

Camp Fire – Fire Progression Timeline

CA OSFM, CHAPTER 7A

Alexander Maranghides
Eric Link

Erin Ashley (FEMA)

Will Brewer (CALFIRE)

Chris Brown

Nelson Bryner

Ryan Falkenstein-Smith

Lucy Fox

David Hawks (CALFIRE)

Steven Hawks (CALFIRE)

Nicole LaRosa (USFA)

William "Ruddy" Mell (USFS)

Cartier Murrill

Becky Turnbull

Bob Vihnanek (USFS)

Doug Walton

Mike Wilson (CALFIRE)



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192 Contributors — THANK YOU!

Office of the State Fire Marshal

Law Enforcement

Emergency Medical Services

Damage Inspectors (DINS)

Town of Paradise

National Weather Service

Data Collectors

Transportation

Reviewers

Fire Departments

Water Districts

Public Affairs Office



Presentation Themes

- ***Well prepared Intermix community***
- ***Rapid Fire Spread to and within Paradise***
 - impact on life safety, response and losses
- ***Burnovers***
 - large number (documented *versus* reported)
 - occurred in town and on major egress arteries
 - significant impact on life safety
- ***Not a unique event***
 - how many other communities are in a similar situation?



NIST Interface Case Studies and WUI Scale

Introduction and Previous Case Studies

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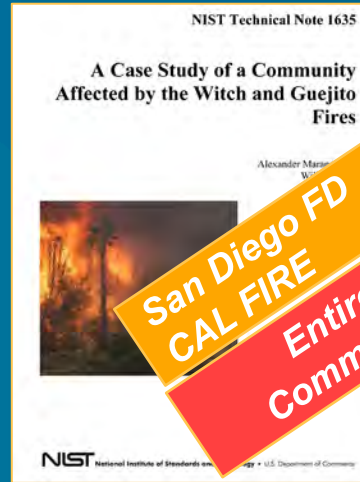
General Fire Behavior

Primary Driving Factors

Technical Findings

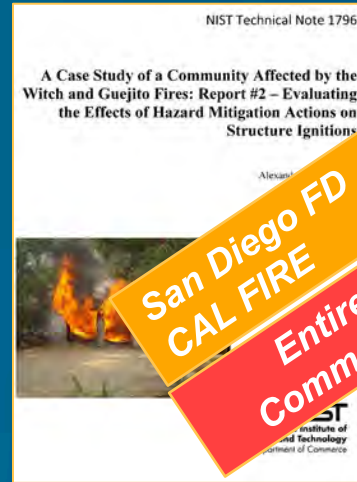
Recommendations

NIST TN 1635 (Witch #1)



San Diego FD
CAL FIRE
Entire Community

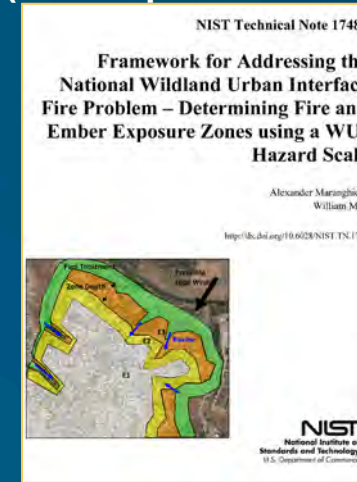
NIST TN 1796 (Witch #2)



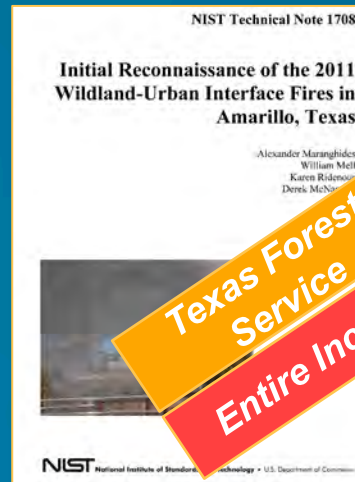
San Diego FD
CAL FIRE
Entire Community



NIST TN 1748 (WUI Exposure Scale)

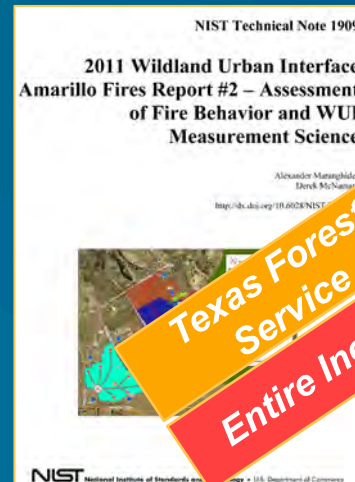


NIST TN 1708 (Amarillo #1)



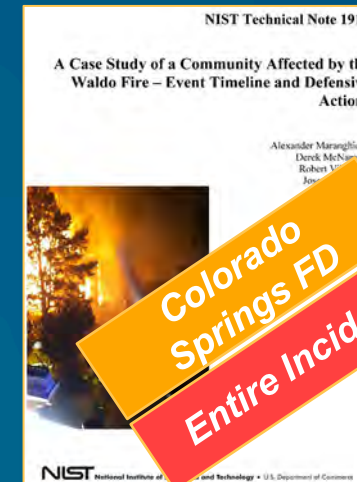
Texas Forest Service
Entire Incident

NIST TN 1909 (Amarillo #2)



Texas Forest Service
Entire Incident

NIST TN 1910 (Waldo)



Colorado Springs FD
Entire Incident



Community Differences

Interface/Intermix, housing density

2018 (pre)



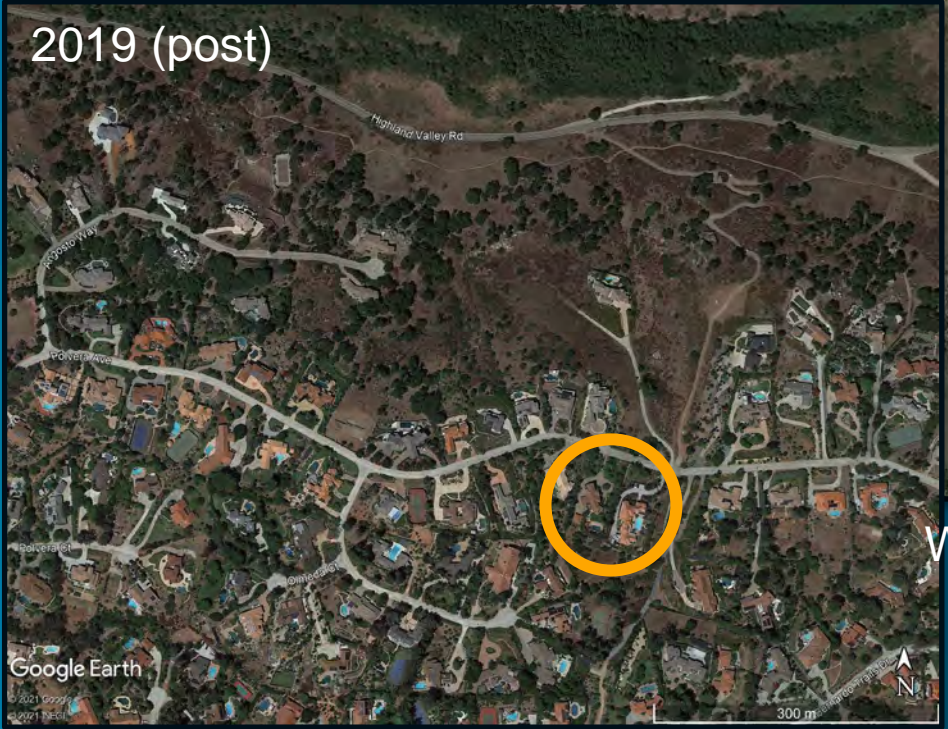
Camp Fire, Intermix

2018 (post)



Waldo Canyon Fire, Interface

2019 (post)



Witch Fire, Interface

equal scale images

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Community Differences

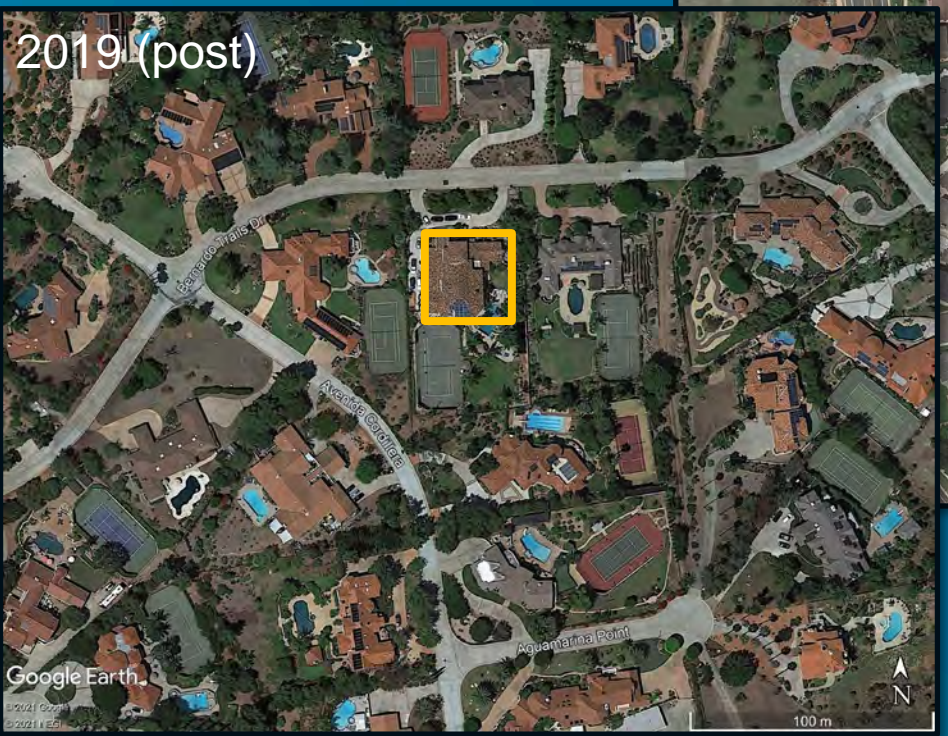
Interface/Intermix, housing density



Camp Fire, Intermix



Waldo Canyon Fire, Interface



Witch Fire, Interface

equal scale images



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Intro and Previous Case Studies

Summary of Findings:

- WUI fires vary significantly geospatially and temporally
- Exposures (fire and embers) can vary on a parcel level (less than ¼ acre) scale
- Defensive actions have significant impact on structure survival
- Defensive actions are more effective in low exposures
- Damaged = defended
- Cannot understand the post fire scene unless we understand exposure *and* defensive actions
- Parcel level combustibles (including auxiliary structures) bring fire to the structure

Key Takeaways:

- Know your community; where the fuels are and what can be safely defended
- If a structure is damaged it was most likely defended
- Reduce “fuel wicks” (fences, hedge rows, other linear features)
- Auxiliary structures can pose significant hazard as they can be readily ignitable and frequently are not regulated



Why The Camp Fire?

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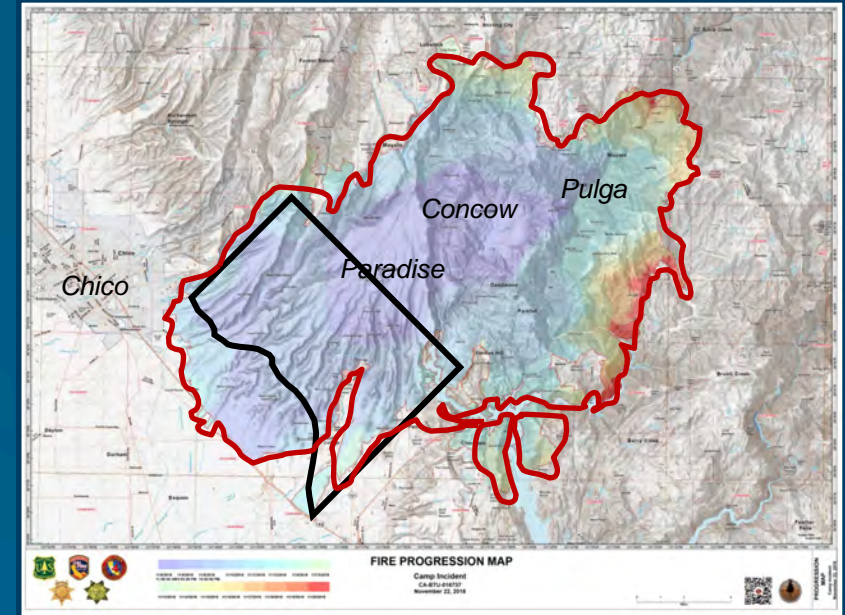
Primary Driving
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- Intermix Fire with:
 - extreme fire behavior
 - size and losses and
 - evacuation of entire town
- Data-rich scene
- NIST technical partnerships in place
- Fully integrated with local officials (CALFIRE)
- Representative of many other similar communities

Camp Fire ~ 14 % Butte County area



Camp Fire ~ 4× Washington, D.C. area



Camp Fire Overview Statistics

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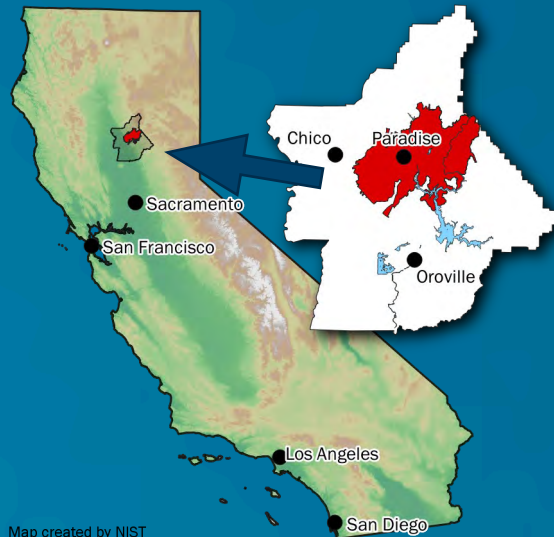
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Primary Driving Factors

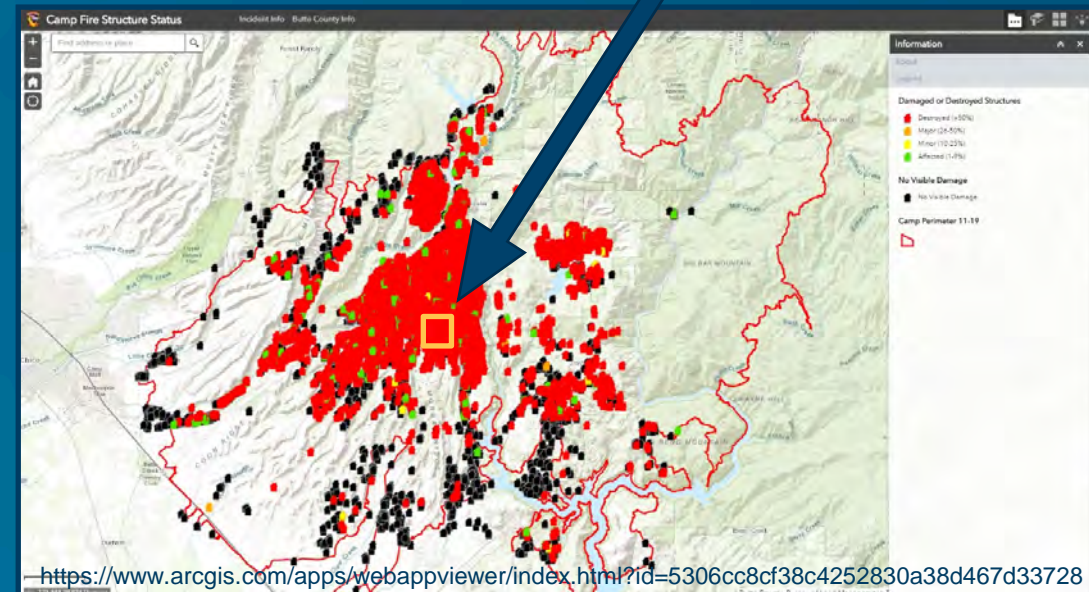
Technical Findings

Recommendations

- *Size: 153 336 acres*
- *Start: Nov 8, 2018, ~6:30 am*
- *Dates: Nov 8–25, 2018 (18 days)*
- *Structures Damaged/Destroyed: 19 531*
- *Population Displaced: over 50 000*
- *Fatalities: 85*
- *Persons Located: 3266*



Map created by NIST
Elevation: USGS | Fire Perimeter: NIFC
Boundaries, Places, Water: U.S. Census Bureau TIGER/Line Shapefiles



Paradise Points of Interest

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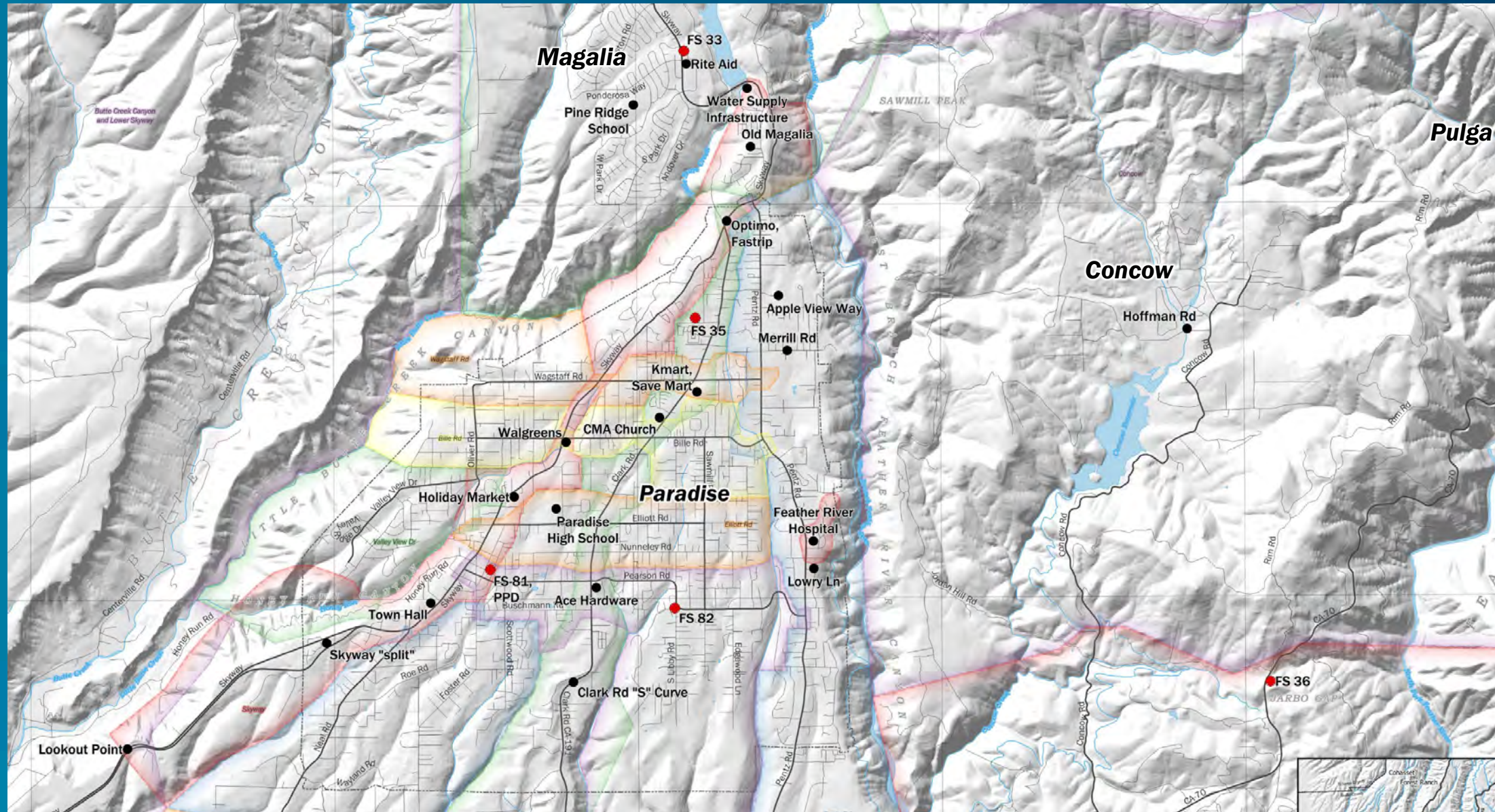
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Camp Fire Structure Losses

Category of Damage ^a	Affected (1-9%)	Minor (10-25%)	Major (26-50%)	Destroyed (>50%)	Total
Single Residence	439	47	3	13 696	14 185
Multiple Residence	21	3	1	276	301
Mixed Commercial/Residential	1	1	0	11	13
Non-residential Commercial	76	18	8	528	630
“Other” Minor Structures ^b	87	32	13	4286	4418
Infrastructure ^c	2	0	2	7	11
Total	626	101	27	18 804	19 558

^a Damage categories are adopted from Federal Emergency Management Agency preliminary damage assessment guidelines.

^b “Other” includes uninhabitable structures such as detached garages and sheds > 11 m² (120 ft²).

^c Infrastructure includes communications towers, water supply equipment, and bridges.

90% of all structures damaged or destroyed

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The NIST Camp Fire Case Study

- ✓ **Report #1:** Camp Fire Preliminary Reconnaissance
- ✓ **Report #2:** Preliminary Data Collected from the Camp Fire Reconnaissance

 ***Report #3: Fire Progression Timeline***

- **Report #4:** Notification, Evacuation, Temporary Refuge Areas, and Burnovers
- **Report #5:** Emergency Response and Defensive Actions
- Data Visualization Tool



Camp Fire Technical Research

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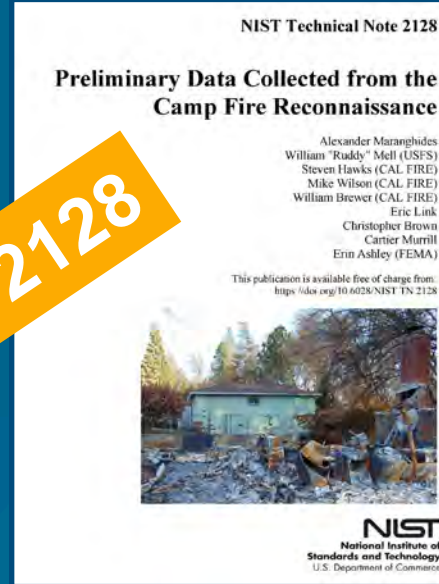
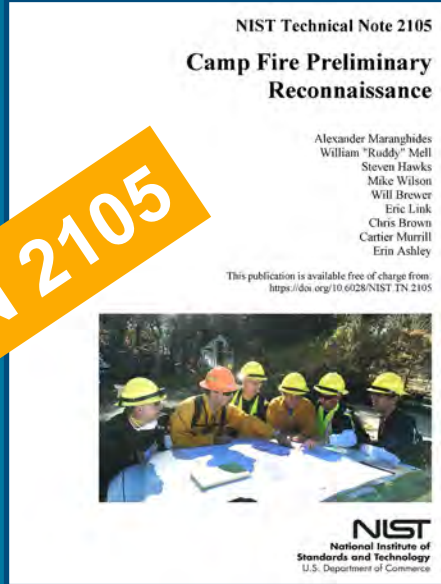
Burnovers

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<https://www.nist.gov/el/fire-research-division-73300/wildland-urban-interface-fire-73305/nist-investigation-california>



Five Research Questions

- 1. How can a fire event of the scale of the Camp Fire be documented to facilitate the extraction of information for reducing future losses?*
- 2. How did the fire spread to and within Paradise?*
- 3. What were the primary causes of the extensive devastation?*
- 4. What fire spread pathways caused structural ignitions?*
- 5. How unique is Paradise as a community at risk of WUI fires?*



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**Pre-Fire
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Pre-Fire Conditions

wind + drought + topography + fire history



Butte County Fire Hazard Severity

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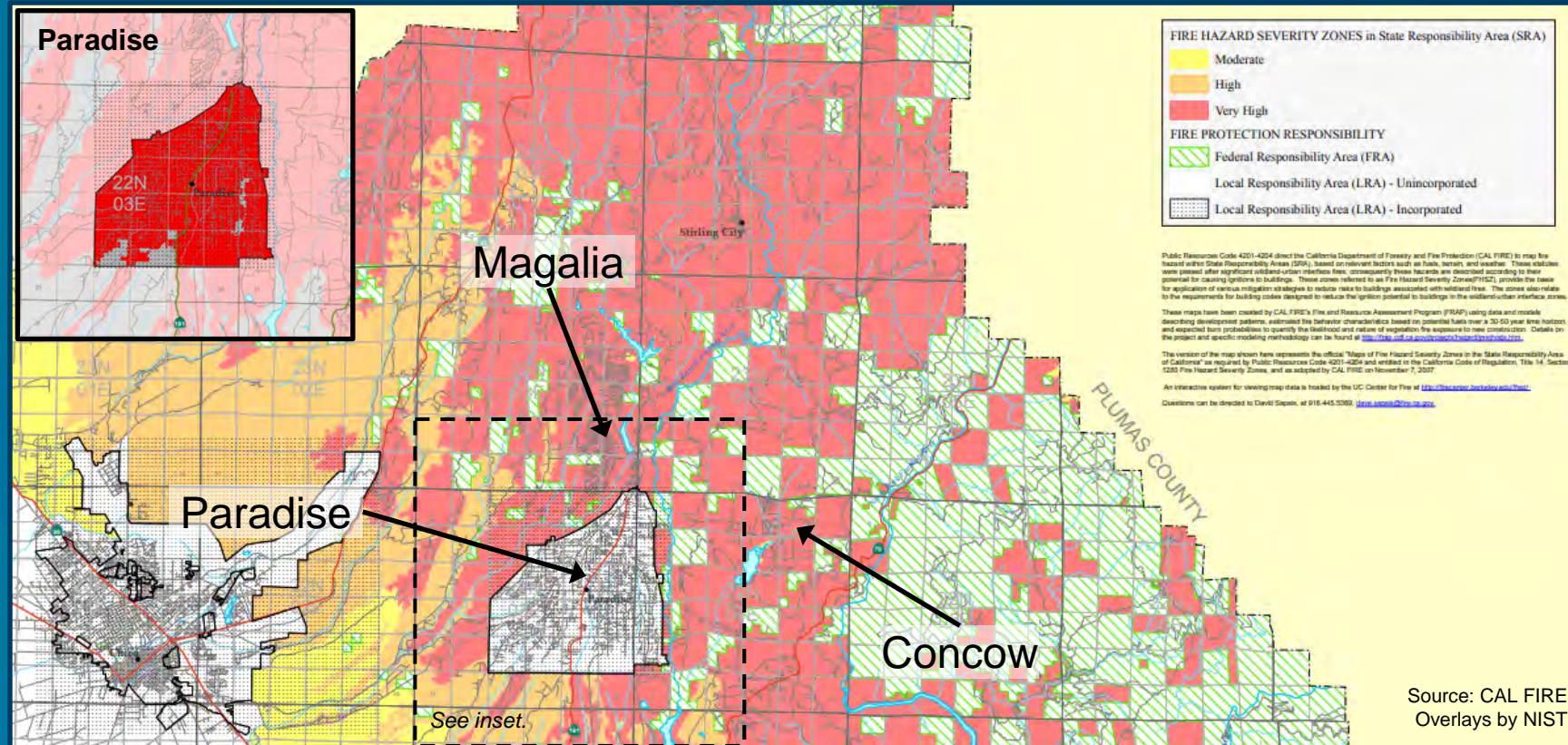
Burnovers

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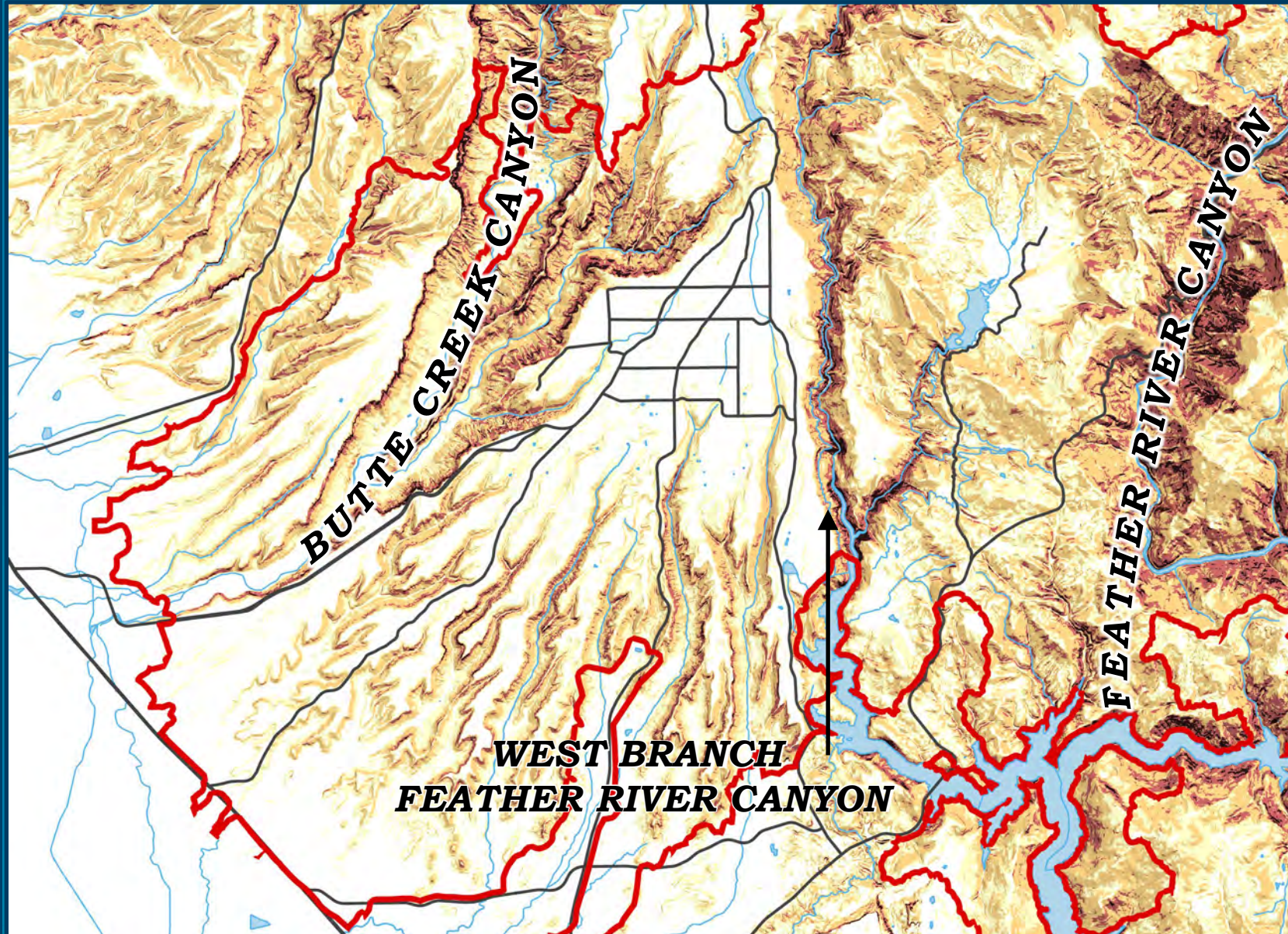
Recommendations



Majority of area Very High Fire Hazard Severity Zone



Topography



- Significant steep canyons
- Localized wind alignment
- Difficult access
- Restricted egress



Red Flag Warning and Drought

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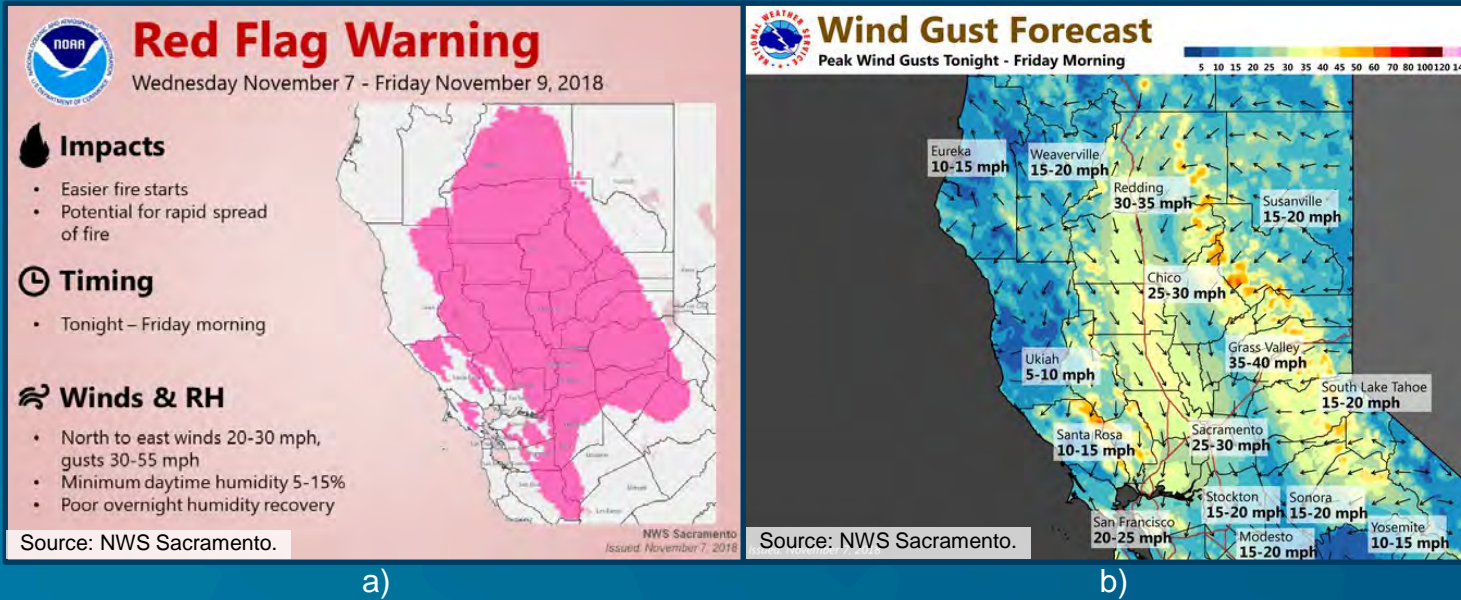
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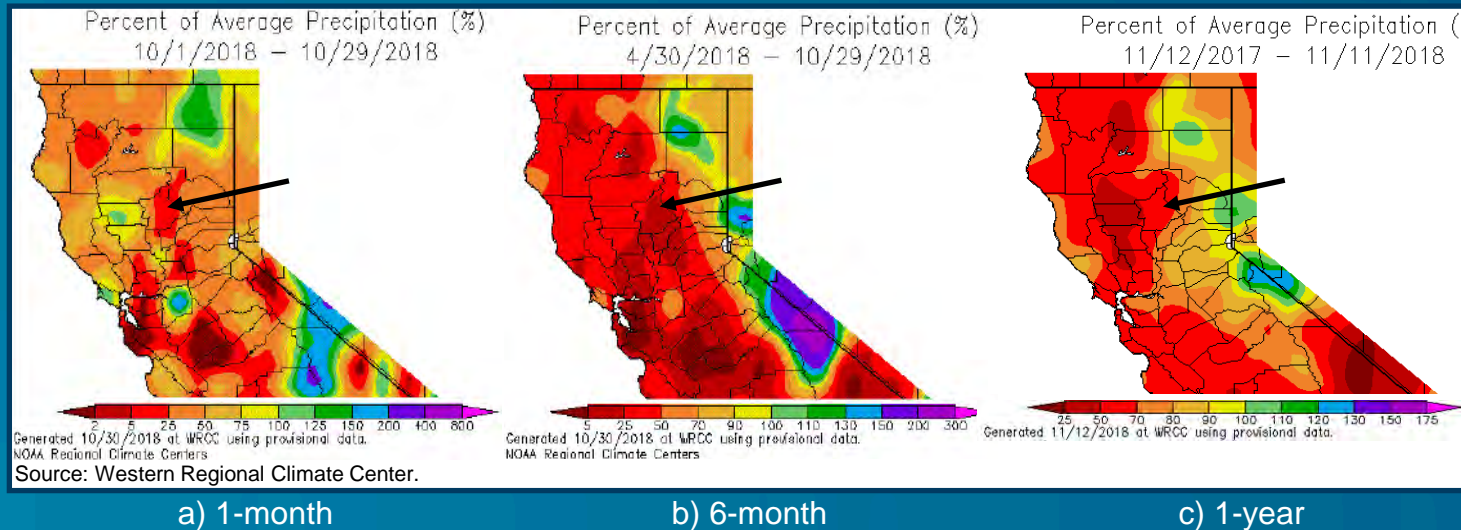
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- Widespread Red Flag Warnings for November 8
- Wind gust forecast showing peak winds exceeding 50 mi/h



- Dry conditions following 200 days without precipitation



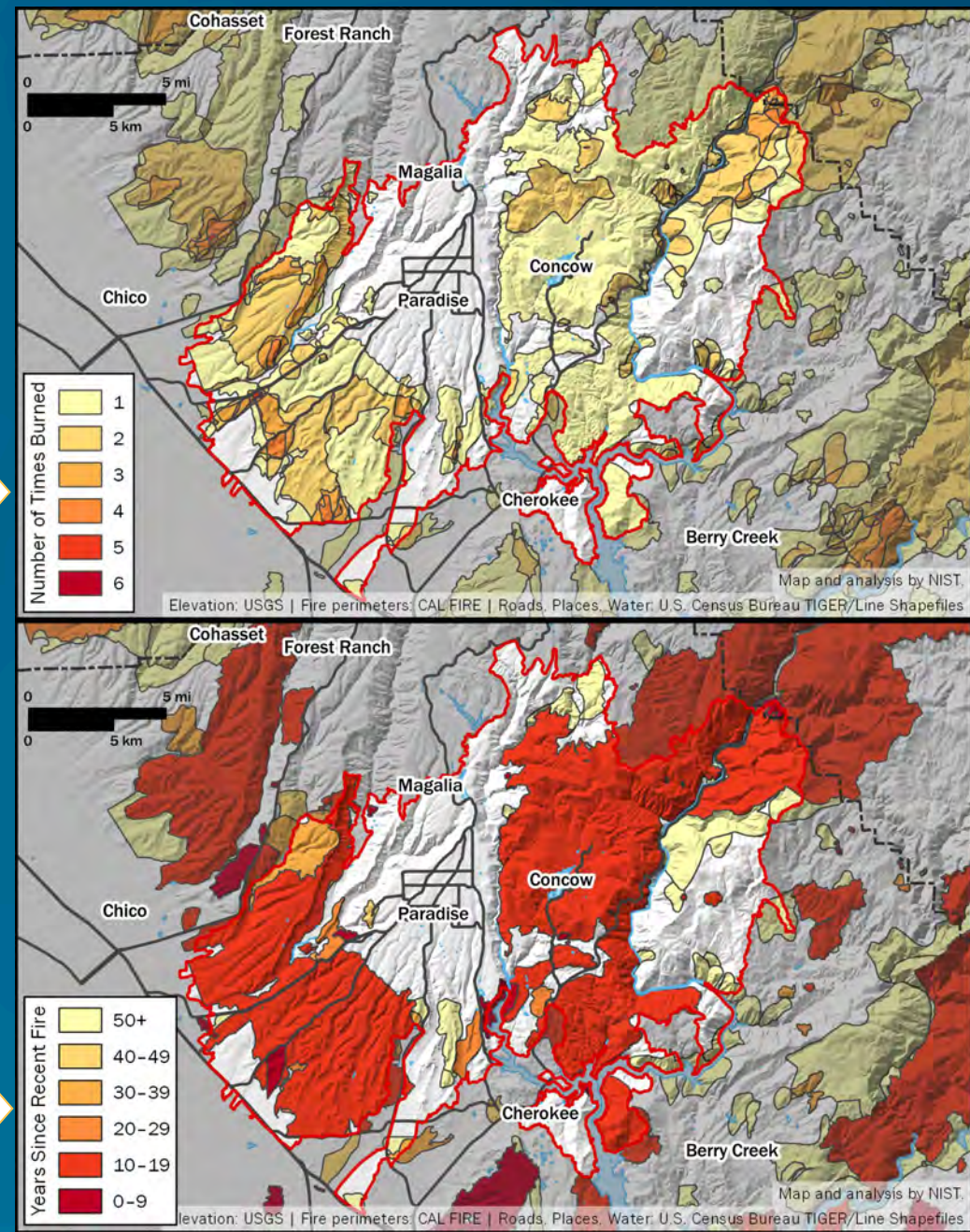
Fire History

Historic fire perimeters in northern Butte County (1911–2018)

Number of times each area has burned. →

- 42% had never burned including all area in/around Paradise.
- 17 of 20 prior years had 1 or more fires

Number of years since the last fire. →



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Range of Housing Density in Paradise

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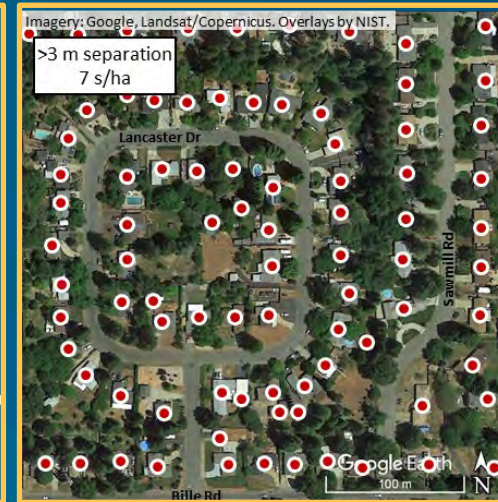
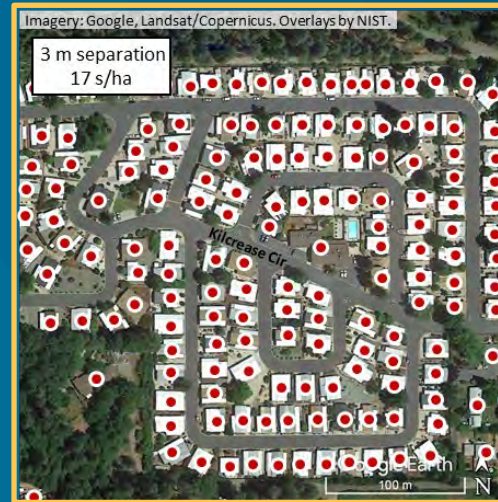
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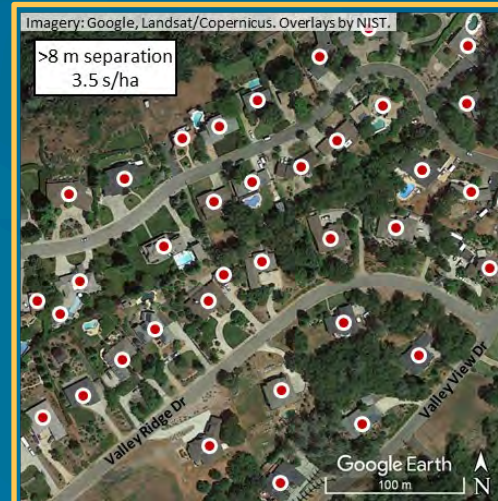
Recommendations

- a) Apple Tree Village Mobile Home Park
- ≤ 3 m (10 ft) separation
 - 7 structures / acre



- b) Lancaster Dr (Bille Rd)
- 3 m (10 ft) separation
 - 2.9 structures / acre

- c) Valley Ridge Dr
- 8 m (26 ft) separation
 - 1.4 structures / acre



- d) Round Valley Ranch Rd
- 25 m (82 ft) separation
 - 0.3 structures / acre



Preparedness

Community Preparedness

1. Communities did have multiple programs in place to increase awareness of and reduce fire hazards associated with WUI fires.
2. The Town of Paradise did have an emergency notification and evacuation plan.
3. Paradise Public Works staff had received training in how to respond to a WUI fire.
4. Infrastructure was specifically addressed in pre-fire preparations.



Preparedness

Infrastructure and Firefighting Preparedness

1. Communication battery backup updated day before fire
2. Water systems (PID and Del Oro) at full capacity
3. Fire fighting staffing at increased level (Locally and regionally) – more in report #5.



Pre-fire Conditions

Summary:

- Fire history, drought, weather event and topography all came together – the perfect storm
- Well prepared intermix community:
 - Evacuation plan in place, practiced
 - Hardened infrastructure
 - Public works trained in fire
- Fire fighting staffing at increased level in town and regionally

Implementation:

- Prepare, prepare, prepare
- Know your community (fire history, fuel loadings, local conditions and severe weather events)
- Consider fuel treatments around critical infrastructure
- Plan for COG
- Assess communications in context of power outages and evacuation of key in-town facilities
- Assess the potential for loss of water



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Fire Progression

IC overview | detailed narrative | analysis | maps



Incident Commander Account

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Detailed account of event from IC perspective, including:

- Resource requests
- Fire location
- Fire behavior
- Evacuation orders
- Life safety
- Response orders
- Multi-agency coordination

IC Technical Discussion

06:31 First dispatch by/under power lines, dispatch B2118, P2121, T2107, E2176, E2161, E2167, E2186, E2182, E2162, Company 67, WT37, WT67, TD2140, TD2142, BFC2, BFC3. These were all sent up to NOPS.

06:44 First engine confirms fire off Camp Creek Road, 35 mi/h sustained wind.

06:44 ECC places request for 15 additional engines, 4 dozers, 2 water tenders, and 4 strike teams of hand crews.

06:45 Received call at home. BC informed me of the incident. Cool morning 40 °F. Fire appears on Flea Mountain camera.

06:54 E2161 request a mandatory evacuation order for Pulga and stage resources at Scooters.

06:55 ECC called BCSO and requested Mandatory Evacuation order for Pulga.

07:02 Duty Chief calls. IC send him to Concow.

07:10 Duty Chief calls back, reports flames visible from Hwy 149.

07:14 B2118 assumes IC.

07:21 Camp IC – “Pulga has been evacuated. If you could make notifications, request representative to Scooters. Have the Sheriff respond to Camelot area for evacuations.”

07:22 Camp IC – “Request evacuation warning for the Concow area – working on exact area and warning/order.”

07:22 ECC called BCSO requesting mandatory evacuation warning for Concow Immediately.

07:26 Camp IC – “shut down Hwy 70 and standby for resource order. Close Hwy 70 from Pentz to Belden.”

07:30 Requests to early up all aircraft - Paradise burning not being considered at that time.

07:32 EVAC warning Pentz Rd west side.

07:33 Resource order for an additional 15 engine strike teams, 15 hand crew strike teams, 10 dozer strike teams, with appropriate overhead.

07:40 T2107 needs 5 engine strike teams on Hoffman Rd can’t get ahold of Camp IC – request relay info.

07:44 ECC takes call at 1900 Drayer Dr/Pentz Rd reporting fire on the Paradise side of canyon – reporting 3 spots.

07:45 At ICP develop incident objectives, box it in: North of Hwy 70, east of Pentz, then west of Pulga and south of Empire Creek. Before objectives are announced on the radio, there are spot fires reported outside the box.

07:44 IC change over to new IC – *for remainder of first day.*

07:45 Camp IC – “We are extending the mandatory evac zone to east of Pentz Rd 3, 8, 14 and everything east of Pentz Rd and everything north of Hwy 70.”

07:46 ECC calls BCSO requesting the above Evacuation Warning. Not thinking spot fires is a crazy issue, spot fires are normal.



Fire Progression –Three Levels of Detail

1. **Overview** in Executive Summary and report findings/conclusions (*3 pages*)
2. **Detailed** fire behavior — by focus regions (*71 pages*)
 - Fire progression described by region and by time
 - 14 large format maps by time (*3 ft x 4 ft*)
3. **All** of the data in Appendix F (*113 pages, 8 font*)



Fire Timeline Focus – 15 Regions

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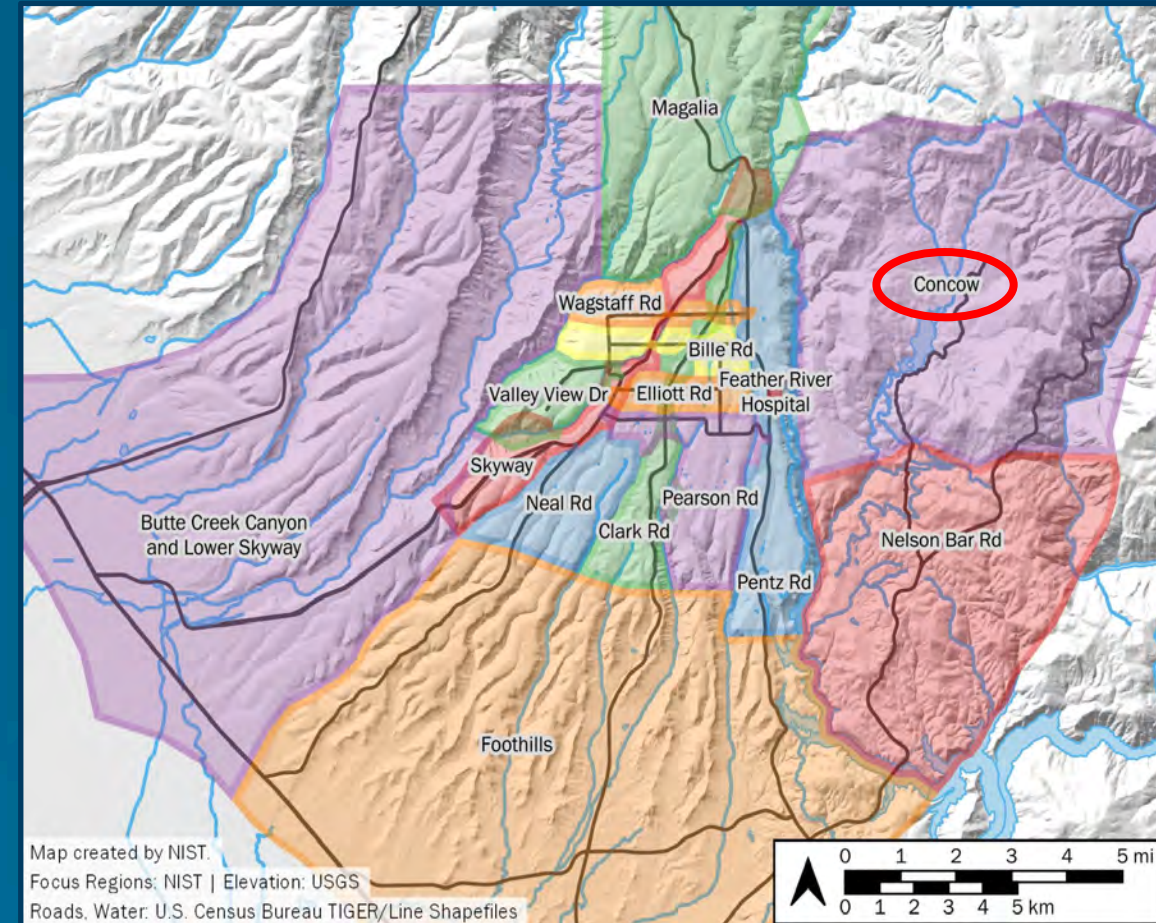
Technical
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1. Detailed Narration

2. Tabulated Highlights

- Time
- Description
- General Location
- Information Source(s)



Note some regions overlap slightly indicated by relative discoloration.



Concow Fire Progression

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Date	Time Range		Fire Behavior Observations	Location	Source #
11/8	06:25	06:40	First report of vegetation fire via 911. Caller reports fire under electric transmission lines within 6 m (20 ft) of tower, estimated size 30 m x 30 m (100 ft x100 ft). Others call to report same fire.	West side Feather River, CA Hwy 70 at Poe Dam	911-001-1 911-002-1 911-004-1
11/8	06:45		First engine gets sight of well-established fire, reports difficult access in nearly inaccessible location. Approximately 15 m/s (35 mi/h) sustained winds. Captain declares potential for a major incident.	West side Feather River, CA Hwy 70 at Poe Dam	TD-028
11/8	06:45		Investigators determined a second power line ignition started another fire which was enveloped in the Camp Fire.	Near intersection of Rim Rd and Concow Rd	VTD-28
11/8	06:45		Fire begins threatening structures in Pulga.	Pulga	TD-029
11/8	07:10		Engine reports fire is now 80 ha to 120 ha (200 ac to 300 ac) with rapid rate of spread toward Concow Reservoir.	Pulga	TD-028
11/8	07:15		Fire spread SW from origin and got established in Flea Valley above Pulga.	Pulga	TD-028
11/8	07:20		Wind pushing fire up slope W, WSW; fire extending up slope and well beyond ridge to W	Pulga	TD-028
11/8	07:20		Multiple (5) small spot fires (3 m x 3 m, 10 ft x10 ft) visible on east facing slopes west of Concow Reservoir.	West side of Concow Reservoir	TD-013
11/8	07:20		Engines attempting access to the north flank of the fire encounter large, a well-established spot fire, 0.1 ha to 0.2 ha (0.25 ac to 0.5 ac).	Rim Rd between Concow and Pulga	TD-005
11/8	07:25		Spot fires are igniting in Concow and homes start to catch fire.	Concow	TD-062
11/8	07:30		Engines responding to Concow encounter 6 m x 6 m (20 ft x20 ft) spot fire burning upwind, threatening homes.	Concow Rd at Cribbage Ln	TD-013
11/8	07:30		First 911 call reporting active fire in yard.	Concow	911-037-1
11/8	07:30		Spot fires up on Rim Rd have grown to several acres within 10 min, spreading up slope, consuming the draw.	Rim Rd between Concow and Pulga	TD-005
11/8	07:40	07:45	Multiple 911 calls report multiple spot fires just below Sawmill Peak, burning on the Paradise side.	Sawmill Peak	911-048-1 911-058-1
11/8	07:50		Fire is well-established in Concow. Multiple structures are burning, and fire is impacting evacuation.	Concow	911-075-1



Caltrans Pulga Maintenance Yard, 07:23

Video courtesy of TD-028, 07:23.
Used with permission.
Composite image by NIST.



- View of the fire looking north from Highway 70.
- Panorama created from video recording.



Concow Fire Progression

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Strong Wind at Rim Road



- Spot fires on ridgetop and into Concow
- Strong east/northeast winds blowing rocks



14 E-size Maps (3 ft x 4 ft)

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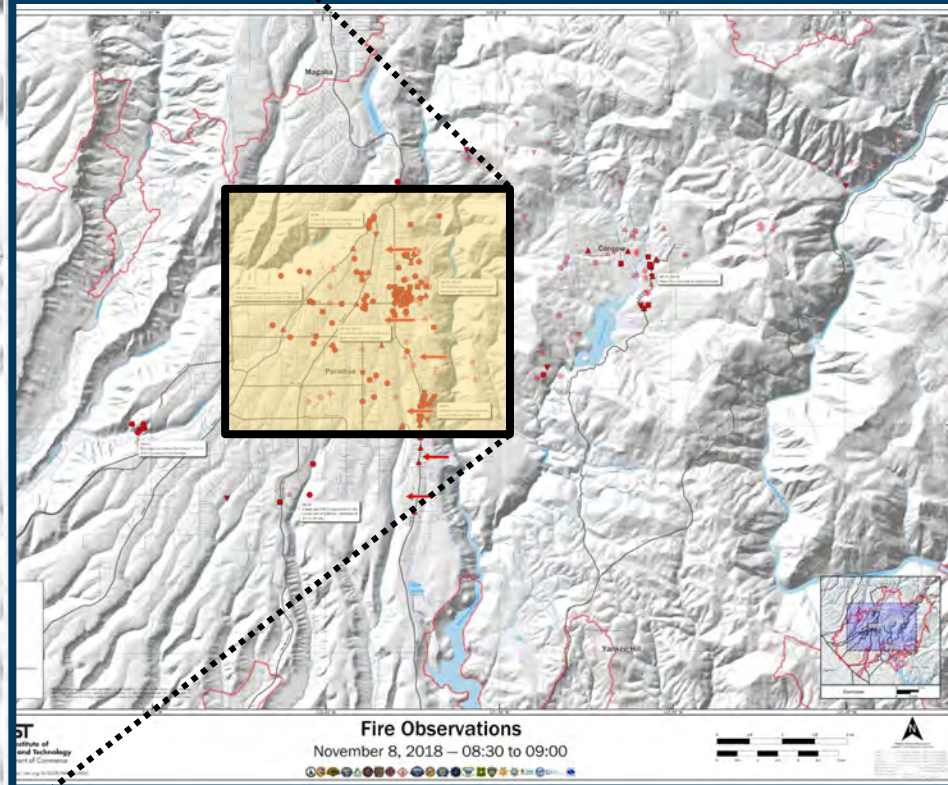
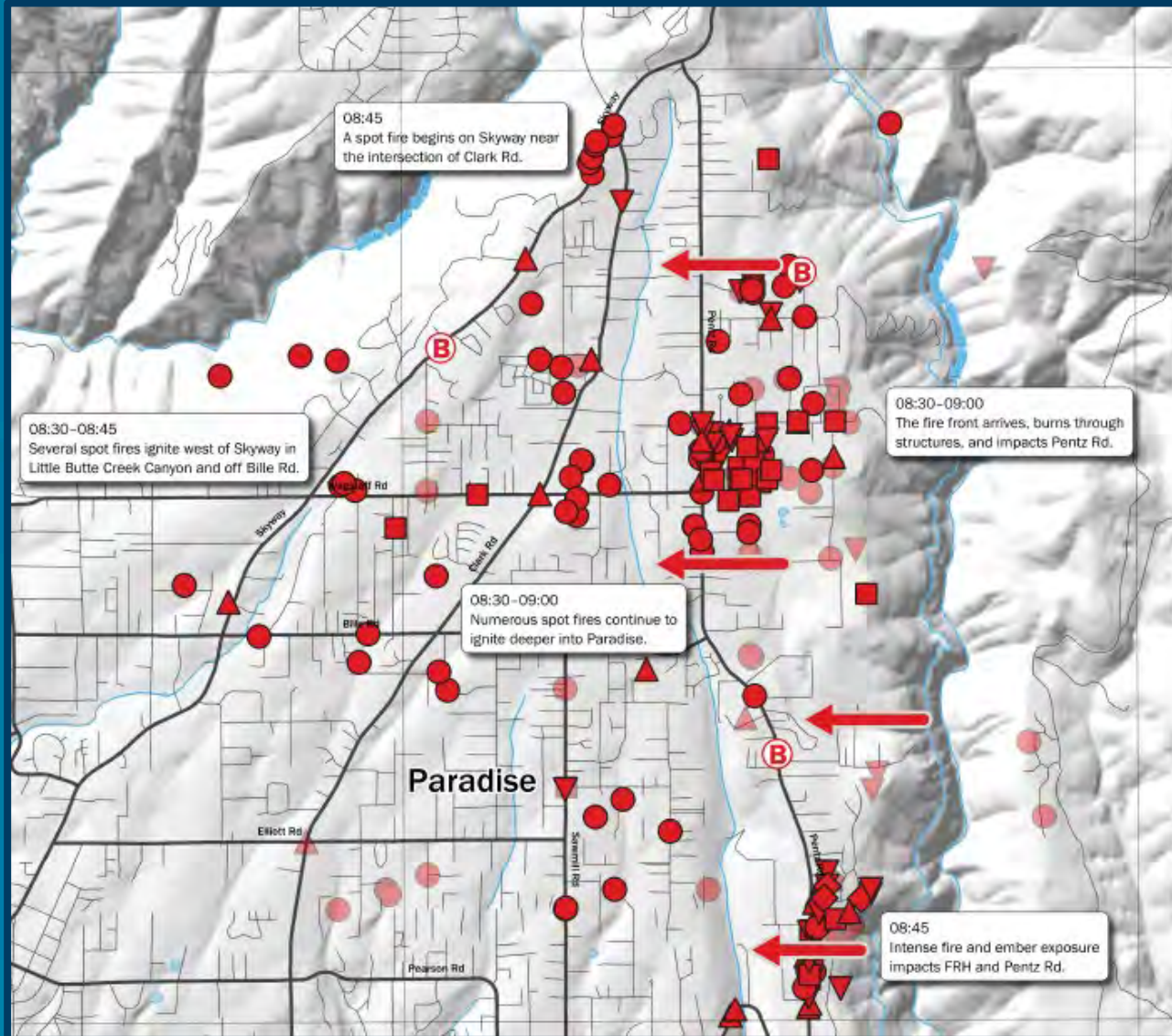
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Fire Progression Summary 06:15 to 07:50

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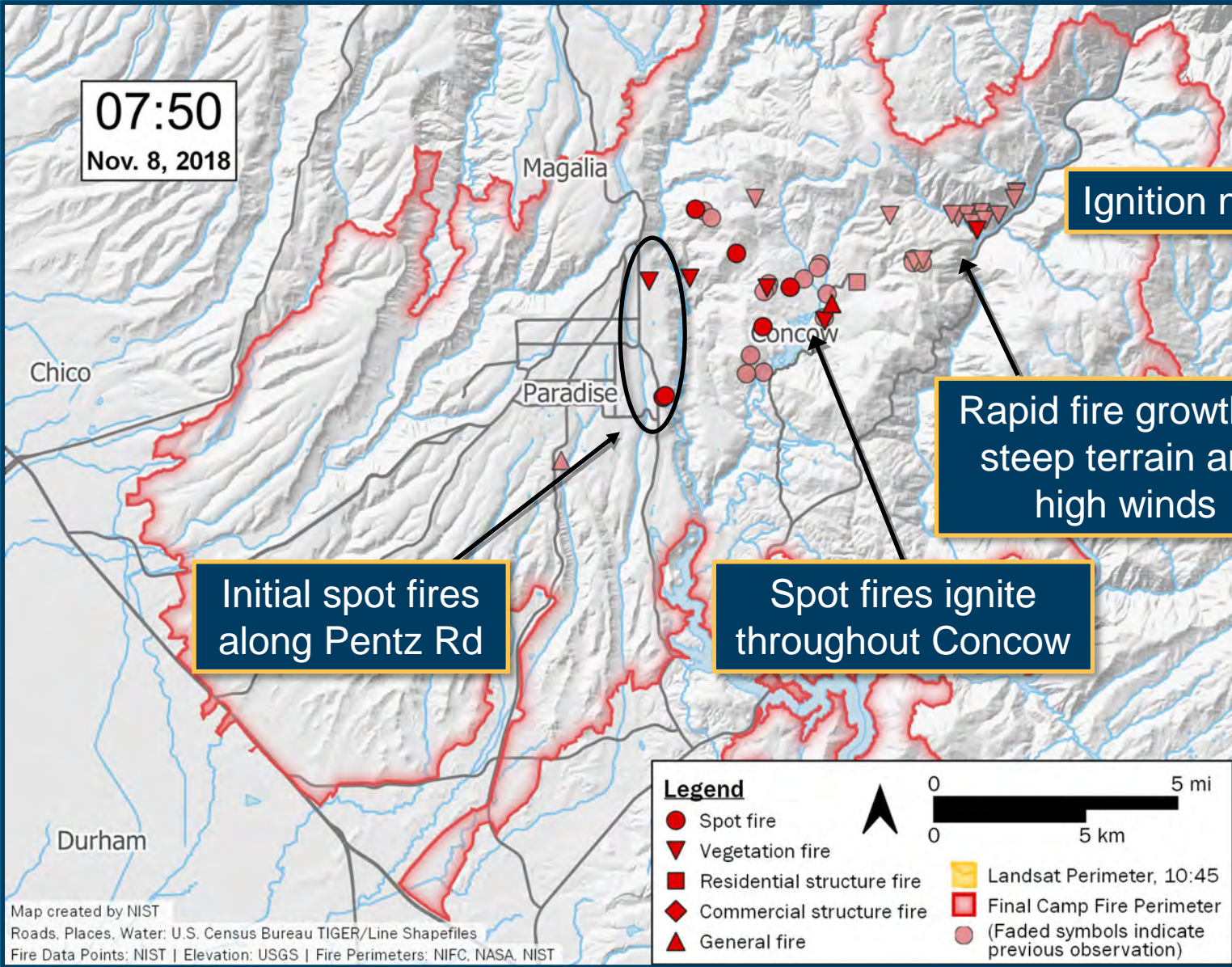
Burnovers

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Fire Progression Summary 07:50 to 08:40

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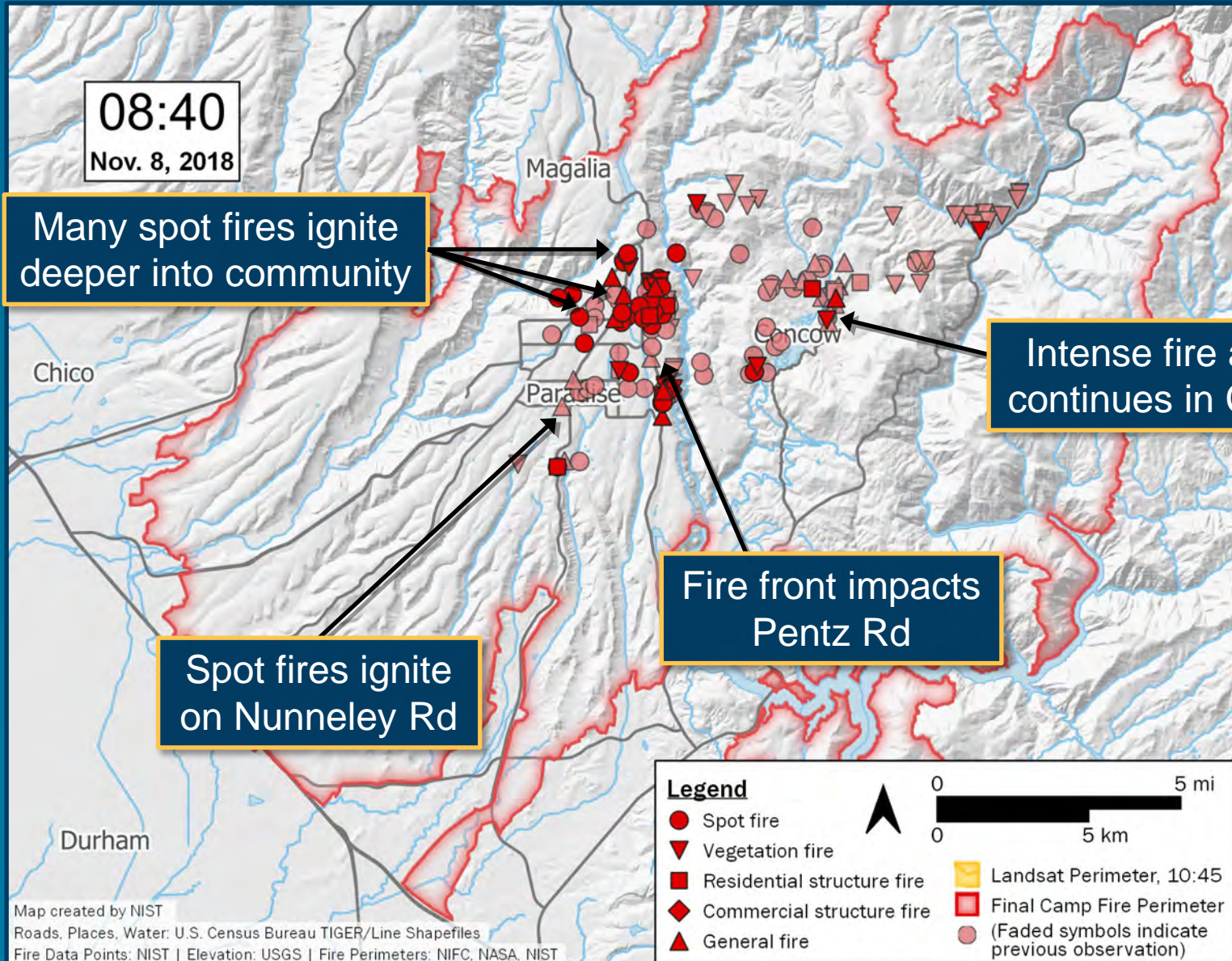
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Fire Progression Summary 08:40 to 09:45

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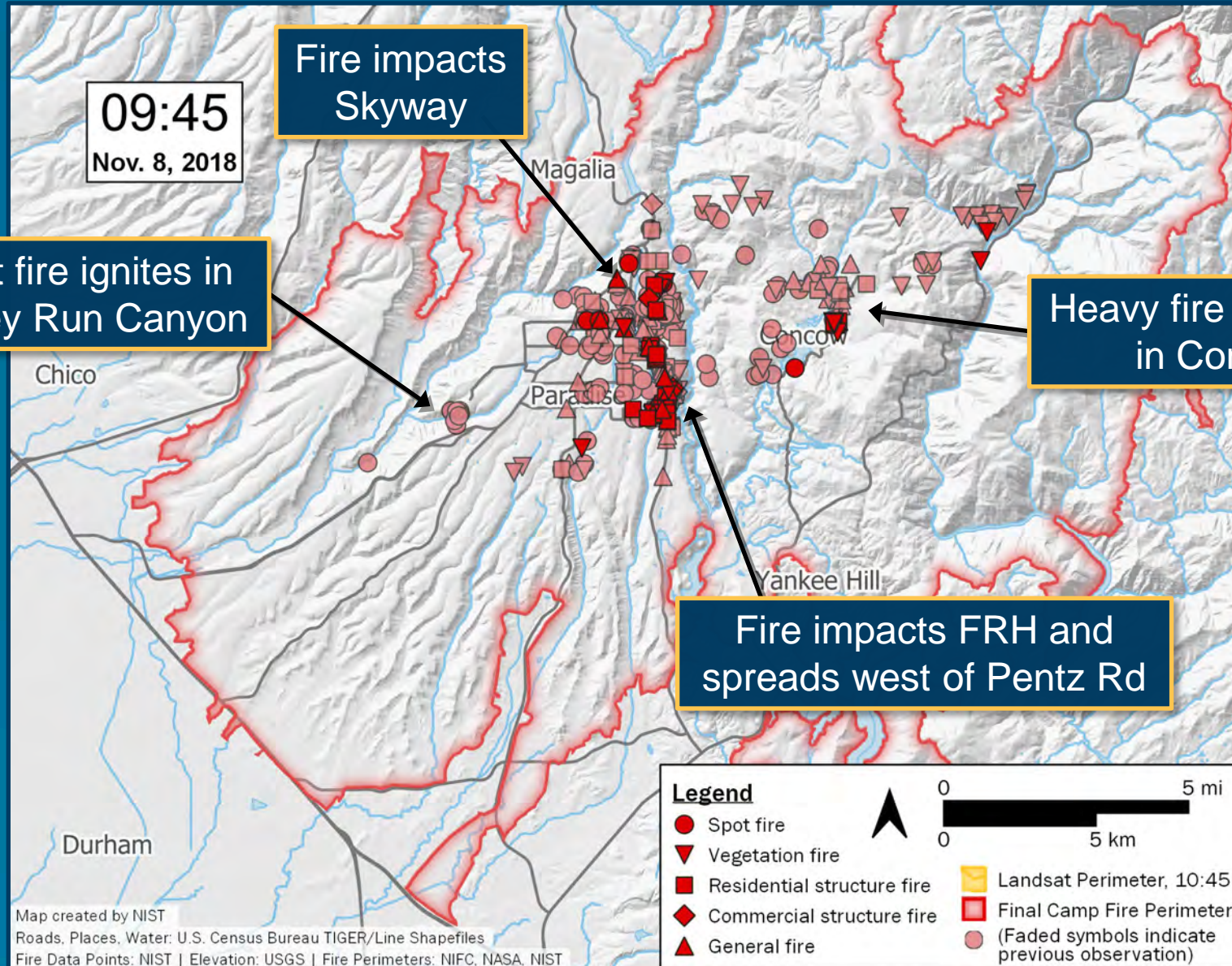
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Fire Progression Summary 09:45 to 10:45

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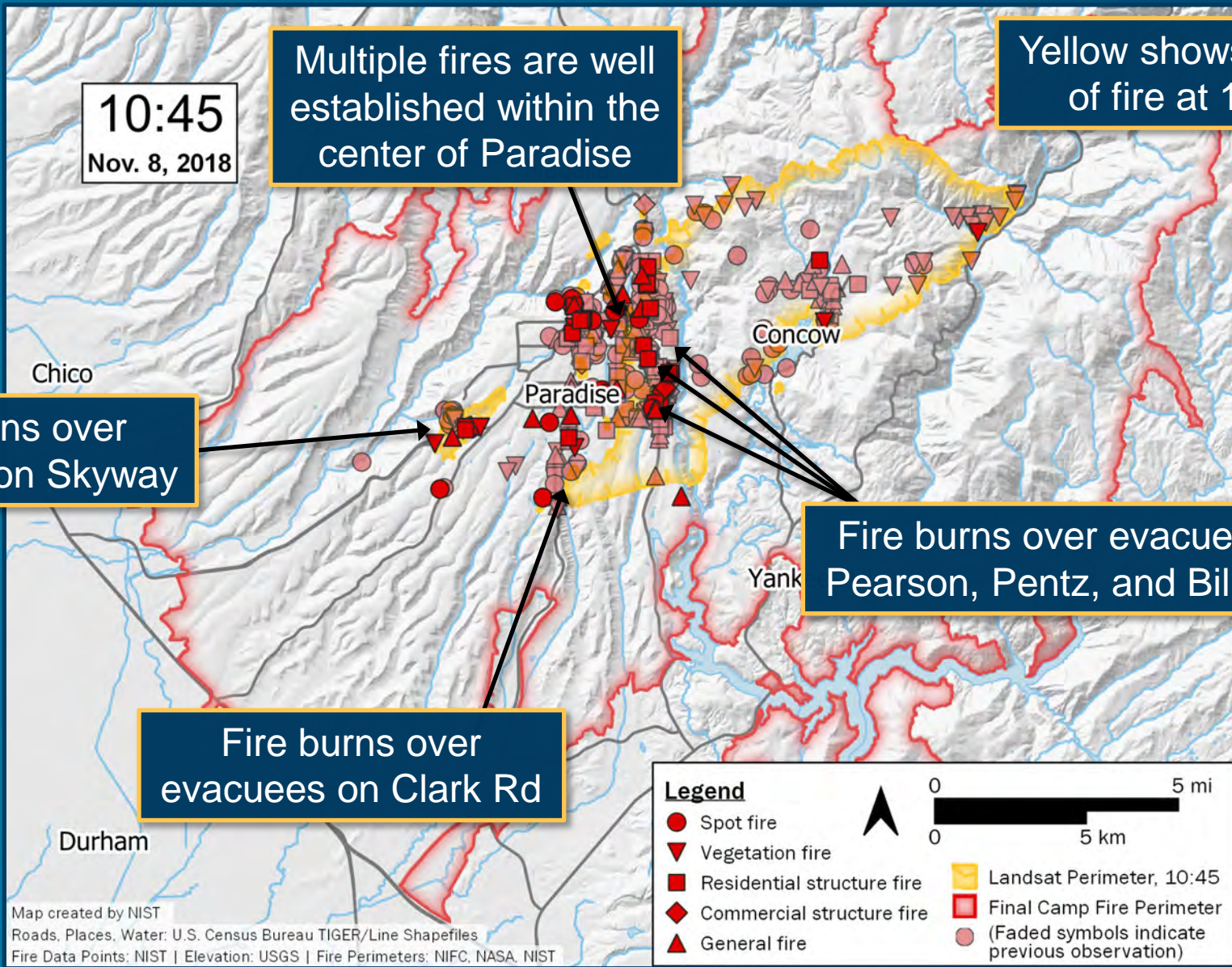
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Fire Progression Summary by 10:45

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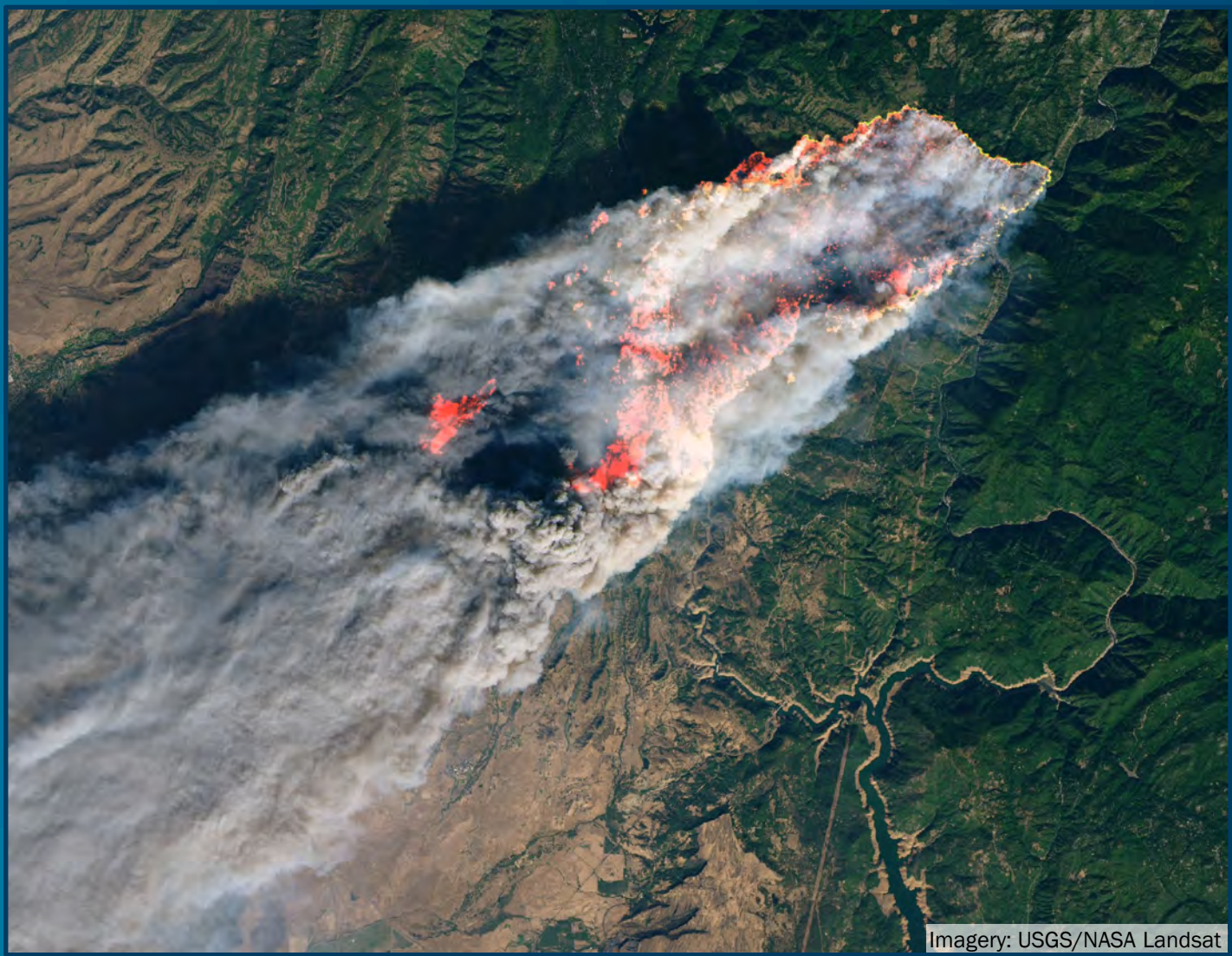
Burnovers

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Imagery: USGS/NASA Landsat



Fire Progression Summary (Day 1)

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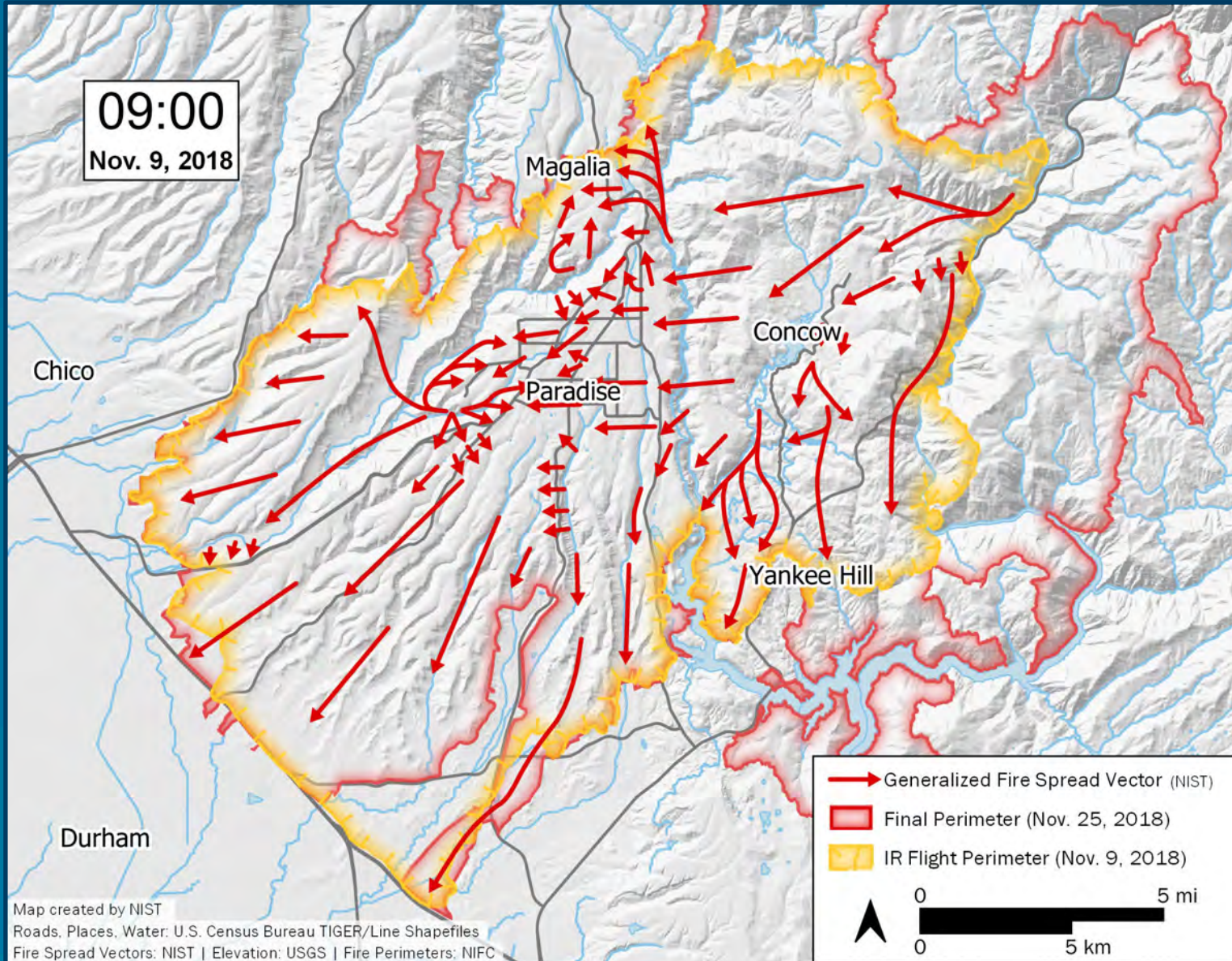
Burnovers

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Fire Progression

Summary:

- Fire spread rate of 7 miles in 90 minutes (4.7 mph)
- Spotting arrived 40 minutes before fire front
- Fire spread was not unidirectional
- At several locations fire “hang-up” for many hours
- Local extreme fire behavior with flame lengths over 100 ft

Implementation:

- Consider extreme weather when establishing trigger points for evacuation
- Consider spotting potential of local fuels
- Consider impact of far field spotting on egress routes
- Identify high hazard locations and installations and have info ready to communicate to mutual aid



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Burnovers

19 documented

11 incidents occurred 7:50 am – 10:00 am



19 Identified Burnovers

Report describes identified:

burnovers, entrapments, and “near misses”

- Unexpectedly caught
- Life-threatening position
- Fire overtakes personnel or equipment
- Escape routes or safety zones are absent, inadequate, or compromised
- May or may not result in injury
- Possible damage to equipment



Source: ViralHog
Used with permission.



Locations of Documented Burnovers

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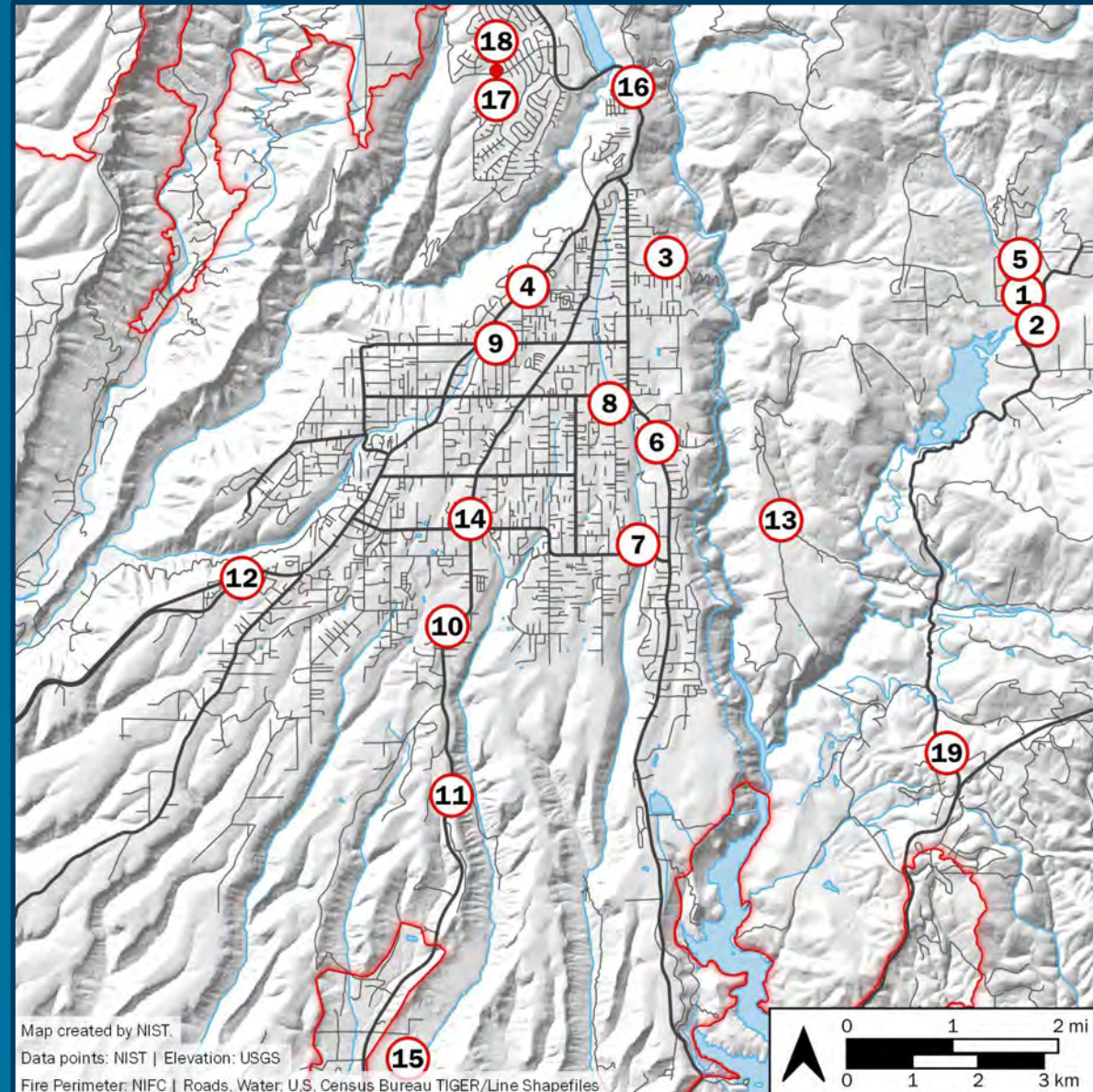
Burnovers

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Identified Burnover Locations by Time of Occurrence and Risk of Injury or Death

ID	Burnover Location	Time	Risk of Injury/Death Category
1	Hoffman Rd	07:50	1
2	Concow Rd	07:50	2
3	Chapman Ln	08:30	1
4	Skyway (upper, between Clark Rd and Wagstaff Rd)	08:30	1
5	Windermere Ln	08:35 ^a	1
6	Pentz Rd	08:45	1
7	Pearson Rd	09:15	1
8	Bille Rd	09:25	1
9	Wagstaff Rd	09:30	2
10	Clark Rd / American Way	10:00	2
11	Clark Rd / Airport Rd	10:00	2
12	Skyway (lower, west of Princeton Way)	10:15	2
13	Jordan Hill Rd /Granite Hill Rd	11:30	1
14	Clark Rd / Black Bear Diner	13:10	2
15	Rattlesnake Flats Rd	15:15	1
16	Coutolenc Rd	00:00 ^b	2
17	Chestnut Cir	06:00 ^b	1
18	Ponderosa Way	07:15 ^b	2
19	Concow Fire Station 37	07:15 ^b	1

^a Burnover conditions existed prior to the first recorded observation.
^b November 9.

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Burnovers Appendix B

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I. Hoffman Road

Date/Time: November 8, 07:50-08:30
Location: Hoffman Road, Concow
Coordinates: [39.783963, -121.509288]
Related TRA/ Safety Zone: after the Hoffman Rd burnover, civilians went to the Camelot Wildfire Safety Zone
Summary: Fire activity in the form of a large spot was first reported in the Hoffman Rd area at 07:35. Within ten minutes conditions deteriorated dramatically, blocking Hoffman Road between the low water crossing and Concow Road, trapping fire fighters and a convoy of civilians trying to evacuate. Evacuees and fire fighters remained at the low water crossing area as the fire burned over the area. Fire shelters were deployed to shield civilians and fire fighters during rescue operations and civilians took refuge in the creek. When local conditions improved the convoy of vehicles migrated towards the intersection of Hoffman Road and Concow Road.

Time	Observation	Source
08:00	four civilians running WB on Hoffman Rd at low water crossing, beard a bit on fire; clothing is burned, civilians advise road ahead is blocked by fire; civilians jump into creek, visibility 0 m to 2 m (0 ft to 7 ft), dark	TD-013
08:00	park on low water crossing, 10 to 15 vehicles of civilians trying to evacuate are stuck in line behind, <i>(west)</i> up Hoffman Rd	TD-013
08:00	small patch of green between Hoffman Rd and lake, fire all around	TD-013
08:00-08:17	vehicles behind <i>(in line to the west)</i> are catching fire, TD-027 goes to evacuate people from vehicles using fire shelters as shields, 4 trips back and forth to grab people, cannot make it back to all vehicles, hard to breathe	TD-013
08:00-08:25	28 to 30 civilians in the creek at the rock wall, 4 to 5 vehicles are burning; wind is from the north	TD-013
08:00-08:25	3 or 4 homes fully involved, propane tanks exploding	TD-013
08:15-08:29	dozer gains access to clear Hoffman Rd, pushing cars off roadway	TD-062
08:15-08:30	head <i>(forward Hoffman Rd on Concow Rd)</i> with a couple engines following; most intense fire conditions; flames horizontal over Hoffman Rd, had to reverse back out of there, engines had difficulty <i>(turning around on narrow road)</i> , total bottleneck in S-curve	TD-110

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Time	Observation	Source
08:15-08:30	trees torching down Hoffman Rd, not safe to go down there to get to TD-013	TD-110
08:17-08:27	plan to get to Camelot Wildfire Safety Zone; stuff all people into 8 vehicles, leave behind the burning vehicles, 2 civilians in front seat <i>(of fire pickup truck)</i> plus 3 in the back seat and TD-027 in the bed camper shell (total of 7 people in pickup); takes maybe 40 min to 60 min from leaving Hoffman Rd to arrive at Camelot Wildfire Safety Zone	TD-013
08:23-08:31	Concow Rd at Hoffman Rd, dozer coming up Hoffman Rd, meet with TD-013 and evacuees; confirm power is dead, and clear powerlines off Concow Rd with bolt cutters; fire right up against road; significant 13 m/s to 18 m/s (30 mi/h to 40 mi/h) wind	TD-062

Topography: low concrete road fording across a creek that feeds into Concow Reservoir, road passes along flat ground

Roadway width: 3 m to 3.5 m (10 ft to 12 ft)

Vegetation setbacks: 0 m to 2 m (0 ft to 6 ft) setback on road, more at creek crossing

Duration: 40 min

Extent of burnover (length of road affected): 250 m (0.15 mi)

Fire direction across road: from northeast to southwest

Wind intensity: estimated 13 m/s to 18 m/s (30 mi/h to 40 mi/h) from north

Fuels: brush / trees

Fire behavior: surface fire, torching trees, visible flames across road or portion of road

Related TD: TD-005, TD-007, TD-008, TD-013, TD-027, TD-062, TD-103, TD-110, TD-137

Related streets or keywords: Concow Rd, Concow Creek, Hoffman Rd, Concow Reservoir

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Street map:

Map created by NIST
Burnovers: NIST | Elevation: USGS | Roads: Water: U.S. Census Bureau TIGER/Line Shapefiles

Satellite view:

Map created by NIST
Burnovers: NIST | Imagery: Google, Mapbox Technologies, USGS, USDA Farm Service Agency

The publication is available free of charge from: <https://doi.org/10.6028/NIST.2155>

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Hoffman Road Burnover Details



Burnover #1: Hoffman Rd

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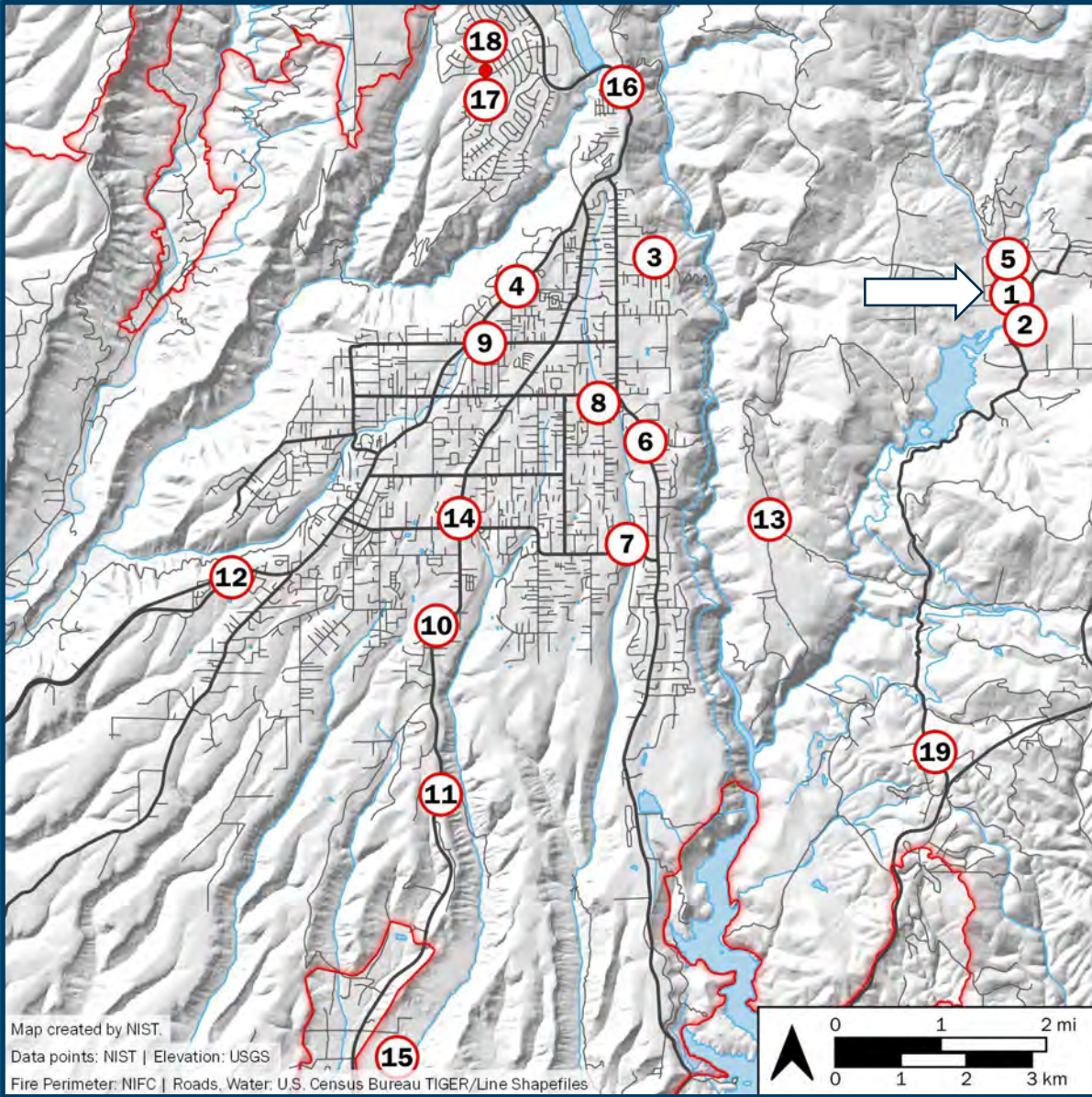
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Burnover #1: Hoffman Rd

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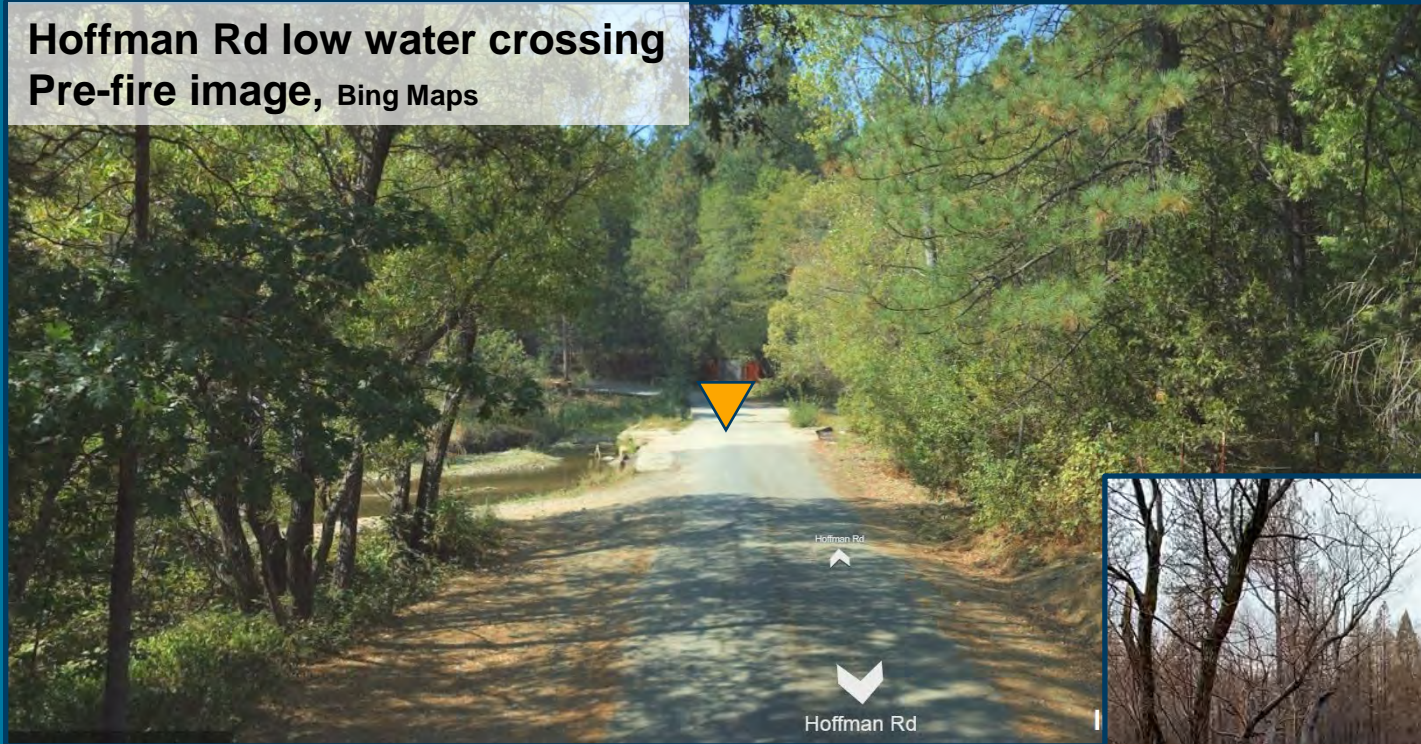
General Fire Behavior

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Hoffman Rd low water crossing
Pre-fire image, Bing Maps



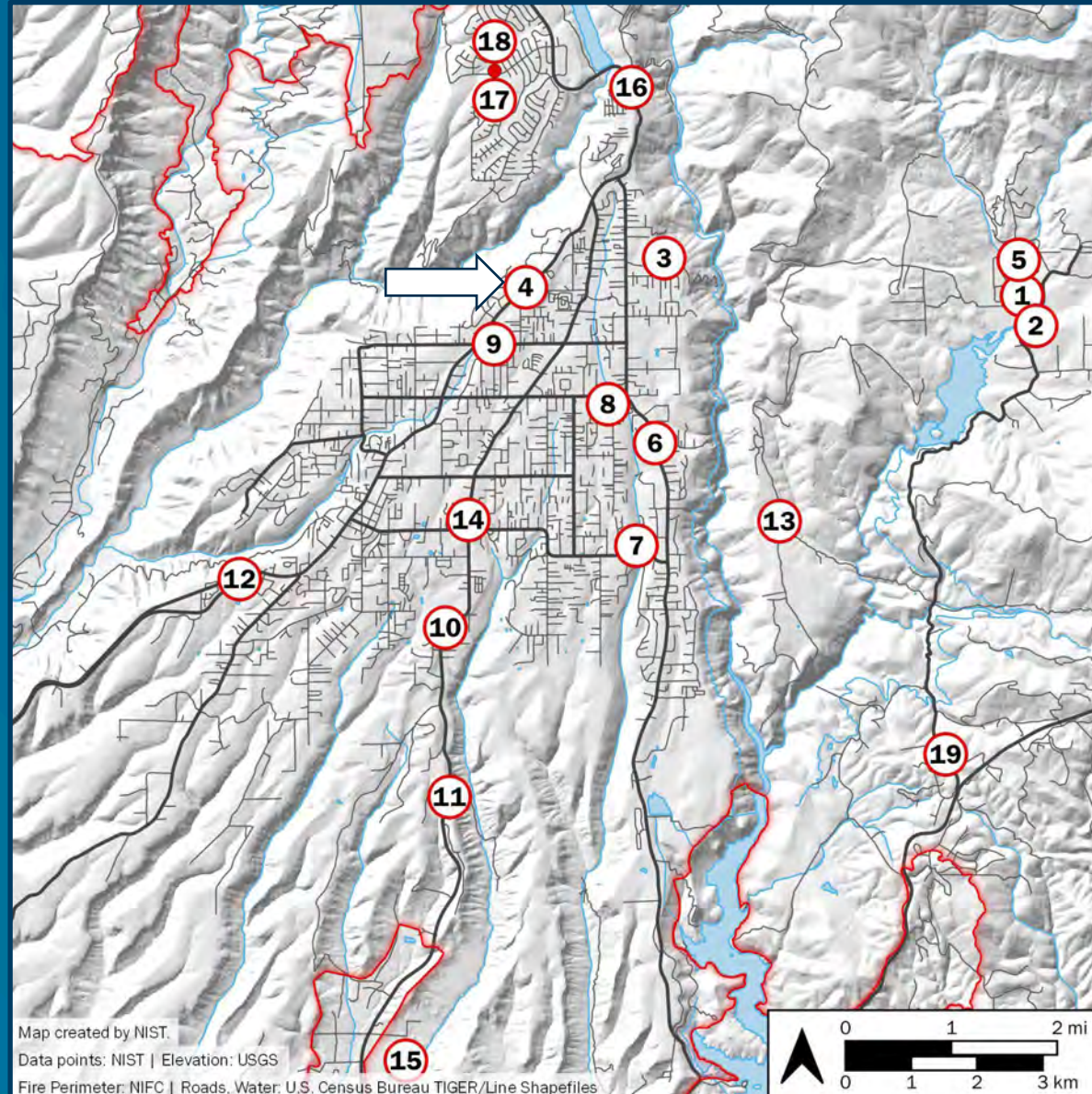
- Rapid expansion of fire
- Vehicles, vegetation, structures burning
- Trees and fire blocking roadway
- Approx. 30 civilians took refuge in creek



Post-fire image, NIST photo Mar 28, 2019



Burnover #4: Upper Skyway



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Burnover #4: Upper Skyway

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Photo courtesy of TD-205, 13:58.
Used with permission.



Photo courtesy of TD-041, 10:49 (Nov 9).
Used with permission.

- Prolonged period of hazardous conditions
- Rapid spread of initial spot fires
- Standstill traffic
- Abandoned vehicles burning in roadway
- Prevented evacuation from points north



Burnover #6: Pentz Road

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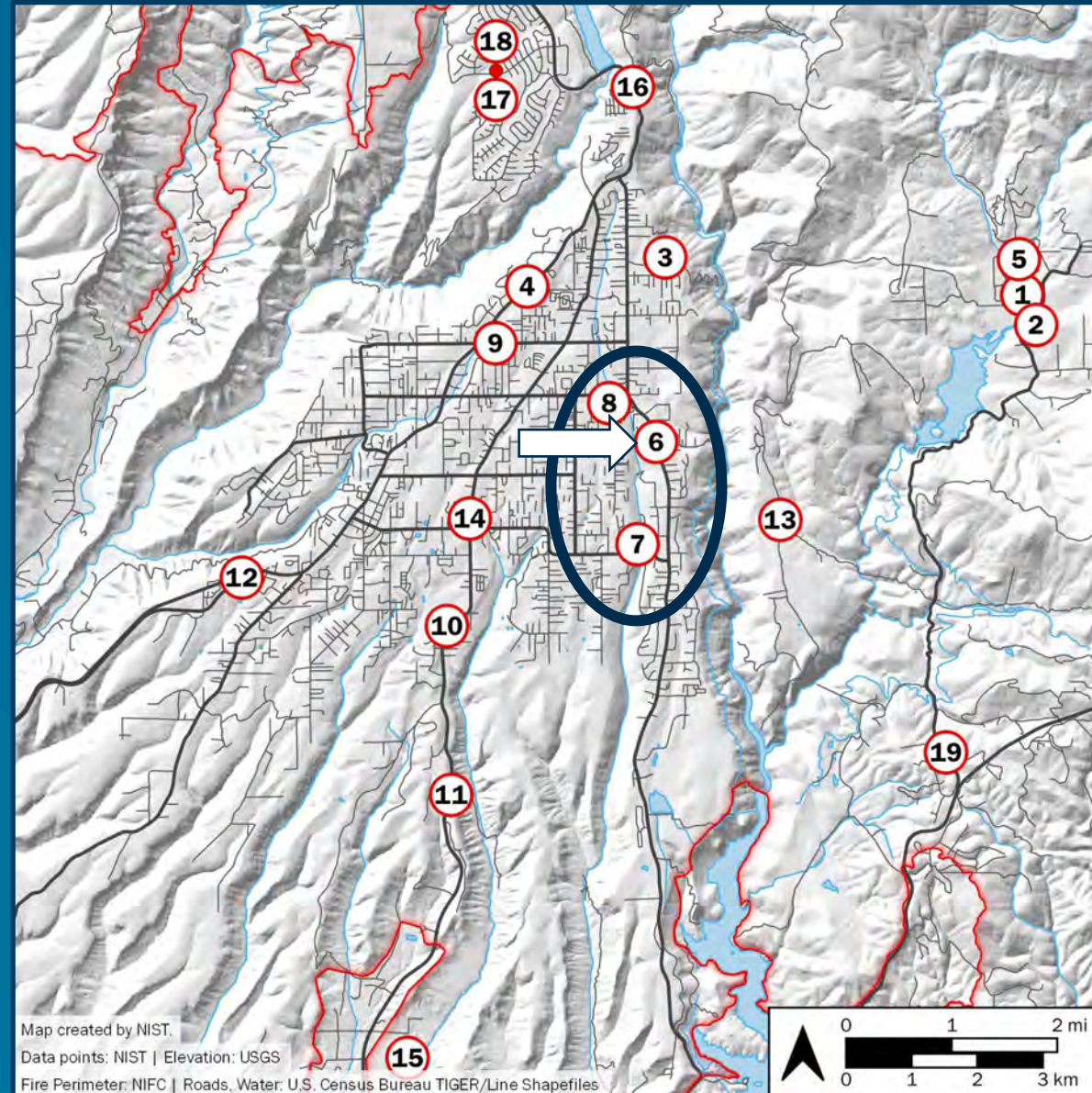
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Burnover #6: Pentz Road

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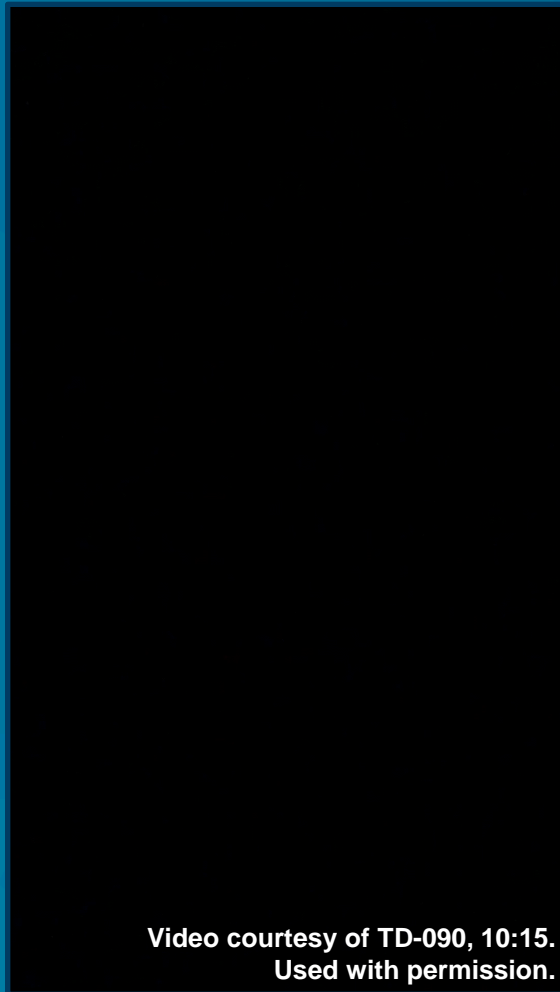
Burnovers

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Zero visibility, on foot, re-directing traffic

- Widespread spot fires
- Standstill traffic
- Zero visibility
- Burning vegetation, structures, and vehicles along roadway
- Multiple civilian rescues
- Shelter-in-place and traffic redirection



Conditions south of hospital after burnover



Burnover #7: Pearson Road

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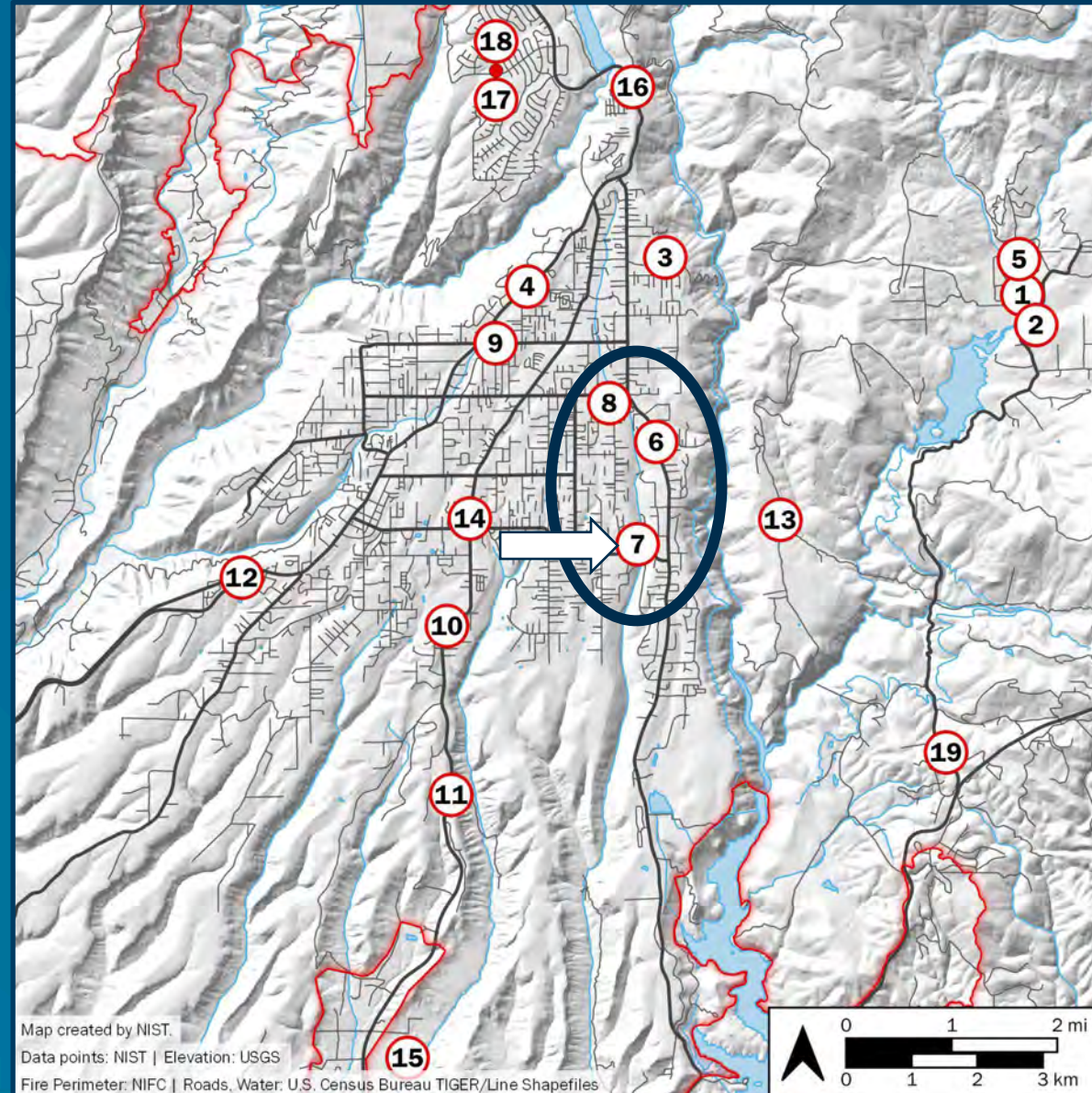
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Burnover #7: Pearson Road

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Photo courtesy of TD-122, 09:40. Used with permission.



Photo courtesy of TD-122, 09:40. Used with permission.

- Standstill traffic
- Intense vegetation fire in drainage near Stearns Rd and Hilbe Dr

- Igniting vehicles and structures
- Fire engines and dozers assisted civilians into temporary refuge area



Burnover #8: Bille Road

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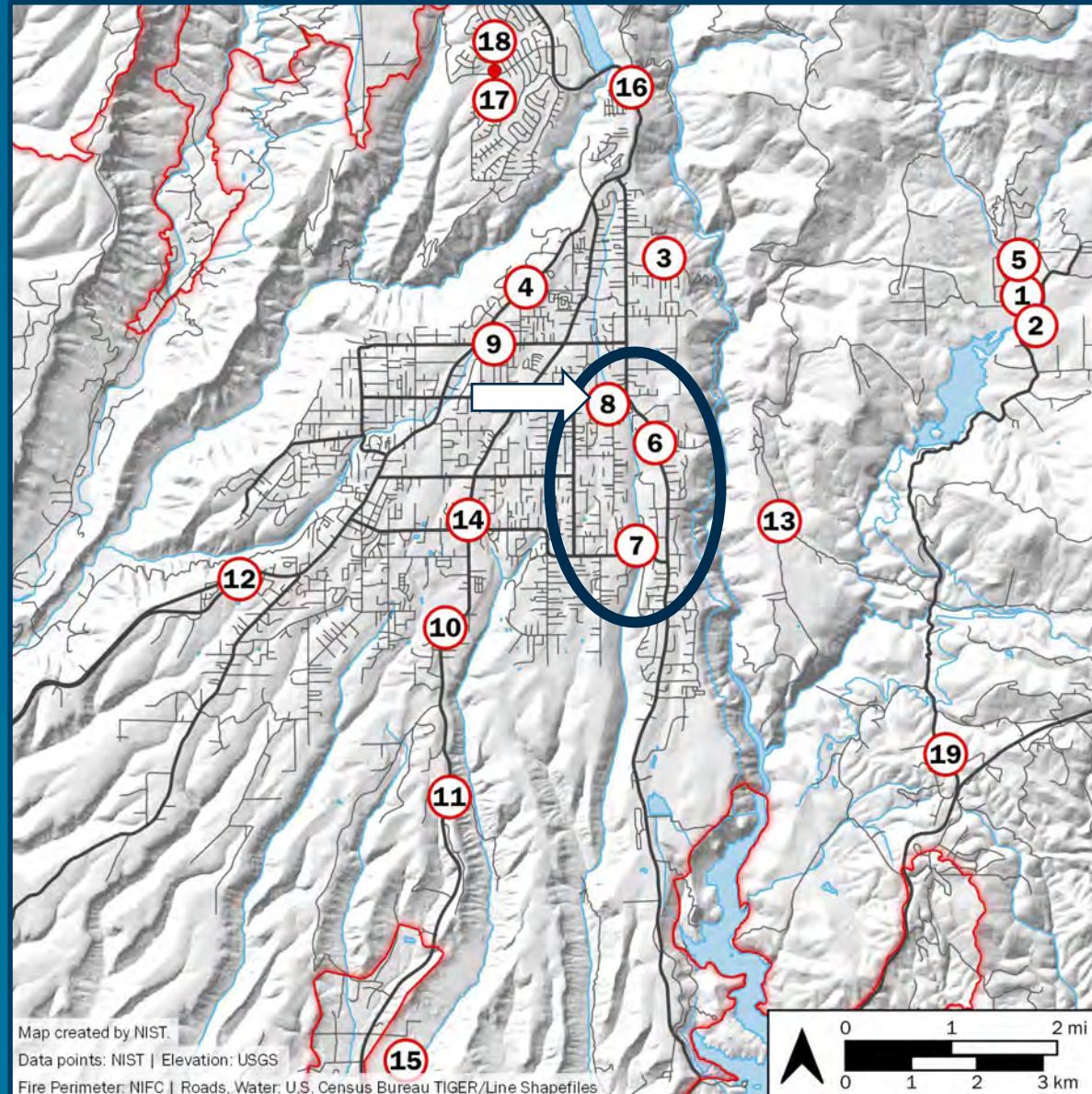
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Burnover #8: Bille Road

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- Fire impacted standstill traffic
- Evacuees fled on foot, abandoning vehicles
- Fire engine at Pentz Rd and Bille Rd protected temporary refuge area with water spray
- Burning vehicles blocked roadway all day



Life Safety

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- 13 of 19 impacted civilian evacuation
- Standstill traffic; abandoned vehicles
- Zero visibility

- Burning vegetation, structures, and vehicles along roadway
- Multiple civilian rescues
- Shelter-in-place and traffic redirection



Severity of Local Conditions

- Severe local exposures impact life safety and buildings
- Parcel and fuel ownership may not correlate
- Might not have control over fuels giving the high exposures



Photo courtesy of TD-112, 11:53. Used with permission.



Video courtesy of TD-127, 10:17. Used with permission.



Photo courtesy of TD-155, 10:21. Used with permission.



Photo courtesy of TD-209, 09:03. Used with permission.

Photo courtesy of TD-209, 09:07. Used with permission.

Difference 0.25 mi and 4 min.



Photo courtesy of TD-101, 12:22. Used with permission.



Photo courtesy of TD-101, 12:01. Used with permission.



Burnovers Summary

Summary:

- Life safety issue for public and first responders
- Can impact not only local traffic but overall community egress
- Can block arteries for hours
- Can generate extreme local fire behavior impacting local traffic and surrounding parcels/fuels
- Backups from one burnover can cause traffic to get in another
- Can prevent first responders from accessing parts of the incident
- Exposures may be from fuels on neighboring parcels

Implementation:

- Consider possible burnover locations in and out of town
- Consider fuel treatments to reduce burnover potential
- Consider safety zones in and out of town, in context of extreme fire spread and burnovers
- Consider fuel ownership in assessing and mitigating potential burnovers



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General Fire Behavior

*effects of wind and terrain / spot fires
structure ignition pathways*



Impact of Winds, Wildland Fuels and Terrain on Fire Behavior

- Firsthand observations on Rim Road at 07:20 on November 8 talked of “softball size rocks hitting the engine” [TD-005]
 - Local winds in the range of 22 m/s to 27 m/s (50 mi/h to 60 mi/h)
 - Values agree with the forecasted ridgetop winds

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Impact of Winds, Wildland Fuels and Terrain on Fire Behavior

- During the Coutolenc Road burnover at 00:30 on November 9
 - very strong, gusty winds coming up from the West Branch canyon
 - estimates of 22 m/s (50 mi/h) [TD-041, TD-061, TD-209]
- Terrain also directly impacted fire behavior
 - dramatic fire behavior around 18:00 on November 8
 - flame lengths of 30 m to 60 m (100 ft to 200 ft) breaking out of the Butte Creek Canyon into Wilder Drive [TD-117]



Early Spot Fires in Paradise

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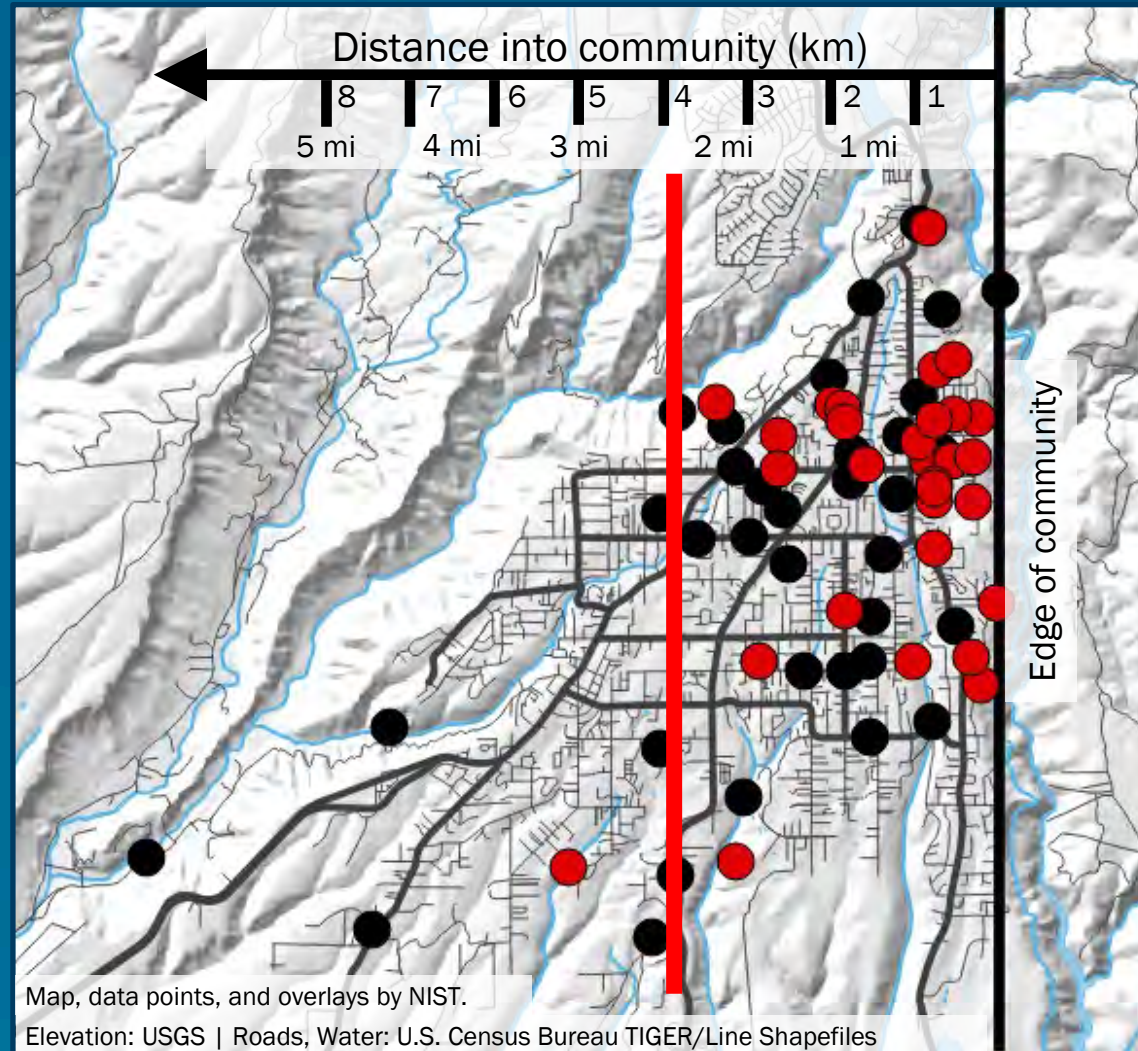
Primary Driving Factors

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Spot Fire Ignitions

- 07:49 – 08:30 (N=30)
- 08:30 – 10:30 (N=35)



30 identified spot fires within first 40 minutes (red)



Structure Ignitions – Exposure and Structure Hardening Relationship



**Chapter 49,
Defensible Space
Chapter 7A Subcommittee 6**



Chapter 7A

a Reduce fire and/or ember exposures

b Hardening for embers and/or fire

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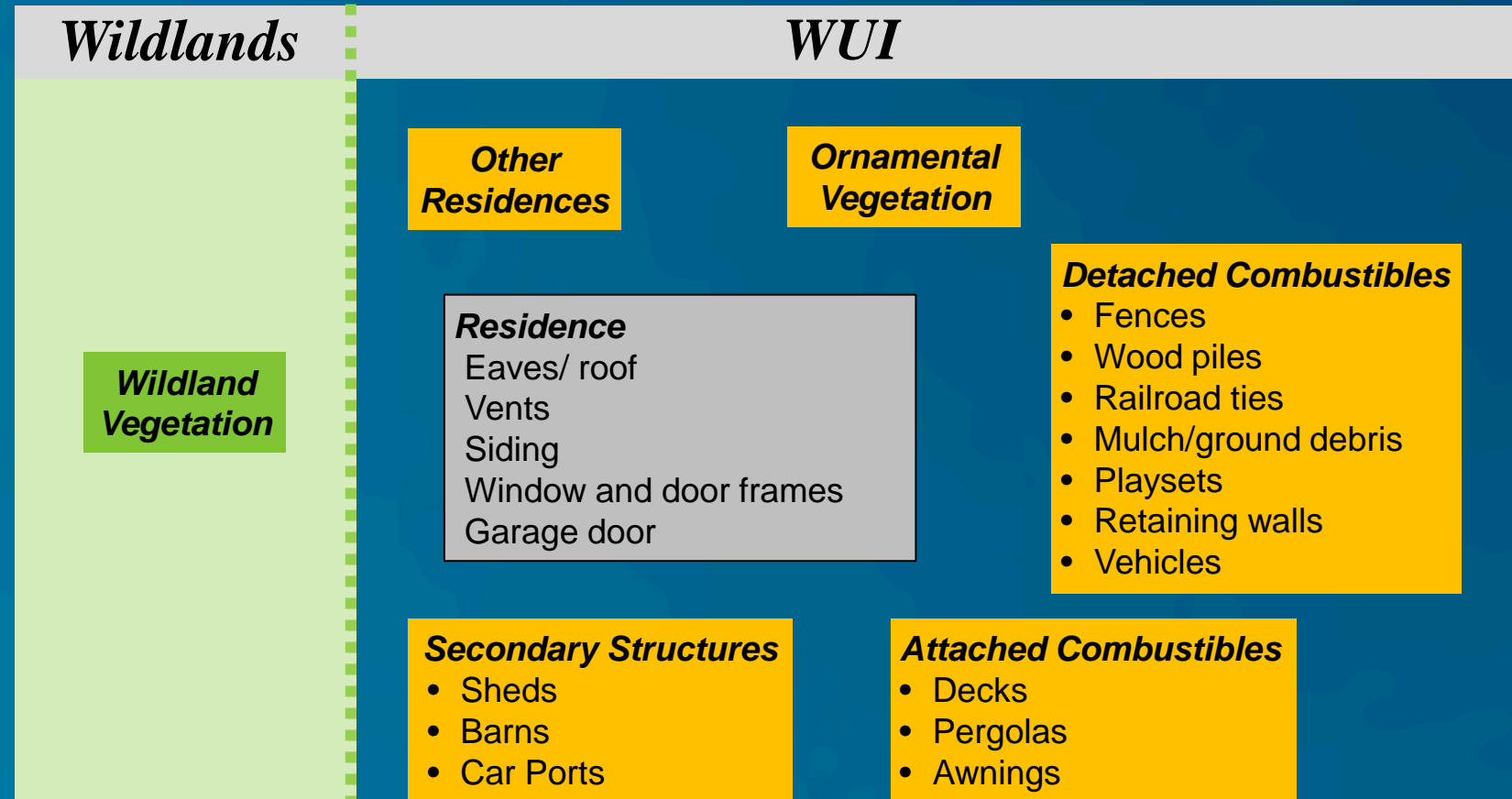
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Structure Ignition Pathways



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Vulnerabilities – Failure Points

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windows



NIST Photo. Camp Fire 2018.

roof / eaves



NIST Photo. Camp Fire 2018.



NIST Photo. Camp Fire 2018.



NIST Photo. Camp Fire 2018.



Vulnerabilities – Failure Points

eaves / vents



Failure: multiple locations along eaves



Failure: eave at fascia board



Failure: eaves/roof truss near eave vent

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Structure Ignition, Example 1

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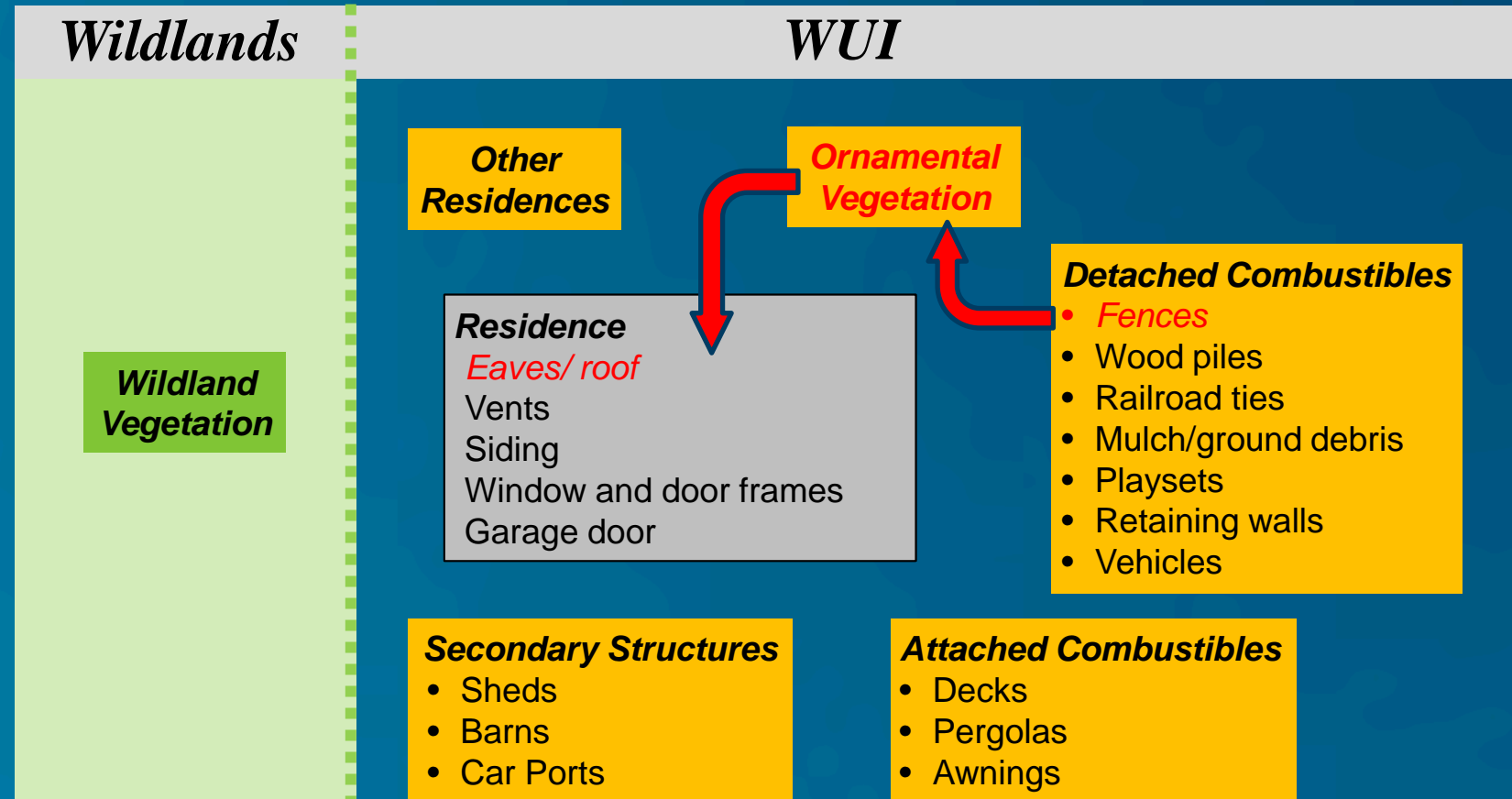
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Structure Ignition, Example 1

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a) $t = 0$ s



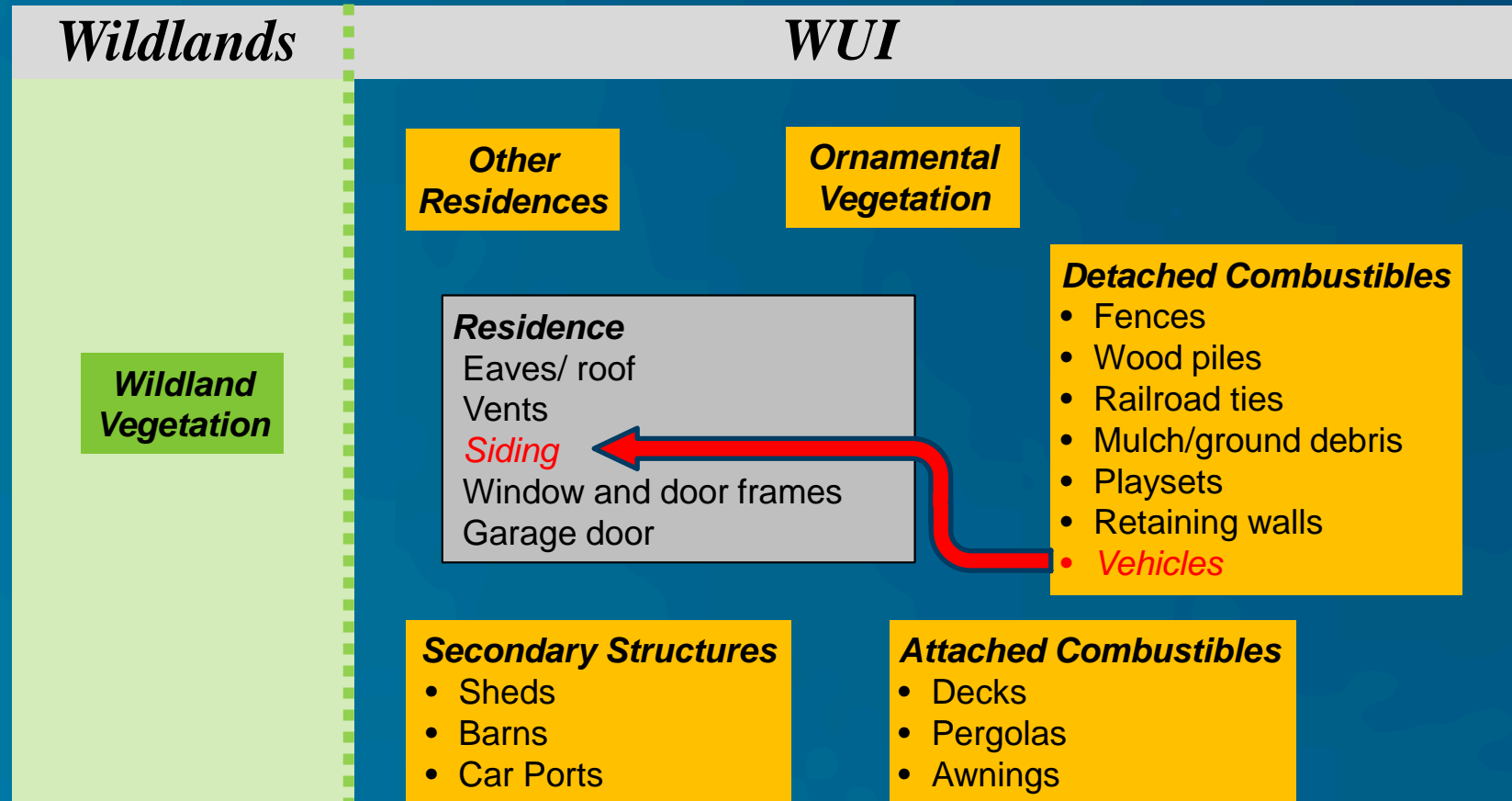
b) $t = 139$ s

Structure ignition on Dade Ct in Magalia. Images are two minutes apart and show fire spread from surface fuels to fence to vegetation to eaves. The combustible fence is estimated to be approximately 1.8 m (6 ft) away from the structure.



Structure Ignition, Example 2

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Structure Ignition, Example 2

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a) A dozer displaced the
vehicle to stop fire spread



b) Associated evidence of the fire
ignition and defensive actions
encountered during NIST damage
assessments.



Structure Ignition, Example 3

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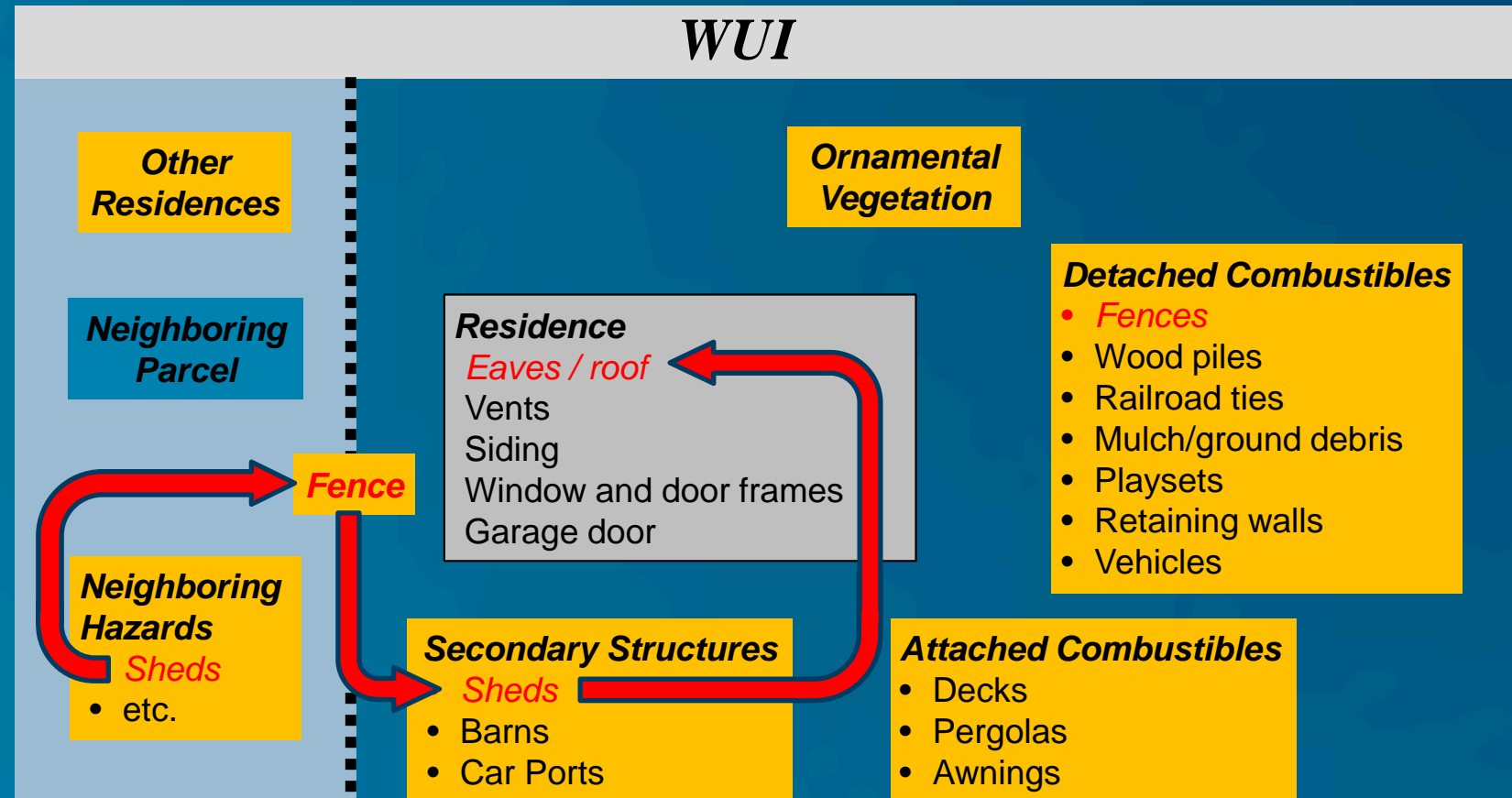
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Structure Ignition, Example 3

Shed ignition leading to residence destruction

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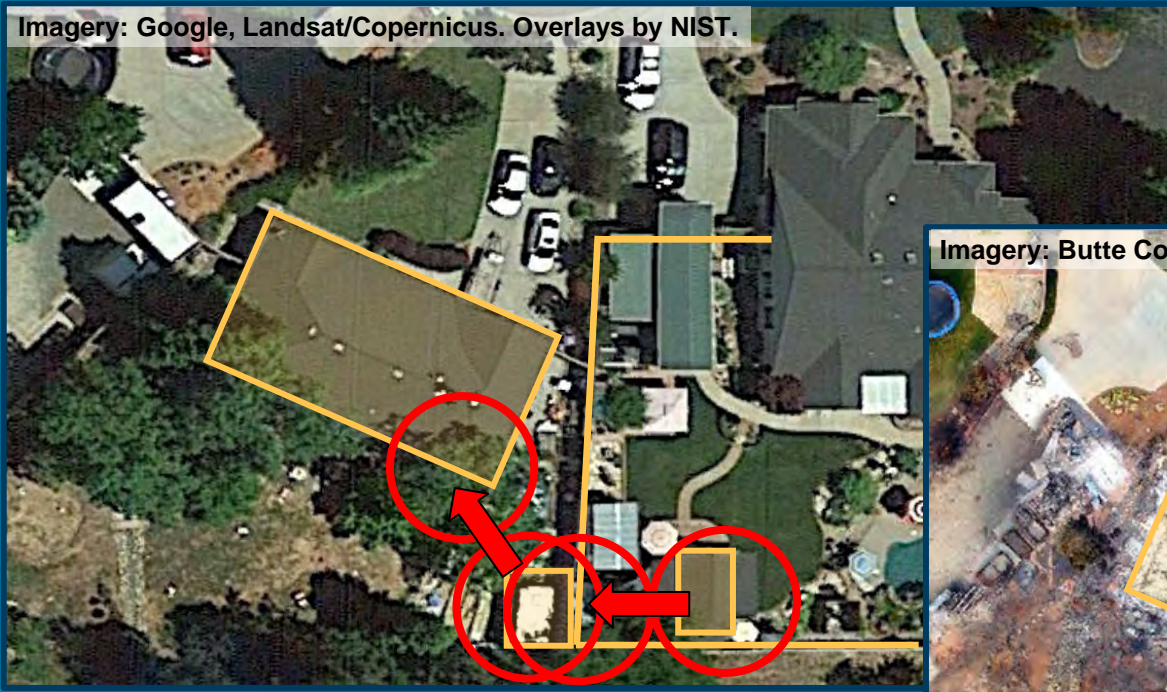
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Fire Spread Pathway:
Shed to Fence to Shed to House



Residential Structure Ignition Pathways Identified by Direct Observation

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**Mulch /
vegetation**

**Detached
combustibles**

Structures

Data Source	Time of Obs.	Location ^a	Building Ignition Pathway	Source to Target Distance	
				m	ft
TD-005	10:20	Canyon View Dr	Bark mulch to wall of house (OSB and vinyl)	unknown	
TD-091	14:06	Neal Rd	Mulch to garage	unknown	
TD-036	14:58	Skyway	Juniper vegetation to eave	against house	
TD-108	17:01	Clark Rd	Juniper vegetation to house	1.3	4
TD-091	17:09	Neal Rd	Burning bark mulch into subfloor vents of house	unknown	
TD-015 TD-017 TD-064 PPD	14:37	Skyway	Fence to wall of building	2.4	8
TD-044	22:30	Valley Ridge Dr	Woodpile to house	0.3–0.7	1–2
TD-060	11:06	Sweetbriar Ln	Structure ignition via radiation from neighboring structure on fire	11	35
TD-100 TD-101	14:53	Pearson Rd	Commercial structure to commercial structure roof to eave	0.7	2
TD-091	17:23	Sutter Rd	8 m x 4 m (26 ft x 13 ft) shed to house eaves	2.4	8

^a Location in Paradise unless noted.



Residential Structure Ignition Pathways Identified by Direct Observation

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Vehicles

Multiple hazards

Data Source	Time of Obs.	Location ^a	Building Ignition Pathway	Source to Target Distance	
				m	ft
TD-091	14:06	Lewis Ranch Rd	Burning car to side of house	1.5–2.4	5–8
TD-205	20:12	Clark Rd	Boat on fire to eaves of house	2.5	8
TD-045	09:10	Chris Ct	Shed to fence to shed to house ^b	2.7	9
TD-092	13:52	Neal Rd	Burning car to shed to house	unknown	
TD-044	19:00	Valley Ridge Dr	Fence to boat to house	2.7–3.6	9–12
TD-041	03:20 ^c	Dade Ct, Magalia	Fence/ground fuel to tree to eaves of house	1.5	5

^a Location in Paradise unless noted.
^b Second shed fire resulted in an explosion that caused a firefighter injury.
^c November 9.



General Fire Behavior

Summary:

- Spotting rate in town was 30 in 40 minutes (45/hour)
- Heavy spotting occurred in the first 3 miles from the community's upwind edge
- Spotting could have traveled from further upwind in the wildfire
- Structure ignitions result from relationship between exposures and structure hardening
- Structure ignitions at the parcel level can occur from flames and/or embers
- Structure ignitions can occur through one or more parcel fuels

Implementation:

- Consider spotting and ignition potential in and around town
- Consider structure survivability in the absence of defensive actions
- Consider parcel-level hazard reduction
- Consider parcel-to-parcel fire propagation



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Primary Driving Factors

ignition potential + fuel density + wind/terrain + extent of fire front



Primary Drivers Influencing the Extent of Damage and Destruction

1. Fuel ignition potential
2. Density of vegetative and structural fuels
3. Wind and terrain
4. Extent/size of fire front reaching the communities

It was the confluence of these four factors that resulted in very aggressive fire behavior.



Fuel Ignition Potential

- Dry fuels receptive to ignitions from embers
- “100 % ember ignitions” [TD-041, TD-079]
- Numerous spot fires ignited in fine fuels (pine needles, ornamental vegetation) well ahead of the fire front
- In Paradise, ignitions started approximately 30 min to 40 min before the arrival of the fire front

Fuel receptivity within the communities caused the large number of spot fire ignitions.



Density of Vegetative and Structural Fuels

- Century-long community growth
 - Wildland-urban intermix developed within wildland vegetation
 - Smaller residential lot sizes
 - Locally low structure separation distances
- No fire history within Paradise and Magalia
 - Long-term accumulation of vegetative fuels
- Post-fire fuel transition to brush and finer fuels in Concow area *[TD-008]*



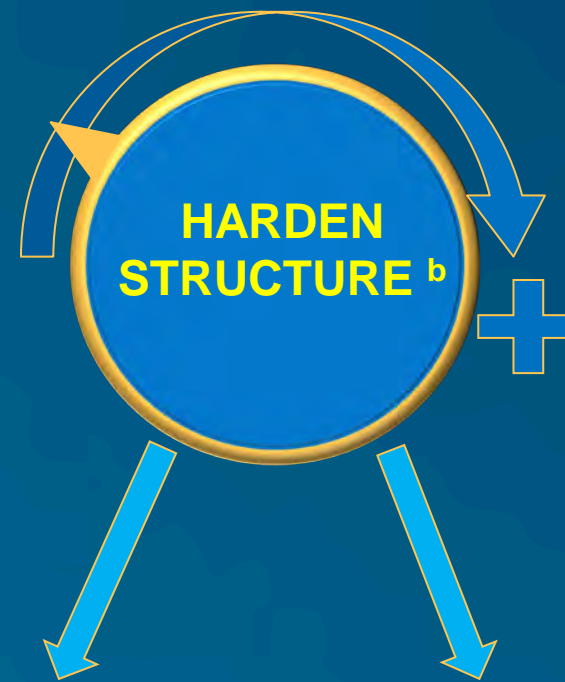
Density of Vegetative and Structural Fuels – Addressing the Hazard



Displace Fuels

Remove Fuels

a Reduce fire and/or ember exposures



Fire Resistant
Design

Ignition/Fire Spread
Resistant Materials

Community Design

Active Systems

b Hardening for embers and/or fire

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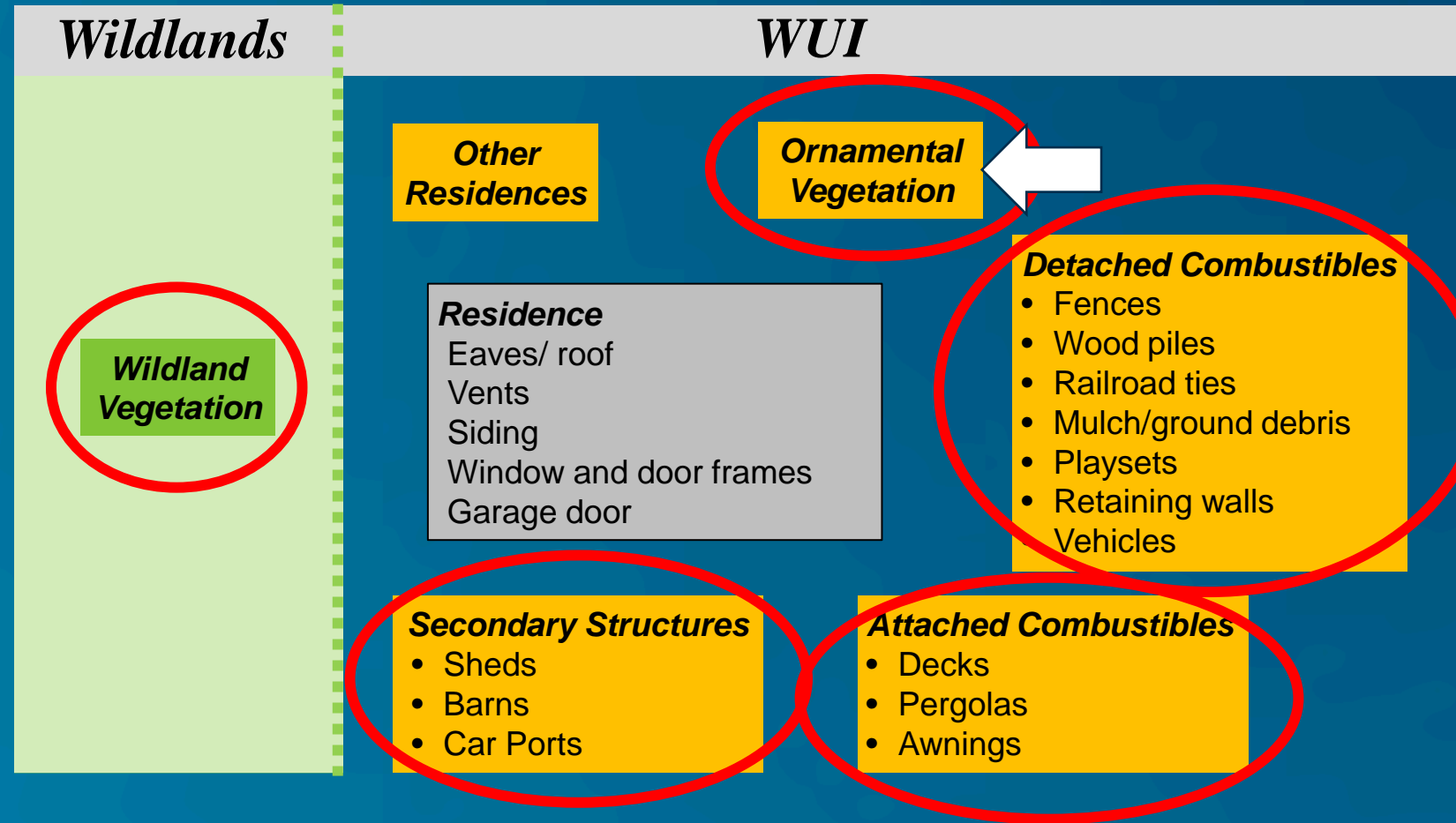
Primary Driving
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Structure Ignition Pathways – Fuels Reduction



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Fuel Treatment Around Critical Infrastructure (Paradise Irrigation District)

Fuel treatment and reduction conducted pre-fire, 2018



Rapid post-fire vegetative growth in pre-fire fuel treatment areas



Note: Imagery captured before completion of fuel treatment

Fuel treatments can reduce exposure but must be maintained



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Fuel Treatment Around Critical Infrastructure (Pine Ridge School, Magalia)



Photo by NIST (June 24, 2019).

Thinning and mastication fuel treatment and reduction conducted pre-fire

- Reduced severity of fire exposure
- Firefighter safety zone
- Designated, pre-planned community assembly point (not used in Camp Fire)



Wind and Terrain

- Jarbo Gap is known for its high winds [TD-003, TD-008]
- Wind* event + topography + dry fuels
 - Rapid fire growth
 - Fire could not be contained soon after ignition



Video courtesy of TD-005, 07:32.
Used with permission.

* Wind was not extreme throughout the event (temporally and spatially)

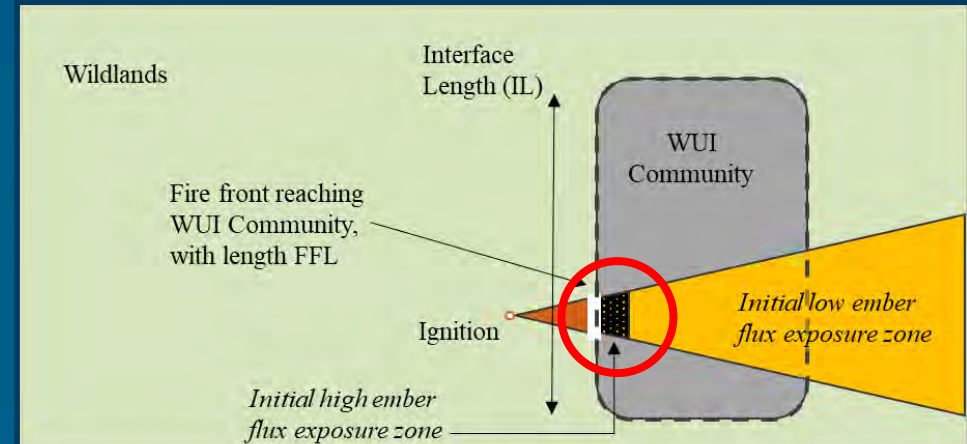


Extent/Size of Fire Front Reaching the Communities

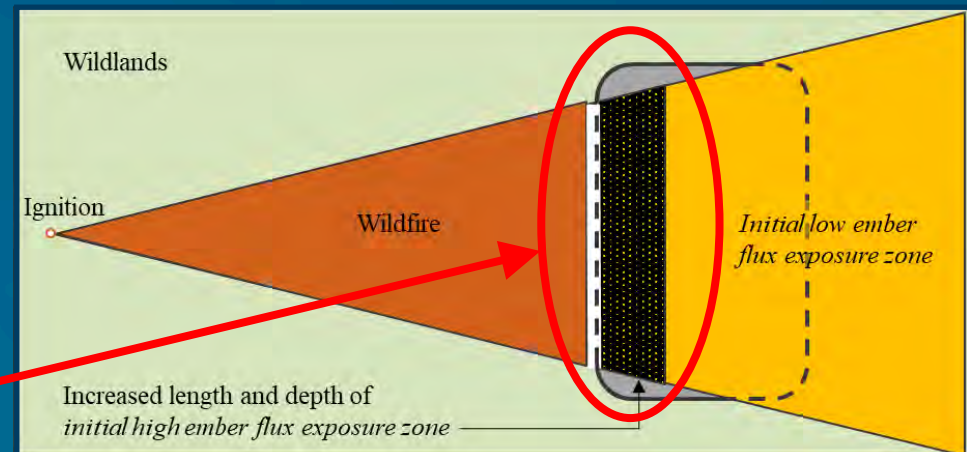
Idealized relationship between ignition location, near or far from WUI Community, and fire front and ember exposures reaching the community.

The wind is directed from left to right.

Critical difference in community-scale exposure



Ignition near WUI community



Ignition far from WUI community



Primary Driving Factors Summary

Summary:

- Ignition potential, terrain and wind played significant role is extreme fire behavior and losses
- Fuel density vegetative and structural/parcel level also played a significant role
- Fuel density is the only critical attribute that can be controlled on and around residential and commercial parcels
- Extend/size of fire front reaching the community rapidly overwhelmed available resources and impacted community evacuation

Implementation:

- Identify areas where local high winds may cause extreme fire behavior and consider how this may impact evacuations
- Consider fuels reductions within communities, at the parcel level, to reduce ignition potential
- Consider far field ignitions and potential size of fire front reaching the community under extreme conditions
- Consider far field ignitions when developing evacuation trigger points



Community WUI Fire Hazard Framework

- WUI fire spread has significant impact on communities well beyond the loss of structures:
 - community evacuation
 - incident response
- WUI Fire Hazard Framework components:
 - Community details
 - Demographics
 - Vegetative and structural fuels
 - Fire history
 - Weather
 - Notification / Evacuation
 - Critical infrastructure
 - Continuity of operations and government
 - Response

Standardized comprehensive community pre-fire hazard documentation is needed



Recommendations

- R1. Characterize fire behavior that leads to burnovers and quantify burnover severity. This information will inform fuel setback guidance for primary egress arteries and provide technical input to evacuation plans. (Section 10.3, F15, F16, F17, F18)
- R2. Develop technical guidance to quantify parcel level exposures. (Section 12.2, F20, F21, F22)
- R3. Quantify fire spread within parcels with focus on fire exposures. (Section 12.2, F20, F21, F22)
- R4. Quantify exposures from adjacent parcels, specifically from neighboring structures, and develop design guidance for structure separation distances. (Section 12.2, F20, F21, F22)
- R5. Develop methodology to connect field-collected ember data, such as ember flux and size distribution, to laboratory scales and develop worst case ember exposure criteria. (Section 15.2, F7, F10, F11)
- R6. Develop spacing/hardening cost benefit relationships for high energy release sources (fences, wood piles, sheds, vehicles, RVs, and residences) and target structures (residential and commercial). (Section 15.2, F20, F21, F22)
- R7. Characterize the relationships among fire history, fuel treatments, and fire behavior. (Section 14.2, Section 15.1, F5, F6, F7, F8, F9, F10, F11, F12, F13, F17, F19, F21, F22)
- R8. Develop a standardized methodology for assessing the exposures from ornamental vegetation. (Section 12.2, F20, F21, F22)
- R9. Develop a plant list for vegetation with unacceptably high fire hazard for northern California and other locations with WUI fire risks. (Section 12.2, F20, F21, F22)

BURNOVERS

PARCEL LEVEL EXPOSURES



THANK YOU!

Contributors – Technical Discussions

151 Technical Discussions

100 Fire Department

19 Law Enforcement

15 Town of Paradise

13 Transportation

2 Water Districts

1 Emergency Medical Services

1 National Weather Service



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Thank You

Contact Information:

Alexander Maranghides

alexm@nist.gov

202-567-1634

NIST

Eric Link

eric.link@nist.gov

NIST



Report: <https://doi.org/10.6028/NIST.TN.2135>

NIST Camp Fire Website:

<https://www.nist.gov/el/fire-research-division-73300/wildland-urban-interface-fire-73305/nist-investigation-california>



Extra Material



Camp Fire Location

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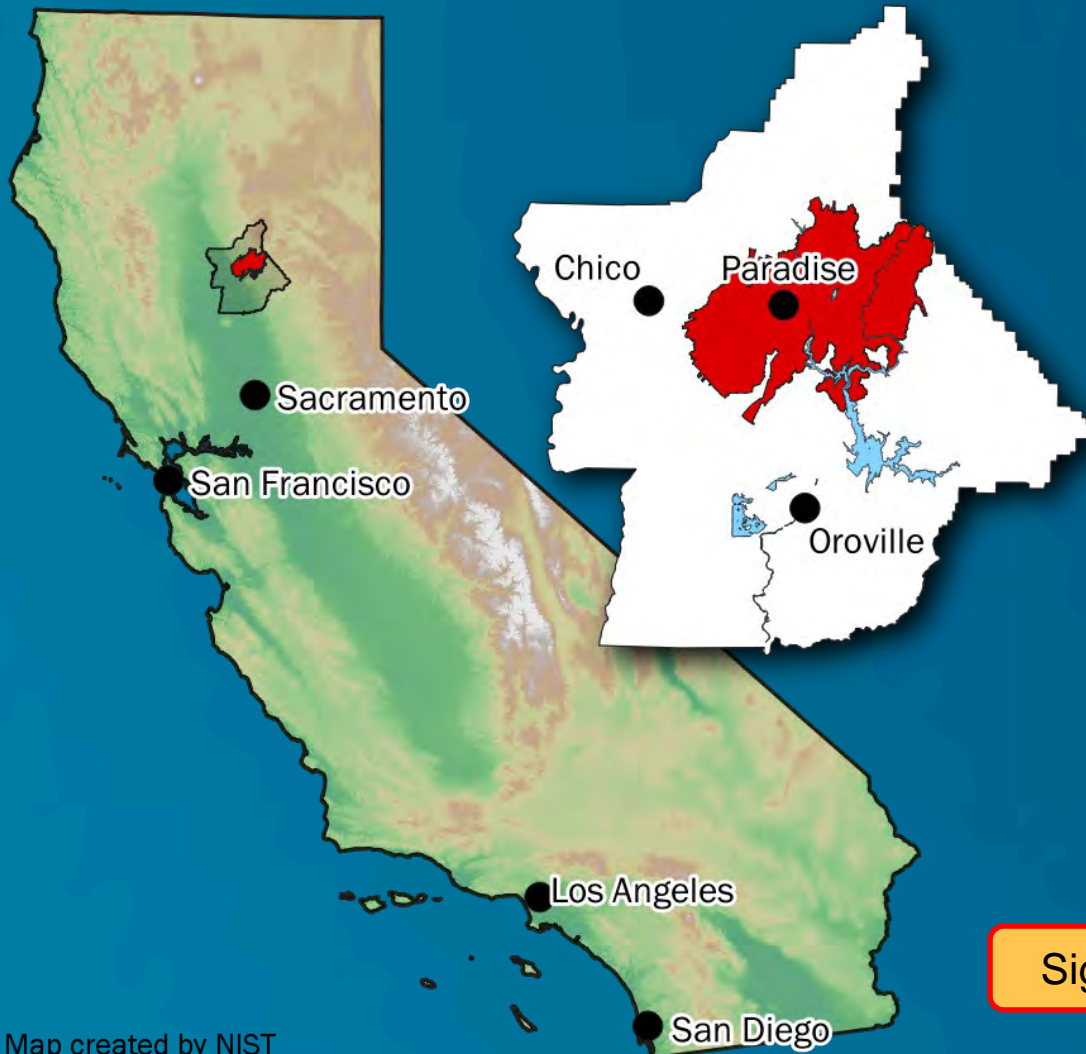
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Map created by NIST
Elevation: USGS | Fire Perimeter: NIFC
Boundaries, Places, Water: U.S. Census Bureau TIGER/Line Shapefiles

2018 Population*

Location	Pop.
Paradise	26 218
Magalia	11 310
Concow	710
Chico (Urban Area)	91 998
Oroville (Urban Area)	41 837
Butte County	227 075

Significant development started during Gold Rush (1850s)

Town incorporated in 1979



Previous NIST Case Studies and WUI Scale

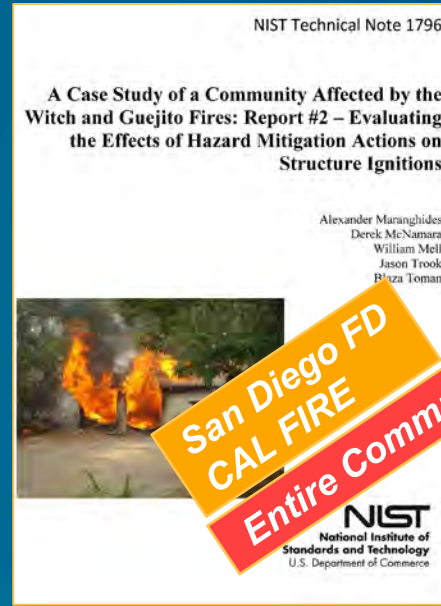
NIST TN 1635 (Witch #1)



**San Diego FD
CAL FIRE
Entire Community**

- Timeline reconstruction
- Defensive actions
- Structure ignitions
- Methodology for future developments

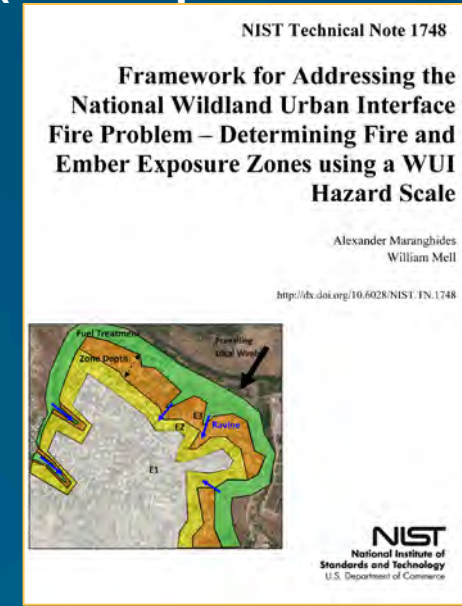
NIST TN 1796 (Witch #2)



**San Diego FD
CAL FIRE
Entire Community**

- Exposure quantification!!!
- Defensive actions
- Effectiveness of mitigation

NIST TN 1748 (WUI Exposure Scale)



- Exposure scale framework
- Linking exposure to building construction through codes and standards

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Previous NIST Case Studies and WUI Scale

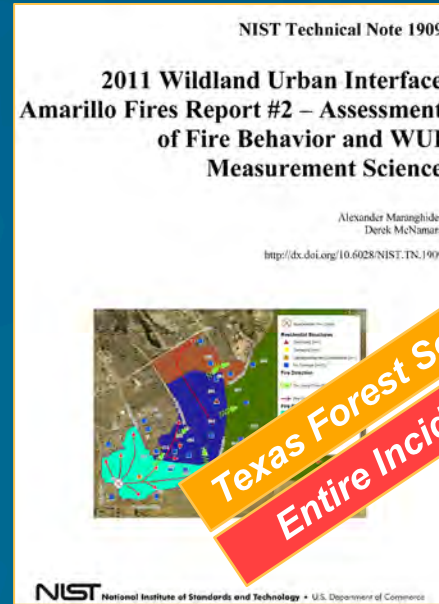
NIST TN 1708 (Amarillo #1)



Texas Forest Service
Entire Incident

- Deployment methodologies
- Damage Assessment Summary

NIST TN 1909 (Amarillo #2)



Texas Forest Service
Entire Incident

- “Area/Neighborhood” Case Studies
- Fire behavior

NIST TN 1910 (Waldo)



Colorado Springs FD
Entire Incident

- Defensive actions
- Timeline reconstruction
- Fire behavior

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Fire Impacts Pentz Road 08:53

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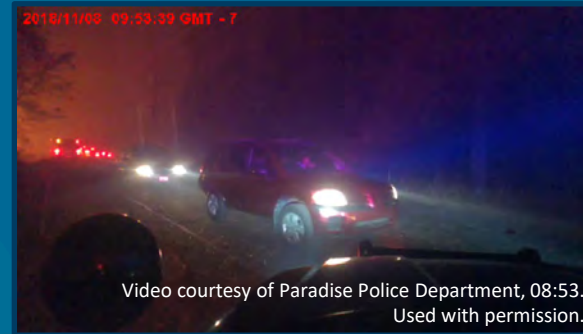
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a) $t=0$ s



b) $t=13$ s



c) $t=19$ s



d) $t=23$ s

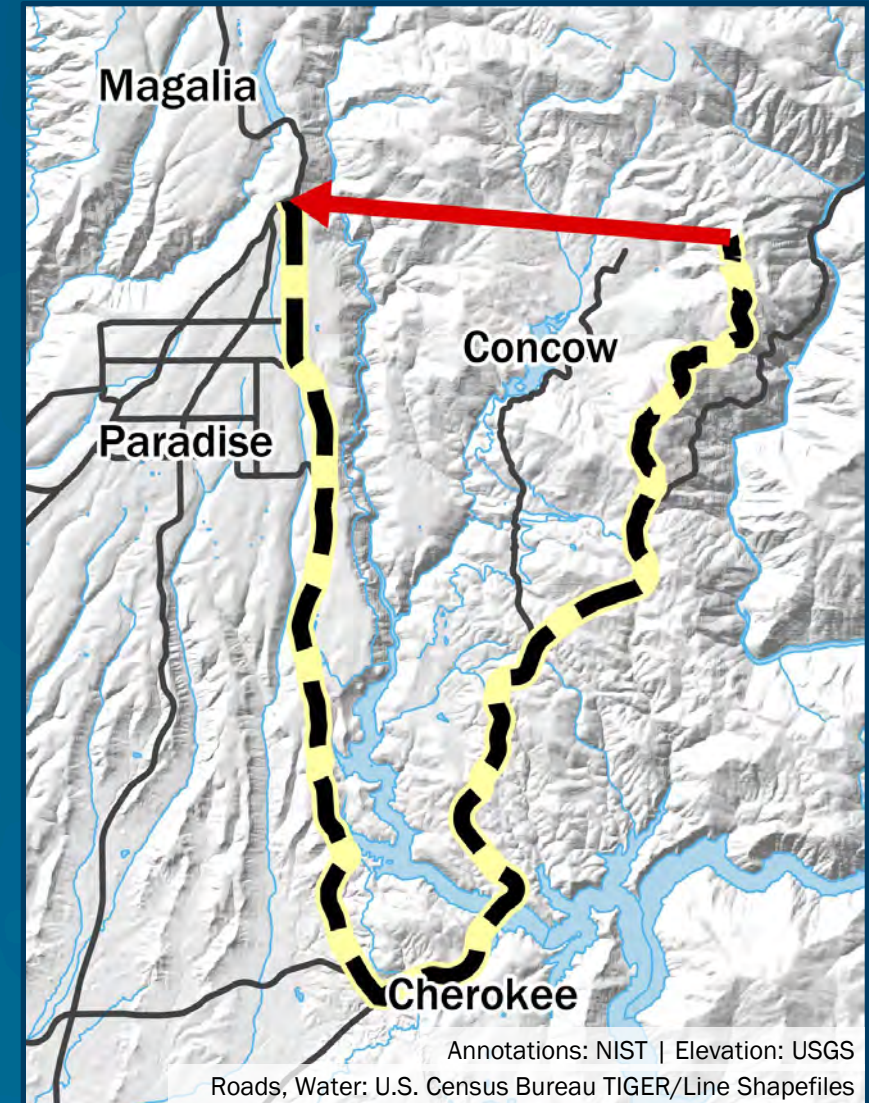


e) $t=37$ s

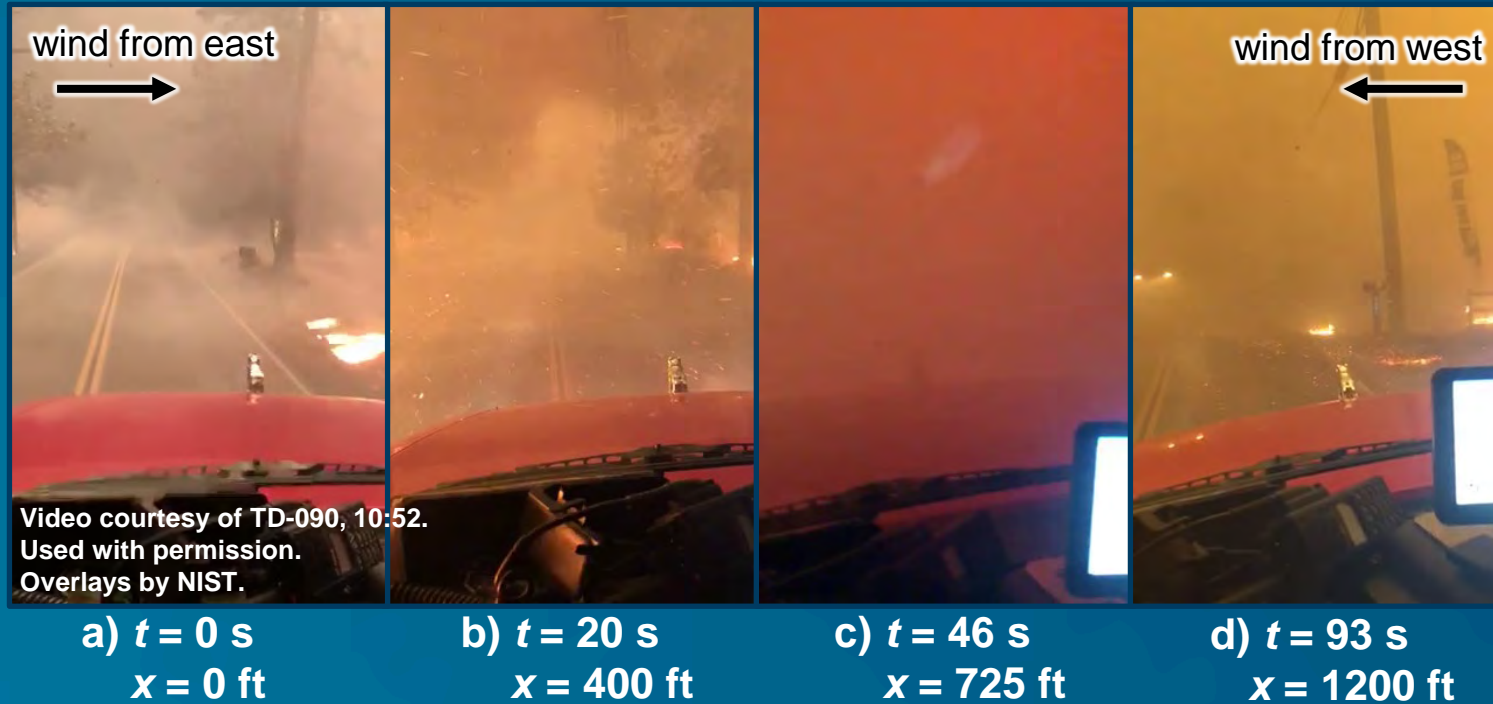


Impact of Winds, Wildland Fuels and Terrain on Fire Behavior

- Terrain restricted or slowed down access by first responders
- Rim Road to Skyway
 - 9.3 km (5.75 mi) straight line
 - 40 km (25 mi) and 43 minutes of drive time



Variability in Local Conditions - Smoke



- Visibility is intermittent and wind directions shift 180° over short distances and time periods.



Wildland Fire Pre-Plan – Butte County Fire Department

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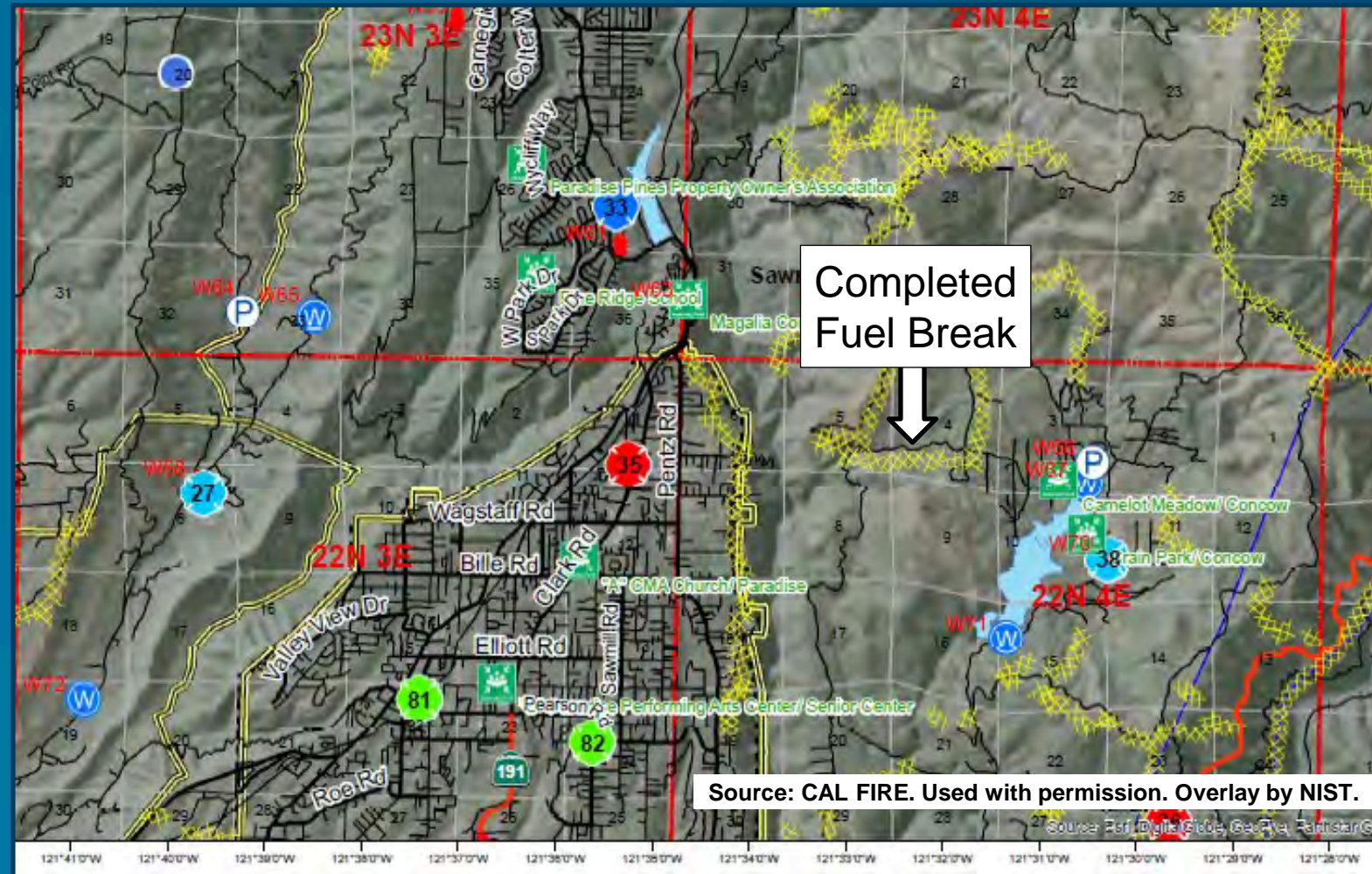
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Technical Findings

community preparedness / pre-fire conditions

fire spread and progression / burnovers / community characteristics



Technical Findings

Community Preparedness

- F1.** Communities did have multiple programs in place to increase awareness of and reduce fire hazards associated with WUI fires.
- F2.** The Town of Paradise did have an emergency notification and evacuation plan.
- F3.** Paradise Public Works staff had received training in how to respond to a WUI fire.
- F4.** Infrastructure was specifically addressed in pre-fire preparations.



Technical Findings

Pre-Fire Conditions

- F5.** Dry winds, with recorded gusts at Jarbo Gap exceeding 22 m/s (50 mi/h) from the northeast, increased fire spread in vegetative and structural fuels.
- F6.** Steep topographical features including river canyons and creek drainages channeled north winds and accelerated fire spread through vegetative fuels.
- F7.** Extremely dry vegetative fuels, associated with over 200 days without any significant precipitation, increased the fuel ignition potential around and within Concow, Paradise, and Magalia.
- F8.** Fire spread toward Paradise from Concow was fueled by heavy conifer forests with brush understory. At lower elevations oak woodlands and savannah grass were the primary fuels.



Technical Findings

Fire Progression

- F9.** Fire ignited near Pulga and Concow, was pushed by gusty wind across steep terrain toward Paradise, swept through Paradise, and then spread into Magalia.
- F10.** Extensive intermediate- and long-range firebrand spotting caused multiple ignitions ahead of the main fire line and resulted in different exposures to fire conditions.
- F11.** The fire travelled and/or spotted more than 11 km (7 mi) downwind of the origin to reach Paradise in less than 1.5 hours after ignition.



Technical Findings

Fire Progression

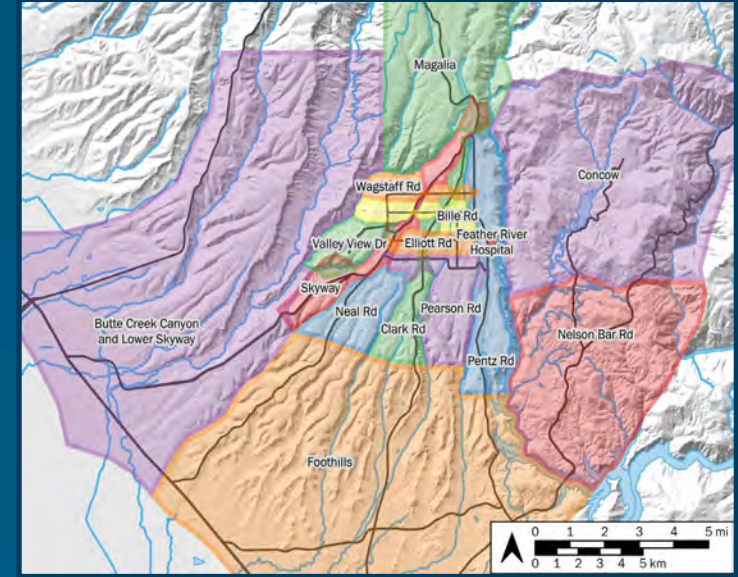
- F12.** Fire consumed a significant fraction of the Town of Paradise over a period of 6 hours, between 08:30 and 14:30.
- F13.** Fire spread down slope through the foothills at an average 1 m/s (2.2 mi/h, 180 ch/h) through grassy wildland fuels south and west of Paradise.
- F14.** Fire spread rates for Paradise and Magalia could not be readily computed due to extensive spotting fire behavior.



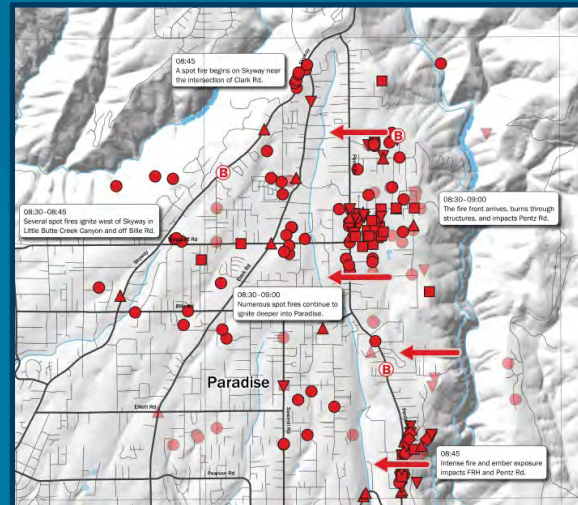
Technical Findings

Fire Spread Summary

- Overview in Executive Summary and report findings/conclusions (3 pages)
- Detailed fire behavior, by focus regions in body of report (71 pages)
- All the data in Appendix (113 pages, 8 font)



Focus Regions



E-size Maps – by time

Date	Time Range	Fire Behavior Observations	Location	Source #
11/8	06:25 - 06:40	First report of vegetation fire via 911. Caller reports fire under electric transmission lines within 6 m (20 ft) of lower, estimated size 30 m x 30 m (100 ft x 100 ft). Others call to report same fire.	West side Feather River, CA Hwy 70 at Poe Dam	911-001-1 911-002-1 911-004-1
11/8	06:45	First engine gets sight of well-established fire, reports difficult access in nearly inaccessible location. Approximately 15 m/s (35 mph) sustained winds. Captain declares potential for a major incident.	West side Feather River, CA Hwy 70 at Poe Dam	TD-028
11/8	06:45	Investigators determined a second power line ignition started another fire which was enveloped in the Camp Fire.	Near intersection of Rim Rd and Concow Rd	VTD-28
11/8	06:45	Fire begins threatening structures in Pulga.	Pulga	TD-029
11/8	07:10	Engine reports fire is now 80 ha to 120 ha (200 ac to 300 ac) with rapid rate of spread toward Concow Reservoir.	Pulga	TD-028
11/8	07:15	Fire spread SW from origin and got established in Flea Valley above Pulga.	Pulga	TD-028
11/8	07:20	Wind pushing fire up slope W, WSW, fire extending up slope and well beyond ridge to W	Pulga	TD-028
11/8	07:20	Multiple (5) small spot fires (3 m x 3 m, 10 ft x 10 ft) visible on east facing slopes west of Concow Reservoir.	West side of Concow Reservoir	TD-013
11/8	07:20	Engines attempting access to the north flank of the fire encounter large, well-established spot fire, 0.1 ha to 0.2 ha (0.25 ac to 0.5 ac).	Rim Rd between Concow and Pulga	TD-005
11/8	07:25	Spot fires are igniting in Concow and homes start to catch fire.	Concow	TD-062
11/8	07:30	Engines responding to Concow encounter 6 m x 6 m (20 ft x 20 ft) spot fire burning upwind, threatening homes.	Concow Rd at Cribbage Ln	TD-013
11/8	07:30	First 911 call reporting active fire in yard.	Concow	911-037-1
11/8	07:30	Spot fires up on Rim Rd have grown to several acres within 10 min, spreading up slope, consuming the draw.	Rim Rd between Concow and Pulga	TD-005
11/8	07:40 - 07:45	Multiple 911 calls report multiple spot fires just below Sawmill Peak, burning on the Paradise side.	Sawmill Peak	911-048-1 911-058-1
11/8	07:50	Fire is well-established in Concow. Multiple structures are burning, and fire is impacting evacuation.	Concow	911-075-1

Tables – by region

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Burnovers

- F15.** Multiple burnovers occurred during the Camp Fire.
- F16.** Burnovers adversely affected pre-planned evacuation routes and led to use of Temporary Refuge Areas.
- 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 and associated electrical and utility lines along roadways blocked multiple streets and impaired access for response and evacuation.



Technical Findings

Wildland Fire Ignition Relative to the Community

F19. The ignition of the fire in wildland fuels over 11 km (7 mi) from Paradise allowed the fire to grow in intensity and size before reaching the affected communities.



Technical Findings

Structure Ignition Pathways

- F20.** Post-fire field data collection and first responder observations identified structure ignition vulnerabilities including structure-to-structure ignition pathways.
- F21.** Fire spread through Paradise, and subsequently Magalia, was fueled by vegetative fuels, including ornamental shrubs, bushes, and trees; structural fuels, including homes, garages, detached auxiliary buildings, commercial occupancies; and cars, trucks, and campers.
- F22.** Separation distances between fuel packages within a parcel as well as between parcels did not prevent rapid fire spread.



Technical Findings

Community WUI Fire Hazard Evaluation Framework

F23. A standardized community wildland-urban interface hazard evaluation framework would improve assessment of fire risk for communities

Community WUI Fire Hazard Evaluation Framework

Community
Population
Notification
Evacuation
Infrastructure
Fire Fighting Response

Data Types
GIS Layers
Histograms
Other

Data Use
Pre-fire
During Fire
Post Fire

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