. The downed poles, along with the associated electrical and utility lines, blocked multiple streets and impaired access for response and evacuation.

Nearly two dozen entrapment/burnover events were identified in the analysis and compilation of data collected from 157 individual first responder accounts as well as numerous photos and videos. Additional detail about the data collection and data integration processes can be found in (Maranghides *et al.* 2021). The detailed narrative of each event is beyond the scope of this paper, but is documented in (Maranghides *et al.* 2021; Maranghides *et al.* 2022), and conveys the range of different scenarios under which burnovers occurred. The presented list does not include an analysis of the local conditions associated with the 85 documented fatalities. Additional burnovers may have occurred that were not captured during the data collection process; however, there is high confidence that nearly all of the large burnover events are accounted for based on the total combined dataset of fire observations (Maranghides *et al.* 2021), traffic conditions, burned vehicles, and TRAs (Maranghides *et al.* 2022).

The 23 documented burnover events occurred throughout the fire area within the first 26 hours of the incident, beginning almost immediately as fire impacted the community of Concow. The location of each event is marked in Fig. 2 with their corresponding ID number, with additional details listed in Table 1. These events affected civilian and/or first responder evacuation and movement, with 12 occurring on major egress arteries (identified by bold type in Table 1).

Many of the entrapments/burnovers significantly impacted evacuation (n=17) and required the formation/utilization of TRAs (n=9) to maintain life safety for residents and firefighters. In at least two cases, fire shelters were deployed by firefighters to reduce radiative exposures to civilians and first responders. Several entrapments/burnovers resulted in civilian or first responder injuries and civilian fatalities.

The burnovers were divided into two categories with respect to risk of injury or death. Fourteen burnovers were identified as “Category 1,” representing the highest potential of death/injury (highlighted red in Table 1), and nine as less-hazardous “Category 2” events. Of the 11 burnovers that occurred before 10:00 on November 8, nine were listed as Category 1, and two as Category 2. All but one of the Category 1 burnovers on the morning of November 8 significantly impacted civilian evacuations. Seven of the 14 Category 1 burnovers resulted in the formation of Temporary Refuge Areas (TRAs). Significant civilian evacuation traffic played a major role in the population exposed to these burnover events.

Local conditions dictated the spatial and temporal extent of each burnover. Burnover durations averaged nearly two hours and were influenced by the type and quantity of vegetative and other fuels in the area, as well as the spatial extent of the event. Overall, vegetation setbacks from the roadway (estimated using photos, video, and imagery) ranged from 0 m to 10 m; however, in most instances the setbacks were 3 m or less. Many events

affected significant lengths of roadway, on average estimated over 800 m per burnover, and ranged from 150 m up to 3 km. Road widths ranged from 3 m on narrow tertiary local roads to 23 m wide multi-lane primary arteries.

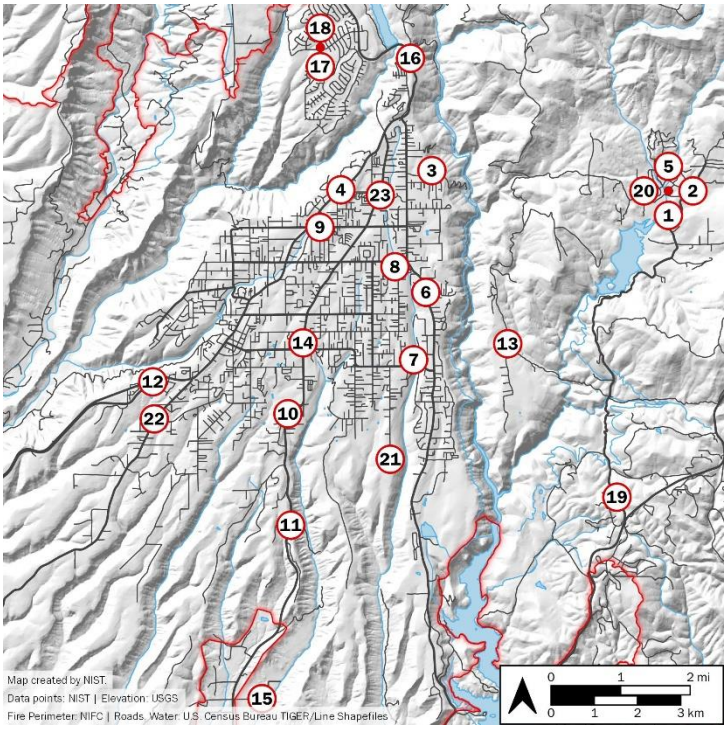

Figure 2 – Locations of the 23 NIST-identified burnover events.

Table 1 – List of burnover details.

ID[a]	Location[b]	Burnover Initiation	Burnover Duration (min)	Road Width (m)	Vegetation Setback (m)	Roadway Length Affected[c] (m)	Impacted Civilian Evacuation (Y if yes)	Fire Shelter(s) Deployed (Y if yes)	TRA Formed (Y if yes)
1	Hoffman Rd	07:50	40	3	0–2, more at creek	250	Y	Y	Y
2	**Concow Rd**	07:50	70	7	0–1	1000	Y		
20	Camelot Ln	07:55[d]	50	6	0	n/a	Y		Y
3	Chapman Ln	08:30	n/d[e]	3	0–3	250			
4	**Skyway** (upper)	08:30	360	8	0–10	2600	Y (street was gridlocked)		Y
5	Windermere Ln	08:35[d]	n/d	4	0–2	1100	Y (fatality)		
6	**Pentz Rd**	08:45	150	8	0–1	1300	Y (street was gridlocked)		Y
7	**Pearson Rd**	09:15	60	11	1–3	800	Y (street was gridlocked)	Y	Y
8	**Bille Rd**	09:25	140	8	0–2	500	Y (street was blocked)		Y
21	Edgewood Ln	09:30	n/d	3	0–3	250	Y (fatalities)		
9	**Wagstaff Rd**	09:30	60	8	0–3	500	Y		
10	**Clark Rd** / American Way	10:00	120	11	1–3	700	Y		
11	**Clark Rd** / Airport Rd	10:00	90	9	1	1500	Y		
12	**Skyway** (lower)	10:15	90	7–20	1–3	1000	Y		
13	Jordan Hill Rd / Granite Hill Rd	11:30	n/d	5	0–4	800	Y		
22	**Neal Rd**	11:30	90	6	1–3	800	Y (street was gridlocked)		
23	**Clark Rd**/Cypress Ln	11:45	n/d	8	0–6	1300	Y		
14	**Clark Rd** / Black Bear Diner	13:10[d]	n/d	23	3 (structure)	150			
15	Rattlesnake Flats Rd	15:15	15	3	0	300			
16	Coutolenc Rd	00:00 (Nov 9)	120	7	0–2	3000			Y
17	Chestnut Cir	06:00 (Nov 9)	n/a	9	0–1	150			
18	Ponderosa Way	07:15 (Nov 9)	n/d	12	0–3	400	Y		Y
19	Concow Fire Station 37	07:15 (Nov 9)	n/d	9	0–3	600			Y

[a] Events are listed chronologically. ID #20–23 are out of sequence because they were added in a second round of analysis.
[b] Roadways in **bold** denote major artery roads significant for evacuation.
[c] The roadway segment affected by each burnover was estimated from the technical discussions.
[d] First time of observation. Burnover conditions existed prior to the first recorded observation.
[e] No data.

3. Discussion / Implications of Findings

One may first notice the large number of identified events. The mission focus of the fire service, the relatively specific definition of burnovers versus entrapments, as well as the potential negative stigma of burnovers (Strohmeyer *et al.* 2018), may all combine to a general under-reporting of such events (Jolly *et al.* 2019). Additionally, the majority of reported entrapments are likely reported in wildland fire settings opposed to WUI fire settings in more developed infrastructure with additional urban fire service mutual aid. The fact that 23 individual instances were identified within one incident suggests that this may be a more frequent issue, specifically in the context of WUI fires. Fourteen incidents were labeled “Category 1,” indicative of higher severity and significant threat to life.

It is important to note that these events also had a significant impact on civilians. Overall, these events have a different narrative compared to many firefighter-only burnovers experienced during suppression efforts. Of the 23 events, only 2 include officially documented firefighter injuries sustained during fire suppression efforts.

Those events, #15 and #18, injured 5 firefighters and were reported in an after action "Green Sheet" report (CAL FIRE 2018). The rest of the identified events were dominated by civilian presence, often with the assistance or guidance of first responders to locate a safer TRA. In very few cases was active suppression used or available to protect civilians from fire exposures.

Half of the events occurred in Paradise during overlapping time windows (IDs 4, 6, 7, 8, 21, 9, 10, 11, 12, 22, 23) early in the incident, stressing emergency resources. Simultaneous events, particularly across large spatial areas, significantly stretch the resources available to respond to each event to protect evacuating civilians. Early evacuation is key; however, this may not always be feasible. In rapidly developing events, a well-planned and efficient evacuation plan will need to be tailored to local conditions. The need to protect civilian evacuations may significantly change the operations of the fire service, resulting in additional fire spread and structure/infrastructure loss.

While 14 of the 23 incidents occurred before 11:00 on Day 1 (when more civilians were involved), several did occur the following day on November 9, impacting first responder operations. The potential for such events must be considered throughout the entire incident, not only for first responders but also for situations where fire continues to progress and impact additional populated areas. There are also significant long-lasting effects of burnovers in WUI areas, particularly as abandoned/burned vehicles and burned and downed power poles and lines can block passage for hours, impacting evacuation and first responder operations.

4. Conclusions

This portion of a greater case study into the 2018 Camp Fire in Butte County, California presents a unique dataset of burnover events that impacted mass evacuations during a WUI fire. Twenty-three burnover events threatening the safety and trapping or restricting movement of first responders and hundreds of evacuating civilians, were identified through in-depth analysis of data collected from technical discussions with first responders. Seventeen burnovers directly impacted the evacuation of civilians, 12 of which occurred on major evacuation roadways. Most burnover events lasted between 1 and 2 hours in duration and impacted an average roadway length of 800 m. Two events injured firefighters and were documented by the incident in official "Green Sheet" reports.

This is an important area of study as the frequency of fast-moving fires requiring last-minute large-scale evacuations increases. In intermix communities, the presence of primarily wildland vegetation along evacuation routes and some secondary roadways, likely amplified by local topography and wind, can result in significant entrapments/burnovers. There is limited technical information to provide reliable guidance on the relationship among vegetative fuel type, density, and setback from the roadway, along with topography and exposures, that can be used to develop reliable guidance for the protection of egress arteries against burnovers. Additional research is needed to characterize fire behavior that leads to burnovers and to quantify burnover severity. Such a study would need to capture the necessary fuels, weather, and fire behavior information. This work must be undertaken immediately following the event, as much of the data will originate from first-hand observations and perishable field data, such as post-fire fuel consumption measurements. This information would inform fuel setback guidance for primary egress arteries and provide technical input to evacuation plans.

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