American Fires:

Water Infrastructure and Community Resilience

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A special thanks to the many people who made this possible

Our Focus

Water Safety and Disasters

Infrastructure Construction and Repair Technologies

Waste Materials and Management Solutions





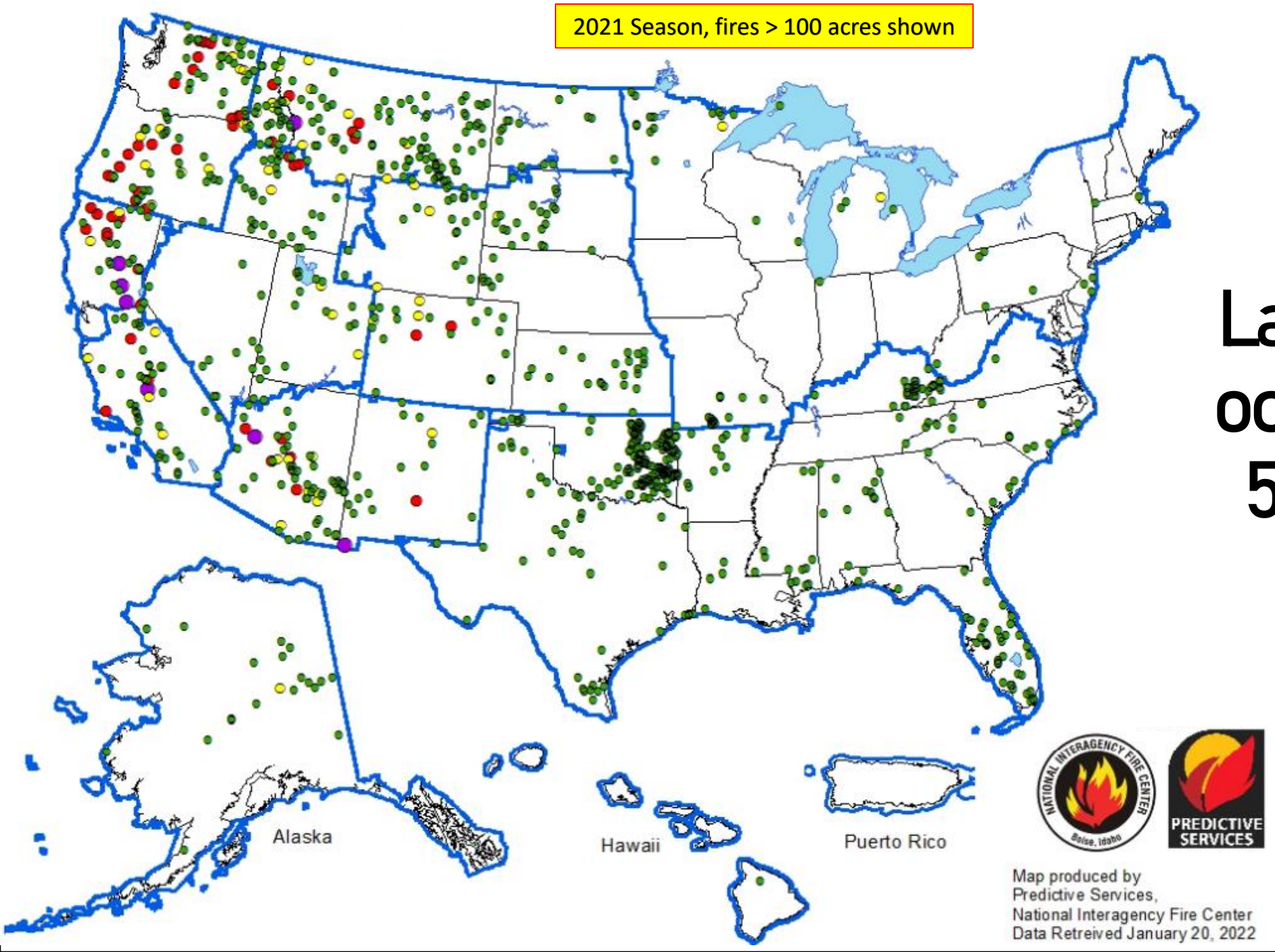



Resilience (n.)

The ability to bounce back from misfortune and change

Four Phases of Disaster and Emergency Management (per US FEMA)

1. **Mitigation**: BEFORE event, lessen loss of life and infrastructure.
2. **Preparedness:** BEFORE event, planning, training, and educational activities.
3. **Response:** Coordination and management of resources (including personnel, equipment, and supplies) utilizing the ICS in an all-hazards approach to reduce life/property/environmental safety impacts.
4. **Recovery:** Restoration activities that occur concurrently with regular operations and activities.



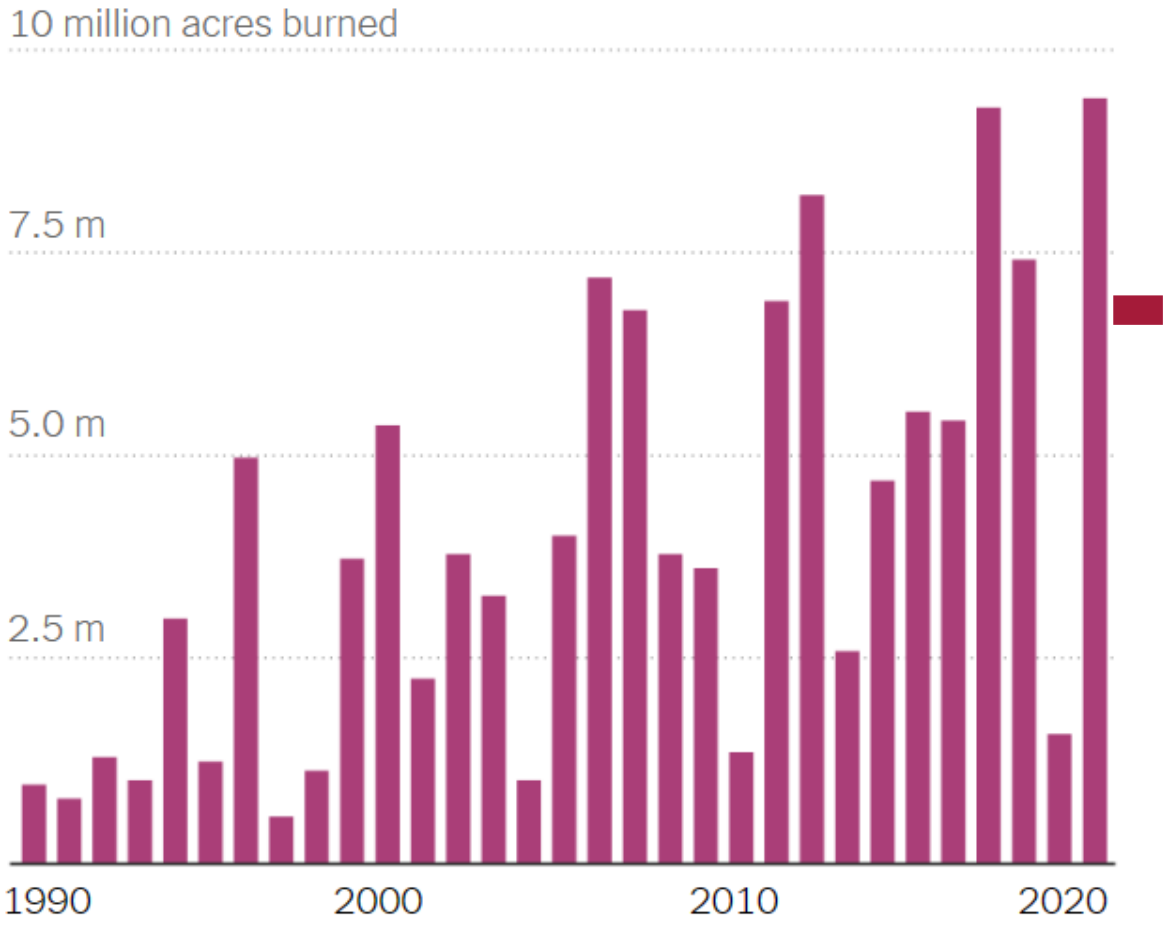
Large fires occur in all 50 states

Wildfires cause health and safety risks, and are increasing in intensity as well as the number of acres burned (UNEP 2022)

U.S. Fire Administration
Working for a fire-safe America

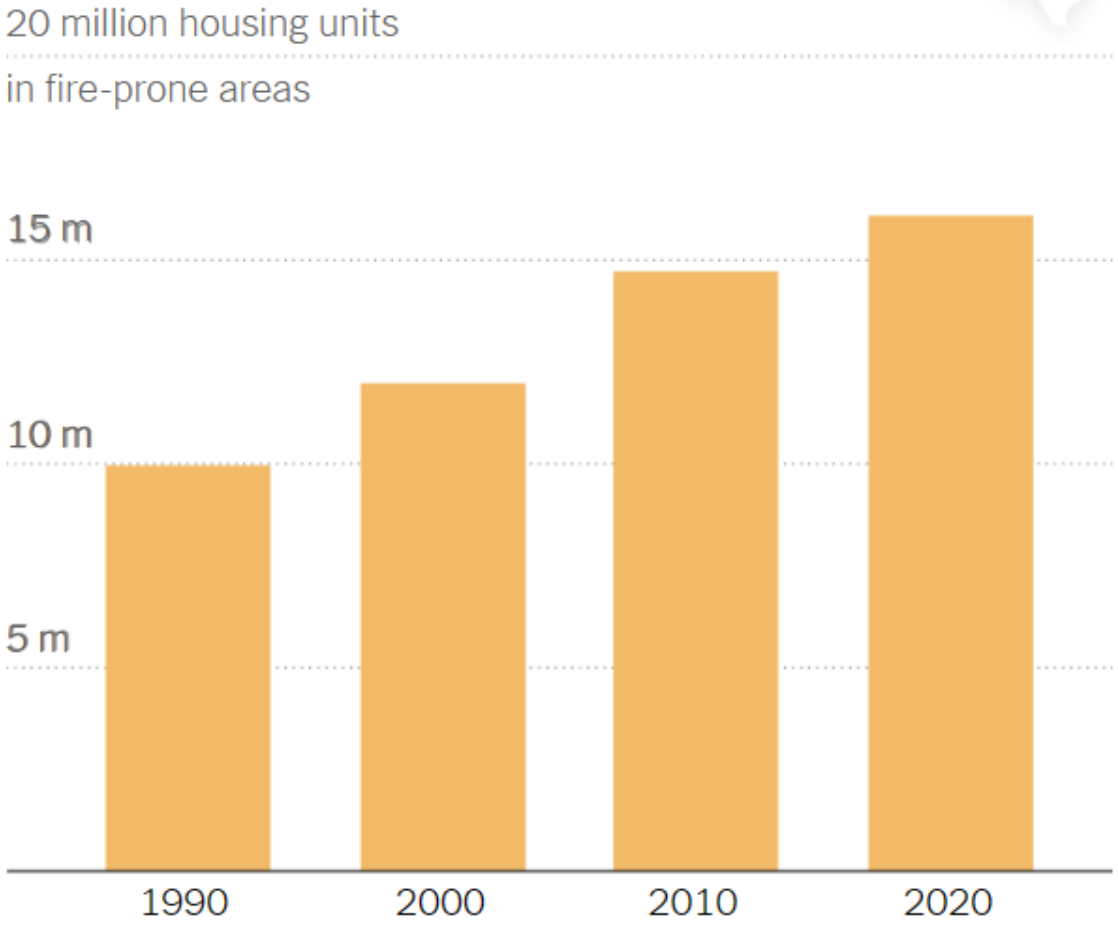
In the U.S. more than 46 million residences in 70,000 communities are at risk (USFA, 2022)

The amount of land burned in Western wildfires has increased.

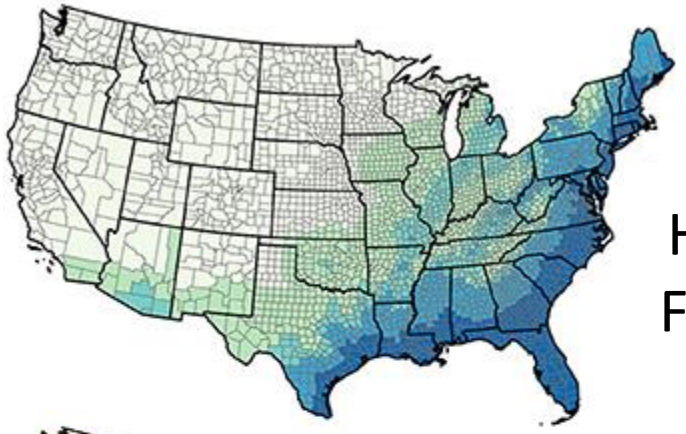


[SILVIS LAB – Spatial Analysis For Conservation and Sustainability – UW–Madison (wisc.edu)]

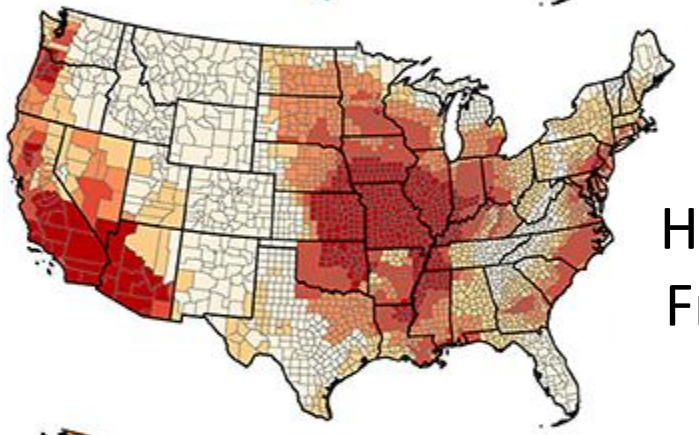
So has the number of people living in fire-prone areas.



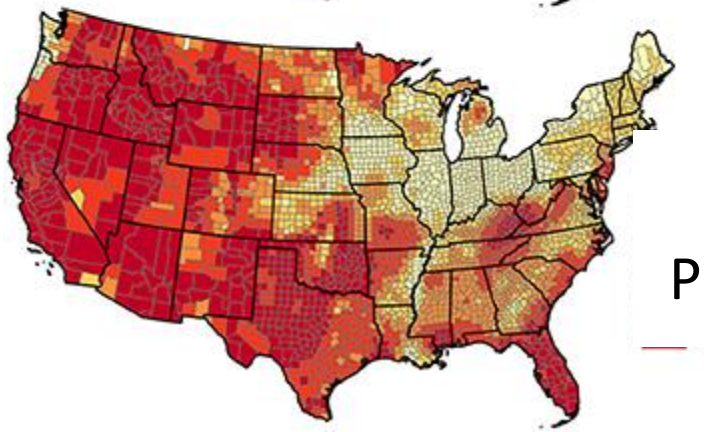
Popovich and Plumer. As Wildfires Grow, Millions of Homes Are Being Built in Harm's Way. *Wall Street Journal.* September 9, 2023.



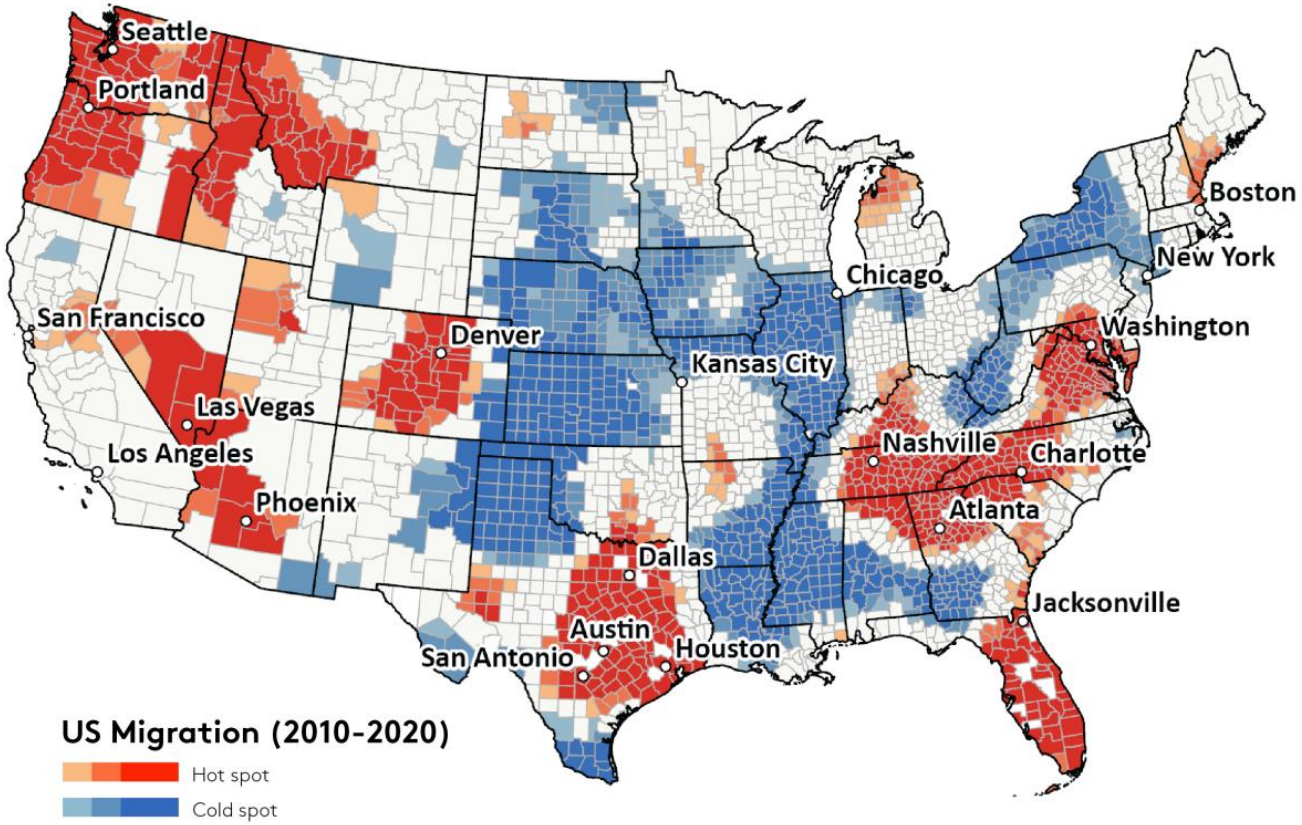
Hurricane Frequency



Heat Wave Frequency



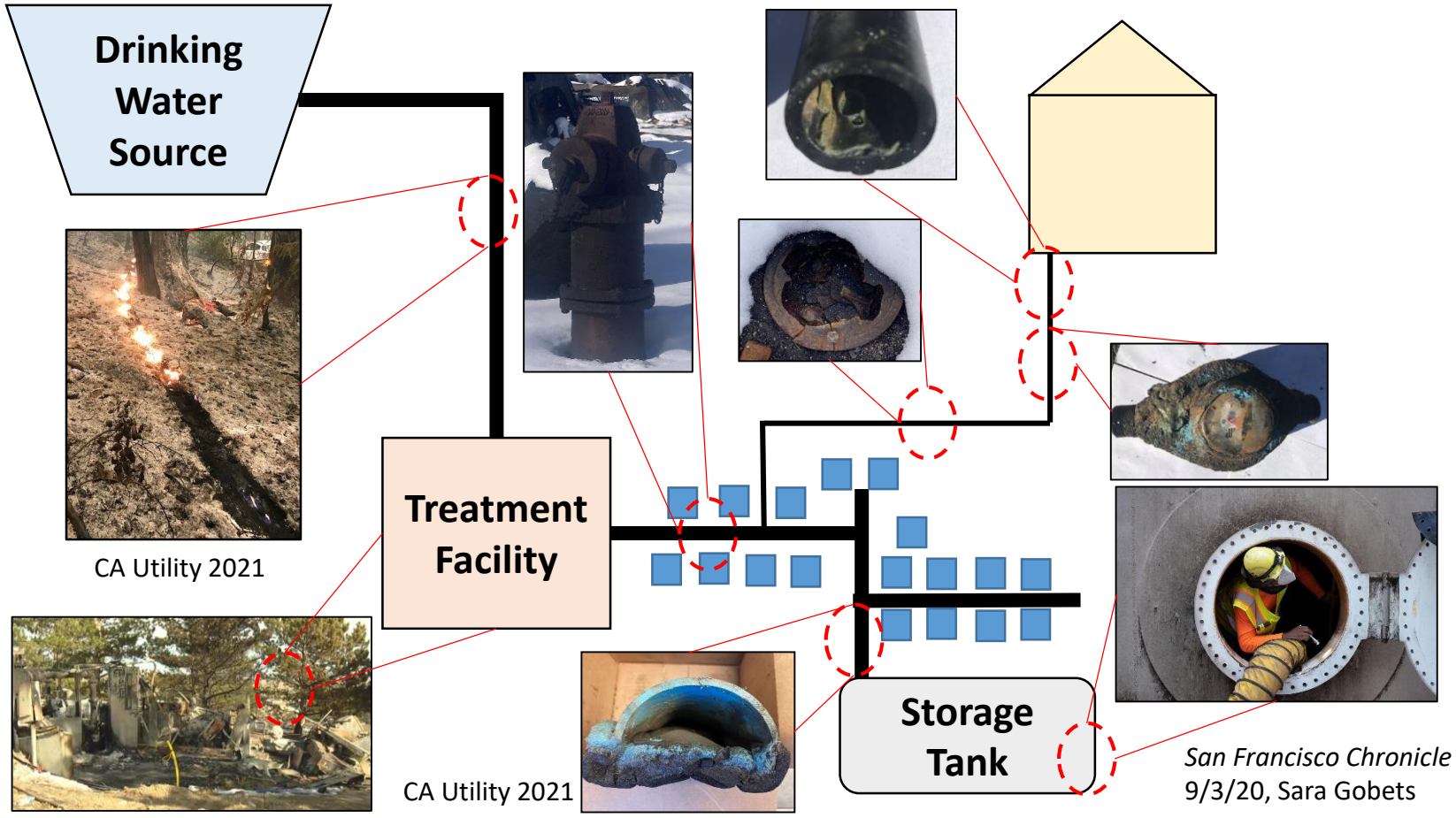
Wildfire Probability



Clark et al. 2022. *Frontiers in Human Dynamics.*
https://doi.org/10.3389/fhumd.2022.886545

Public water systems are vulnerable to fire.

USGS 2009



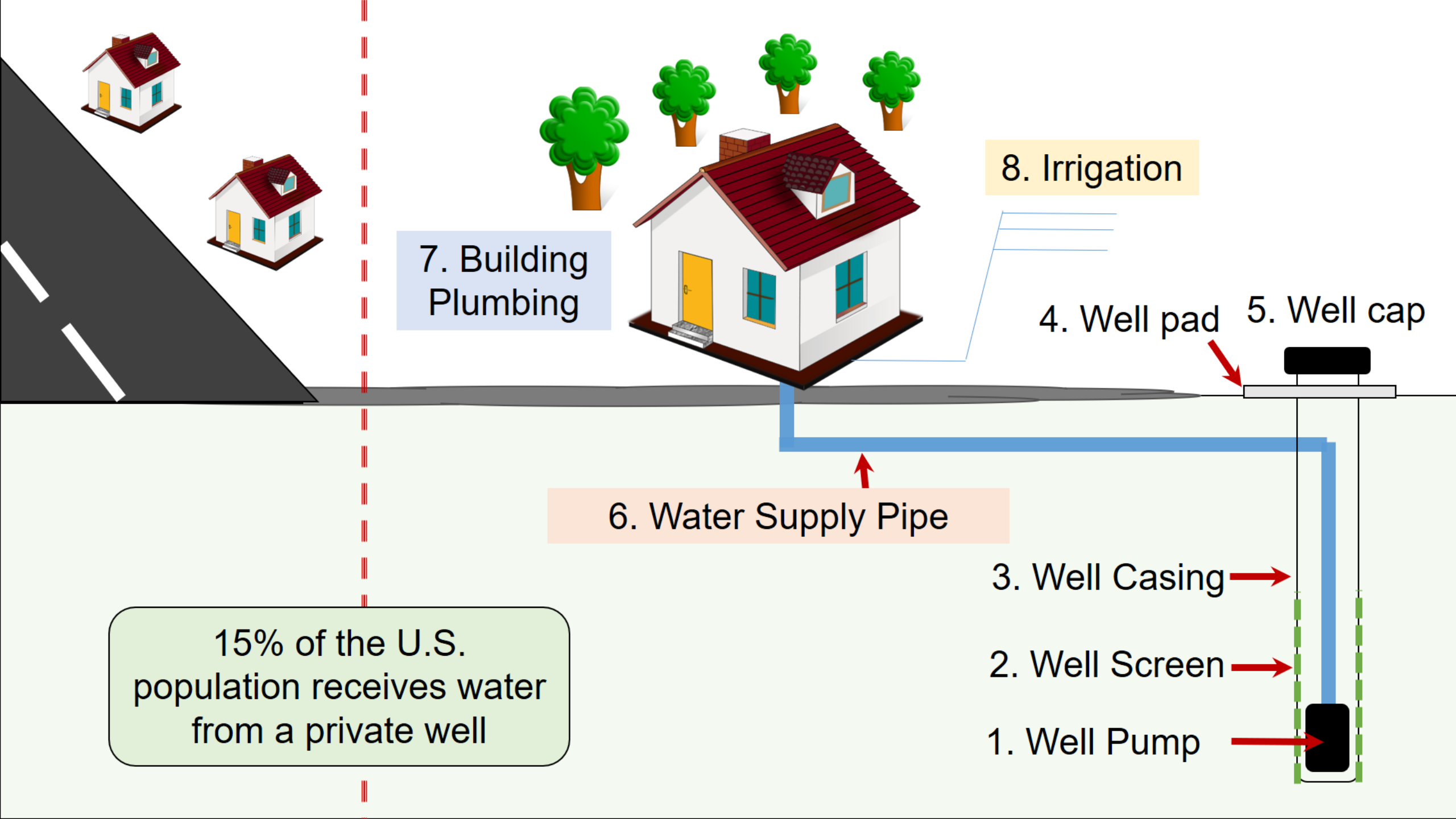
CA Utility 2021

CA Utility 2021

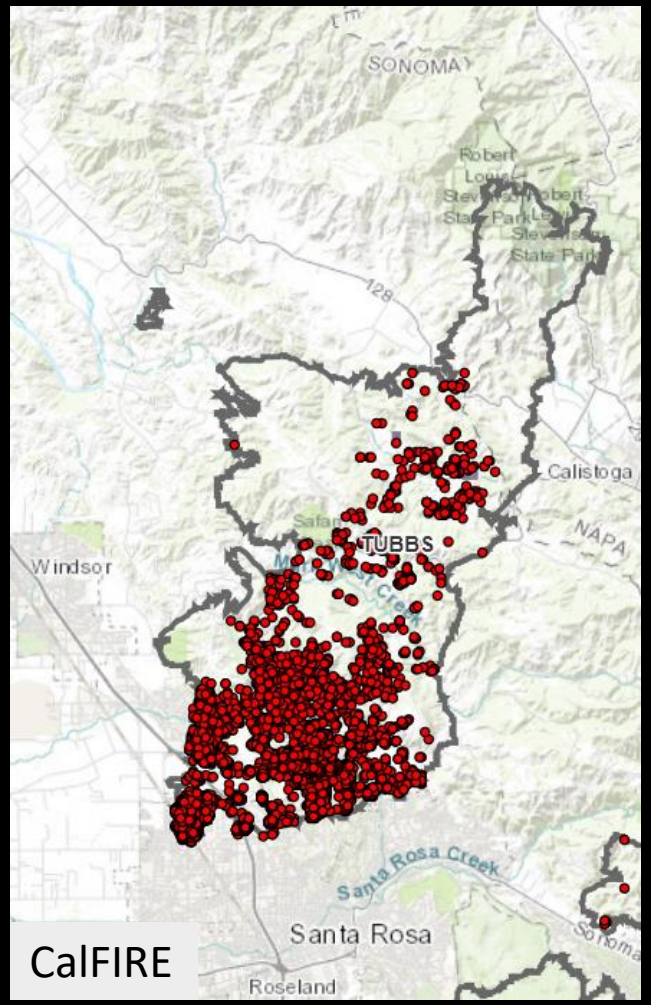
San Francisco Chronicle
9/3/20, Sara Gobets

2017-2021, fires chemically contaminated ***at least 11*** California and Oregon *water distribution systems*

Proctor et al. 2020
https://doi.org/10.1002/aws2.1183
Odimayomi et al. 2021
https://doi.org/10.1007/s11069-021-04714-9


8. Irrigation
7. Building Plumbing
4. Well pad
5. Well cap
6. Water Supply Pipe
3. Well Casing
2. Well Screen
1. Well Pump
15% of the U.S. population receives water from a private well

2017 Tubbs Fire: Drinking Water System Volatile Organic Compound (VOC) Contamination was Discovered



Oct. 8, Fire began – Oct. 31, 2017 contained, 36,807 acres

- 5,656 structures destroyed, in City of Santa Rosa 2,500 parcels burned

Oct. 10, City of Santa Rosa issued boil water advisory

Nov. 8, Drinking water *odor* complaint

- City found benzene > CA MCL (1 ppb) and USEPA MCL (5 ppb)

Nov. 10 – Oct. 11, 2018, Do Not Drink-Do Not Boil advisory

- 352 parcels in advisory area, 0.08% water mains, 0.2% hydrants, 5% of meters, ~5.2 miles
- *Affected only 9 of 13 standing homes (occupied)*
- Less than 20 people affected out of 175,155 on this water system
- Subsequent tests revealed much more VOC water contamination

Proctor et al. (2020) https://doi.org/10.1002/aws2.1183

Response and recovery was overseen by California's SWRCB and USEPA Region 9

- Initial estimated removal/replacement cost: $44 million
  - ❖Actual investigation and replacement cost: $8 million
- Multiple VOCs, SVOCs, TICs detected in the water
  - ❖Multiple VOCs exceeded acute and chronic drinking water exposure limits
- DND-DNB advisory based on early benzene results

JOINT INFORMATION CENTER
SONOMA FIRES: CENTRAL LNU COMPLEX
PRESS RELEASE

City of Santa Rosa

FOR IMMEDIATE RELEASE
MEDIA CONTACT: 707-565-3040

Date: November 10, 2017

Do-Not-Drink and Do-Not-Boil Water Advisory Issued for Two Specific Areas of Fountaingrove

SANTA ROSA, CA – The City of Santa Rosa Water Department has issued notices to customers in select areas advising them to stop drinking tap water due to recent damage to the water system resulting from the fires.

A total of 13 homes in Fountaingrove received the advisory notice after slightly elevated levels of contaminants were detected in two isolated areas. The Department advised residents in these areas to not use the tap water for drinking and cooking until further notice.
Since the wildfires, the Water Department has increased water sampling beyond required regulations to closely monitor the integrity of the water system and ensure high-quality drinking water for residents. The enhanced sampling identified the contamination, and confirmed that the contamination is isolated to two specific areas of Fountaingrove only. To address the contaminations, Santa Rosa Water is flushing clean water through the system.

Those in the impacted area received the following recommendations:

- Do not drink your tap water – use only bottled water. Bottled water should be used for all drinking (including baby formula and juice), brushing teeth, washing dishes, making ice and food preparation until further notice.
- Do not try and treat the water yourself. Because of the nature of the water contamination, boiling or disinfecting your water will not make it safe to drink.

When the advisory is lifted, properties in the affected areas will be individually notified, and a media notification will also be issued.

###

A Few Lessons Learned

- Water tested for 100+ chems, 34 routinely later in response
- Repeated location sampling was necessary to find contamination
- Stagnation "soak time" was needed to find contamination (often ≥ 72 hr)
- More chemicals than benzene exceeded acute and chronic exposure limits
- Sometimes ± 77% benzene difference in duplicate water samples for a single location
- Decided ≥ 0.5 ppb benzene prompted asset replacement
- Greatest VOC contamination found in service lines (max. 40,000 ppb benzene)
- All contaminated hydrants, water mains, ARVs, blow offs, service lines were replaced
- Long-term VOC monitoring required

The 2018 Camp Fire – A Different Scale

Executive Department
State of California

November 8, 2018

Proclamation of a State of Emergency

WHEREAS on November 8, 2018, the Camp Fire began burning in Butte County and continues to burn; and

WHEREAS this fire has destroyed homes and continues to threaten additional homes and other structures, necessitating the evacuation of thousands of residents; and

WHEREAS the fire has forced the closure of roadways and continues to threaten critical infrastructure; and

WHEREAS high temperatures, low humidity, and erratic winds have further increased the spread of this fire; and

WHEREAS the Federal Emergency Management Agency has approved a Fire Management Assistant Grant to assist with the mitigation, management, and control of the Camp Fire; and

WHEREAS the circumstances of this fire, by reason of its magnitude, are or are likely to be beyond the control of the services, personnel, equipment, and facilities of any single local government and require the combined forces of a mutual aid region or regions to combat; and

WHEREAS under the provisions of Government Code section 8558(b), I find that conditions of extreme peril to the safety of persons and property exists in Butte County due to this fire; and

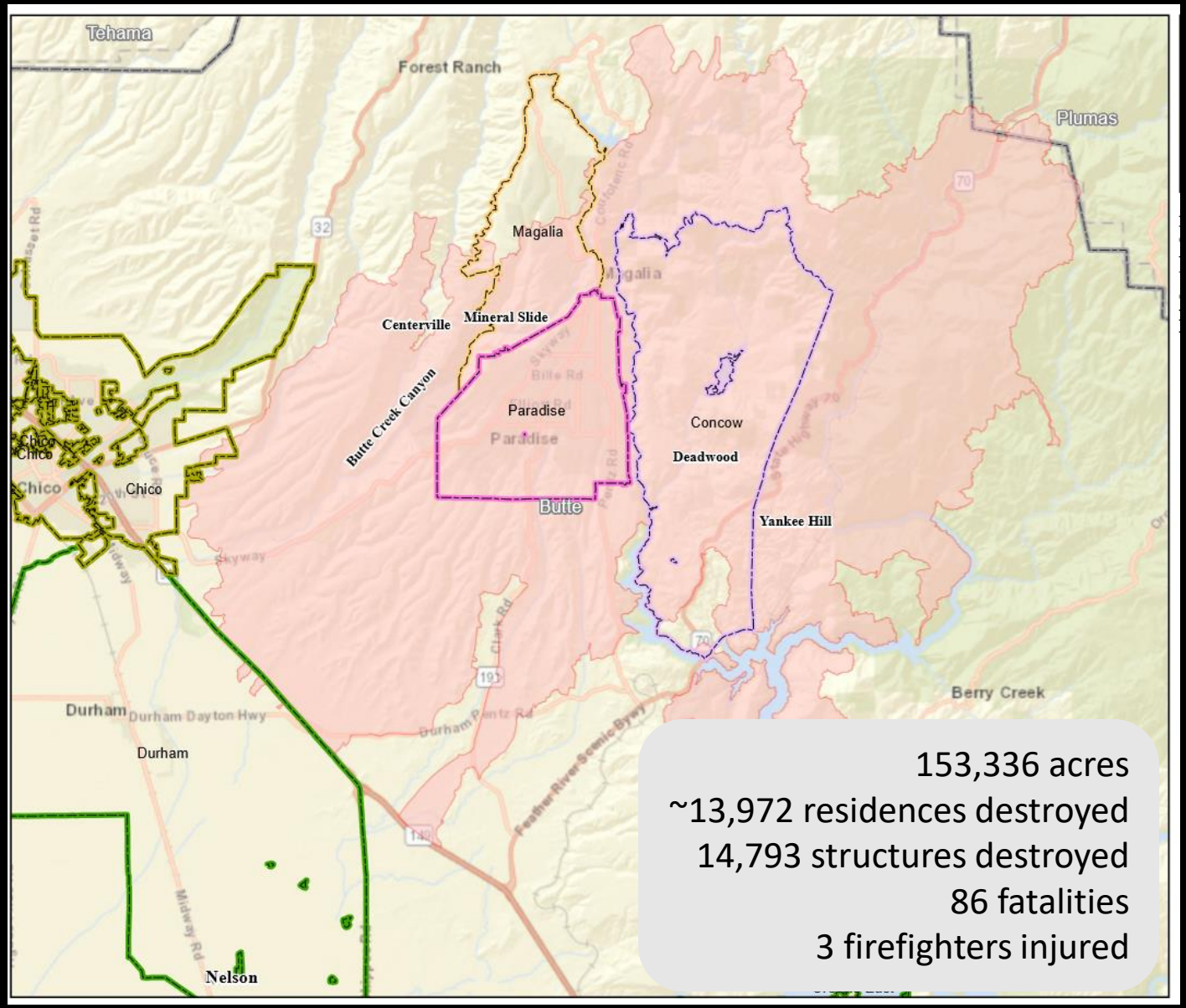
WHEREAS under the provisions of Government Code section 8571, I find that strict compliance with the various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the Camp Fire.

NOW, THEREFORE, I, GAVIN NEWSOM, Acting Governor of the State of California, in accordance with the authority vested in me by the State Constitution and statutes, including the California Emergency Services Act, and in particular, Government Code section 8625, **HEREBY PROCLAIM A STATE OF EMERGENCY** to exist in Butte County due to the Camp Fire.

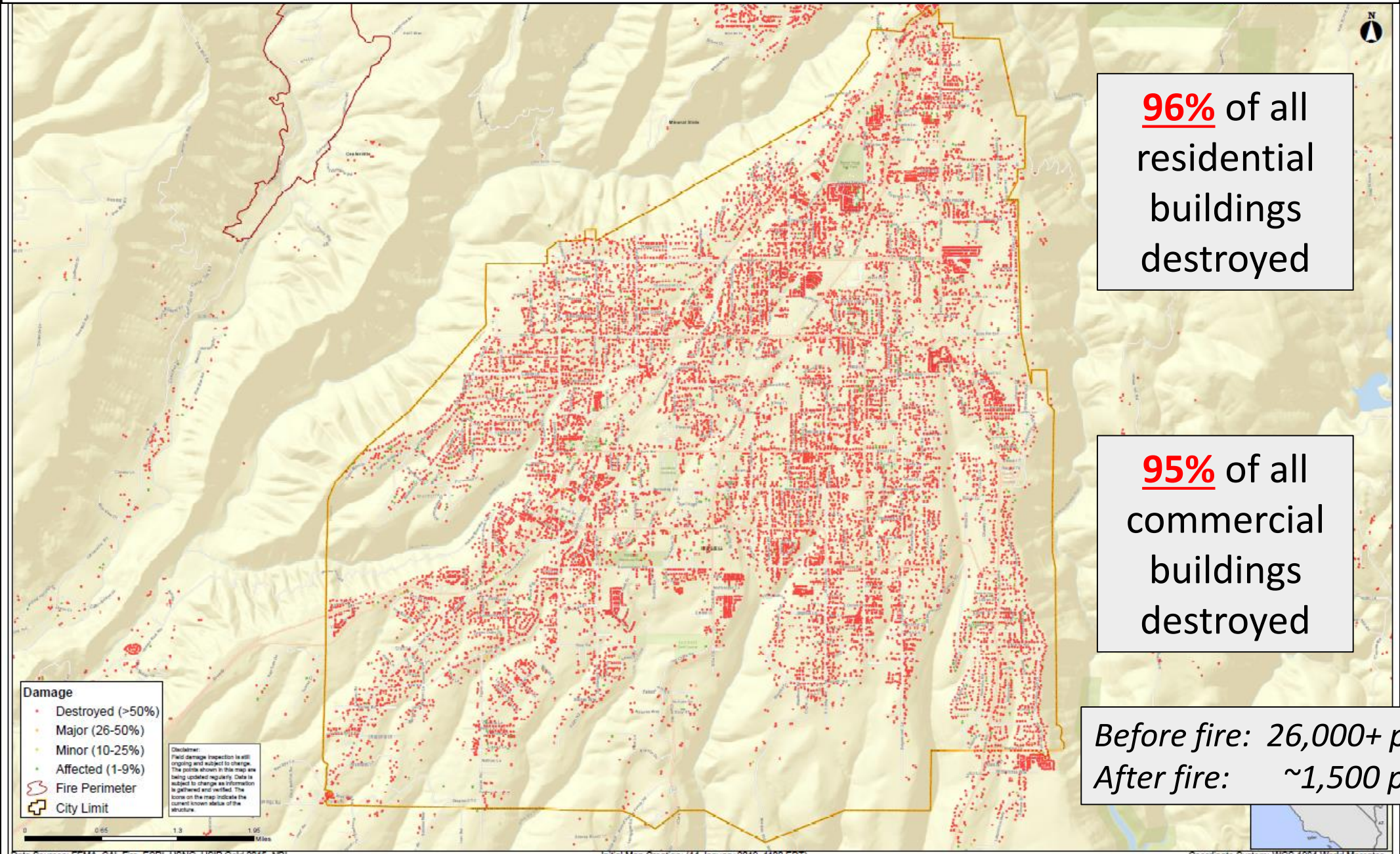
IT IS HEREBY ORDERED THAT:

1. All agencies of the state government utilize and employ state personnel, equipment, and facilities for the performance of any and all activities consistent with the direction of the Office of Emergency Services and the State Emergency Plan. Also, all citizens are to heed the advice of emergency officials with regard to this emergency in order to protect their safety.

2. The Office of Emergency Services shall provide local government assistance to Butte County, if appropriate, under the authority of the California Disaster Assistance Act, Government Code section 8680 et seq., and California Code of Regulations, Title 19, section 2900 et seq.



Town of Paradise Limits



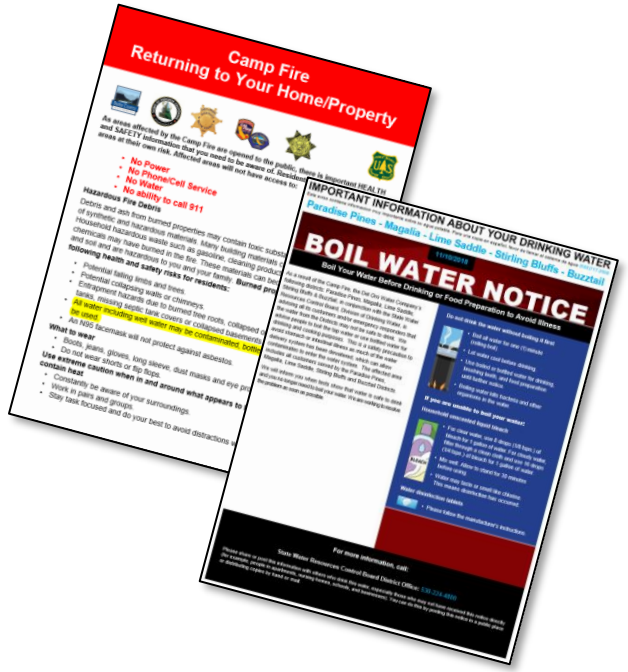
96% of all residential buildings destroyed

95% of all commercial buildings destroyed

Before fire: 26,000+ people
After fire: ~1,500 people

Public Water Systems (% Homes Gone)	Population	Source Water
Paradise Irrigation District (PID) (-96%)	26,032	Surface
Del Oro Water Company (DOWC) – Paradise Pines (-38%)	11,324	Surface
DOWC – Lime Saddle (-50%)	1,106	Surface
DOWC – Magalia (-89%)	924	Ground
DOWC – Stirling Bluffs (0%)	548	Surface
DOWC – Buzztail (-34%)	106	Ground
Foothill Solar Community	180	Ground
Forest Ranch Mobile Home Park	25	Ground
Forest Ranch Mutual Water Company	92	Ground
Gran Mutual Water Company	202	Ground
Humboldt Woodlands Mutual Water Company	75	Ground
Meadowbrook Oaks Mobile Home Park	50	Ground
Mountain Village Homeowners Association	40	Ground

Boil water advisories were issued to 40,000 people



Private wells
13,227 exist in Butte County
2,438 wells in Camp Fire area

February 2019

3 months post-fire





PURDUE UNIVERSITY

MANHATTAN COLLEGE

CalOES, SWRCB, BCHD, FEMA, PID, DOWC, Town, CalFire did not understand how to proceed

< 50 samples had been collected by PID & DOWC

Benzene testing only; State assumed benzene was the only chemical present

Our onsite recommendations:

- Find out what's in the water (not just benzene)
- Reevaluate water use restrictions
- Isolate → Test (72hr) → Decon/replace
- Population in homes needs help, they've been left to fend for themselves

Onsite Visit Response and Recovery Observations Presented to PID February 13, 2019

Purdue University & Manhattan College
Andrew J. Whelton, Ph.D., Amisha Shah, Ph.D.,
Juneseok Lee, Ph.D., P.E., Caitlin Proctor, Ph.D., David Yu, Ph.D.
Questions: awhelton@purdue.edu

A. Overall

- PID has done a good job in moving towards stabilizing their infrastructure. This includes repressurizing distribution systems, identifying damaged assets, fixing breaks/leaks, flushing out contaminated water, issuing appropriate water advisories, and other activities.
- The water system is still in the response phase because the system is not yet stabilized and there are many challenges to resolve: for example, how to test for contamination.
- Persons living in the disaster area have complicated the response because PID has had to take action to both respond to their system damage but also to requests of customers.
- A recommendation is that PID focus on completing the response and moving into recovery, but this is and will continue to be slowed by multiple demands on limited resources. For example, PID staffing has been reduced since the disaster took place and the disaster has created an enormous need for additional staffing for response and recovery.
- A critical element to moving forward in a timely manner will be clear and straight-forward recommendations from CalOES and FEMA regarding funding of response efforts.


11,000+ homes

Damage

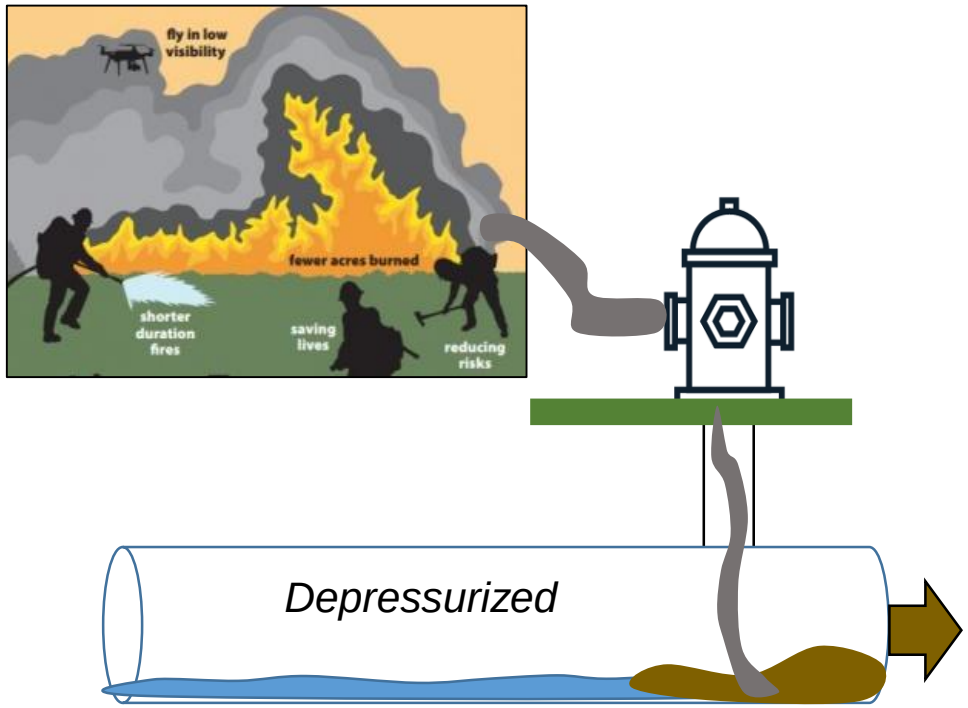
For the Tubbs Fire and Camp Fire, VOCs exceeded *acute* and *chronic* exposure limits

Chemical	Tubbs Fire (11 mo.)		Camp Fire (6 mo. post-fire)					
	Santa Rosa 5.2 miles		PID 172 miles		SWRCB in PID	DOWC (3 systems)		Short-term USEPA 1d-Health Advisory
	n	Max	*n*	Max	*n*=1	*n*	Max	Exceeded
Benzene	8,222	**40,000**	509	**923**	**>2,217**	41-26-82	**8.1**-0-**46**	**Yes (200)**
Methylene chloride	-	< 5	p	**15**	-	p	p	No
Naphthalene	661	**6,800**	p	278	**693**	p	p	**Yes (500)**
Styrene	6,062	**460**	p	**100**	**378**	p	p	No
TBA (NL)	339	**29**	p	**13**	-	p	p	-
Toluene	8,222	**1,130**	p	100	676	p	p	No
Vinyl chloride	6,062	**16**	p	**1**	-	p	p	No

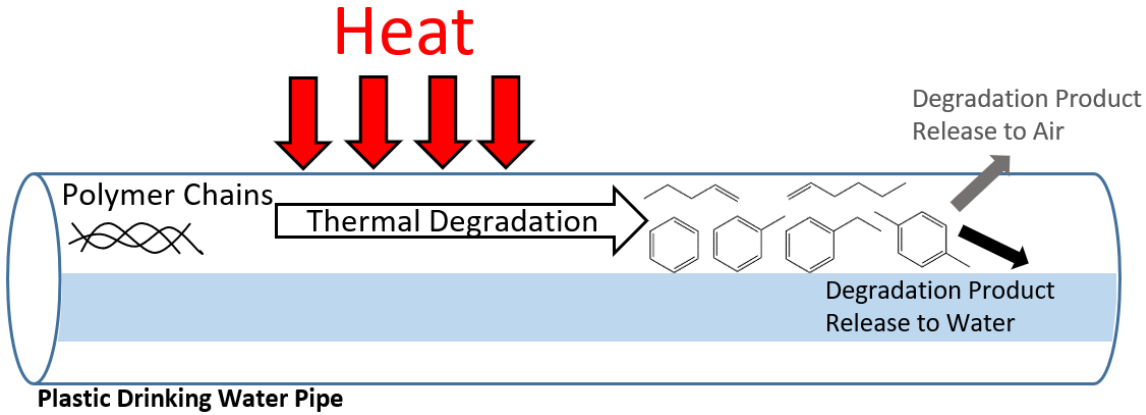
PID used 72 hr stagnation time; DOWC sometimes, but often used 0 hr
p = Utilities did not disclose enough information about their data

Potential PRIMARY Sources

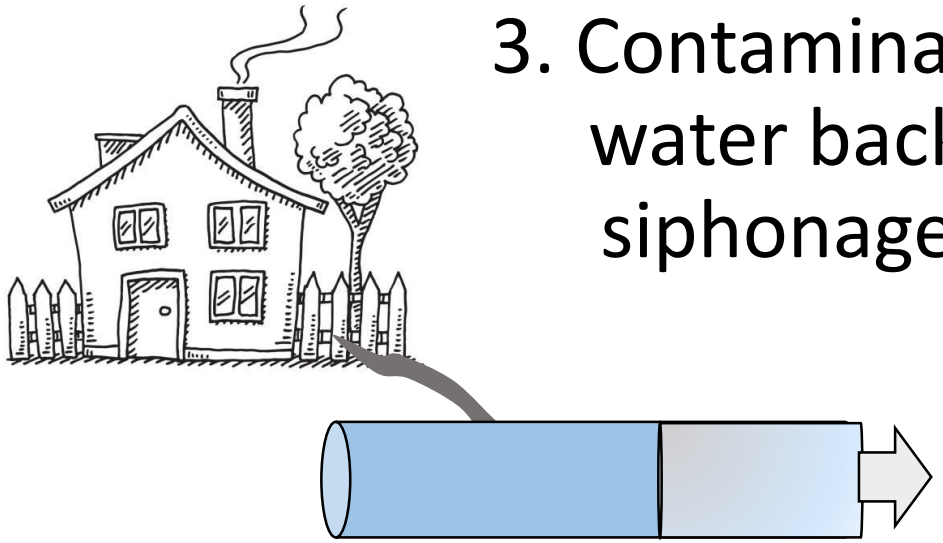
1. Forest biomass or structure combustion



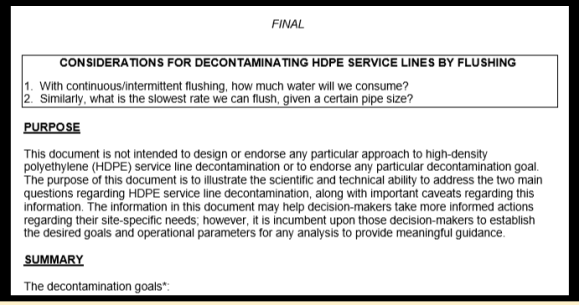
2. Plastic thermal degradation



3. Contaminated water back siphonage



Secondary Sources: Infrastructure desorption



FINAL

CONSIDERATIONS FOR DECONTAMINATING HDPE SERVICE LINES BY FLUSHING

1. With continuous/intermittent flushing, how much water will we consume?
2. Similarly, what is the slowest rate we can flush, given a certain pipe size?

PURPOSE

This document is not intended to design or endorse any particular approach to high-density polyethylene (HDPE) service line decontamination or to endorse any particular decontamination goal. The purpose of this document is to illustrate the scientific and technical ability to address the two main questions regarding HDPE service line decontamination, along with important caveats regarding this information. The information in this document may help decision-makers take more informed actions regarding their site-specific needs; however, it is incumbent upon those decision-makers to establish the desired goals and operational parameters for any analysis to provide meaningful guidance.

SUMMARY

The decontamination goals*:

Science was applied to some water distribution system testing and decontamination decisions, but not all

Stagnation needed for sampling

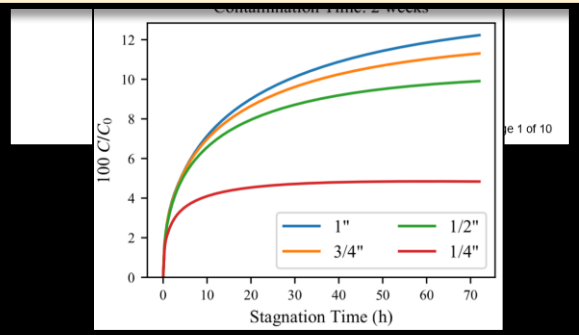
Water Distribution System Decontamination

Collaboration between Us & USEPA

Hydraulics

Polymer Science

Environmental Engineering



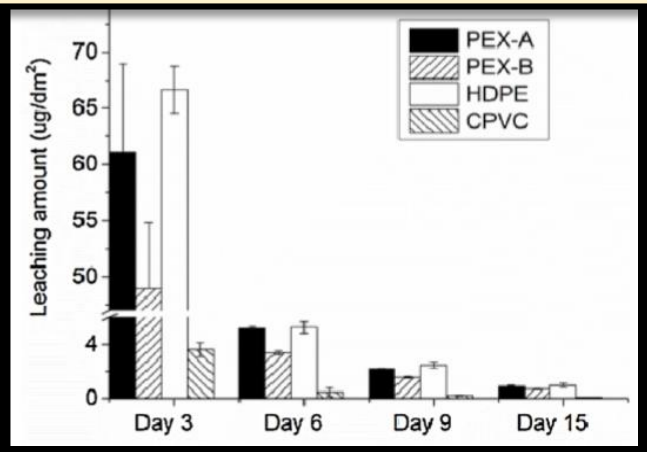
Numerical modeling:

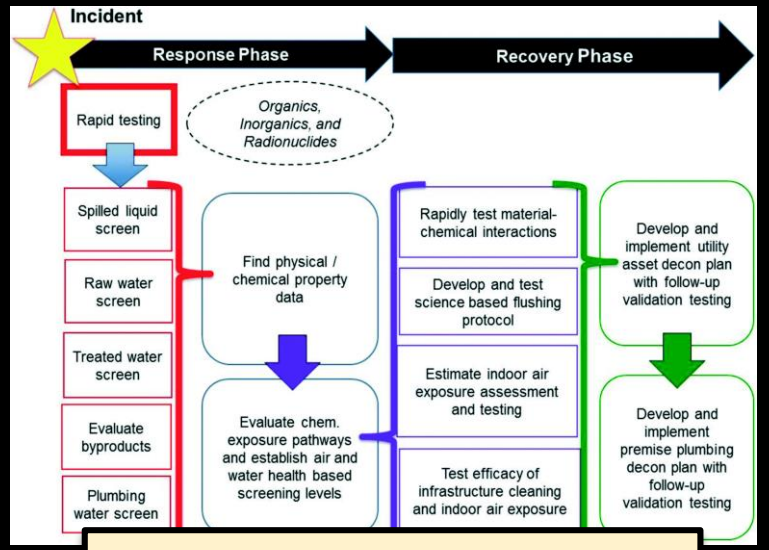
Greater than 286 days vs. less than 64 days of continuous water flushing for 1-inch HDPE service line

(Haupert et al. 2019)

Purdue *(Huang et al. 2017)*

Different plastic pipes uptake and leach different amounts of VOCs and SVOCs





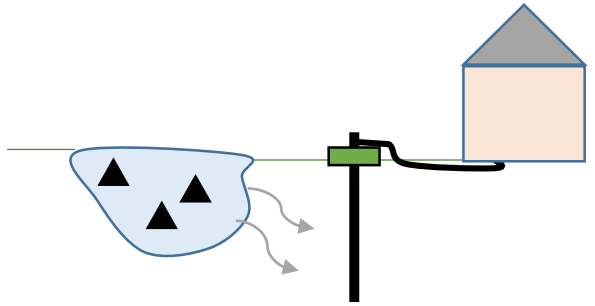
Purdue *(Whelton et al. 2017)*

There is a step-wise process for responding to and recovering from contamination

6 Months Later, Households were Largely on their Own

Water use advisories

- 2 DOWC systems contaminated, but have no water advisory
- Some PID customers are not following water use restrictions
- 26 ppb benzene = acute exposure risk (PID >2,217 ppb, DOWC = 530 ppb)



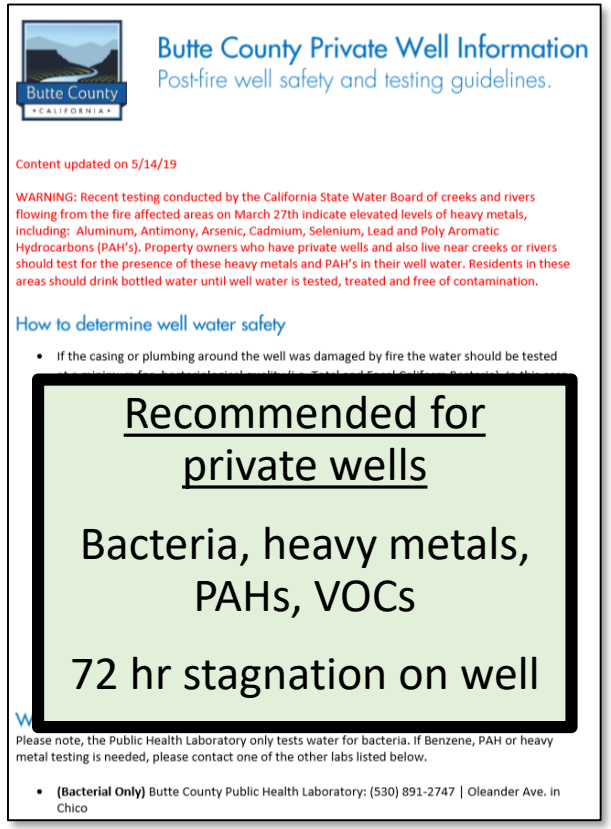
Contaminated water was entering homes

- Utilities were trying to identify their contaminated assets
- Loss of pressure (main break, leak) *could move* contaminated water into a standing home service line

Plumbing received months of contaminated water

Now nonpotable plumbing?
Varied plumbing complexity
Paying for water testing, results not representative
No credible plumbing testing guidance
Irrigation system contamination
External water tank maintenance and microbiological growth
Some have no economic capacity to purchase bottled water, devices

Insurance companies were the in-home treatment deciders



Butte County Private Well Information

Post-fire well safety and testing guidelines.

Content updated on 5/14/19

WARNING: Recent testing conducted by the California State Water Board of creeks and rivers flowing from the fire affected areas on March 27th indicate elevated levels of heavy metals, including: Aluminum, Antimony, Arsenic, Cadmium, Selenium, Lead and Poly Aromatic Hydrocarbons (PAH's). Property owners who have private wells and also live near creeks or rivers should test for the presence of these heavy metals and PAH's in their well water. Residents in these areas should drink bottled water until well water is tested, treated and free of contamination.

How to determine well water safety

- If the casing or plumbing around the well was damaged by fire the water should be tested

Recommended for private wells

Bacteria, heavy metals, PAHs, VOCs

72 hr stagnation on well

Please note, the Public Health Laboratory only tests water for bacteria. If Benzene, PAH or heavy metal testing is needed, please contact one of the other labs listed below.

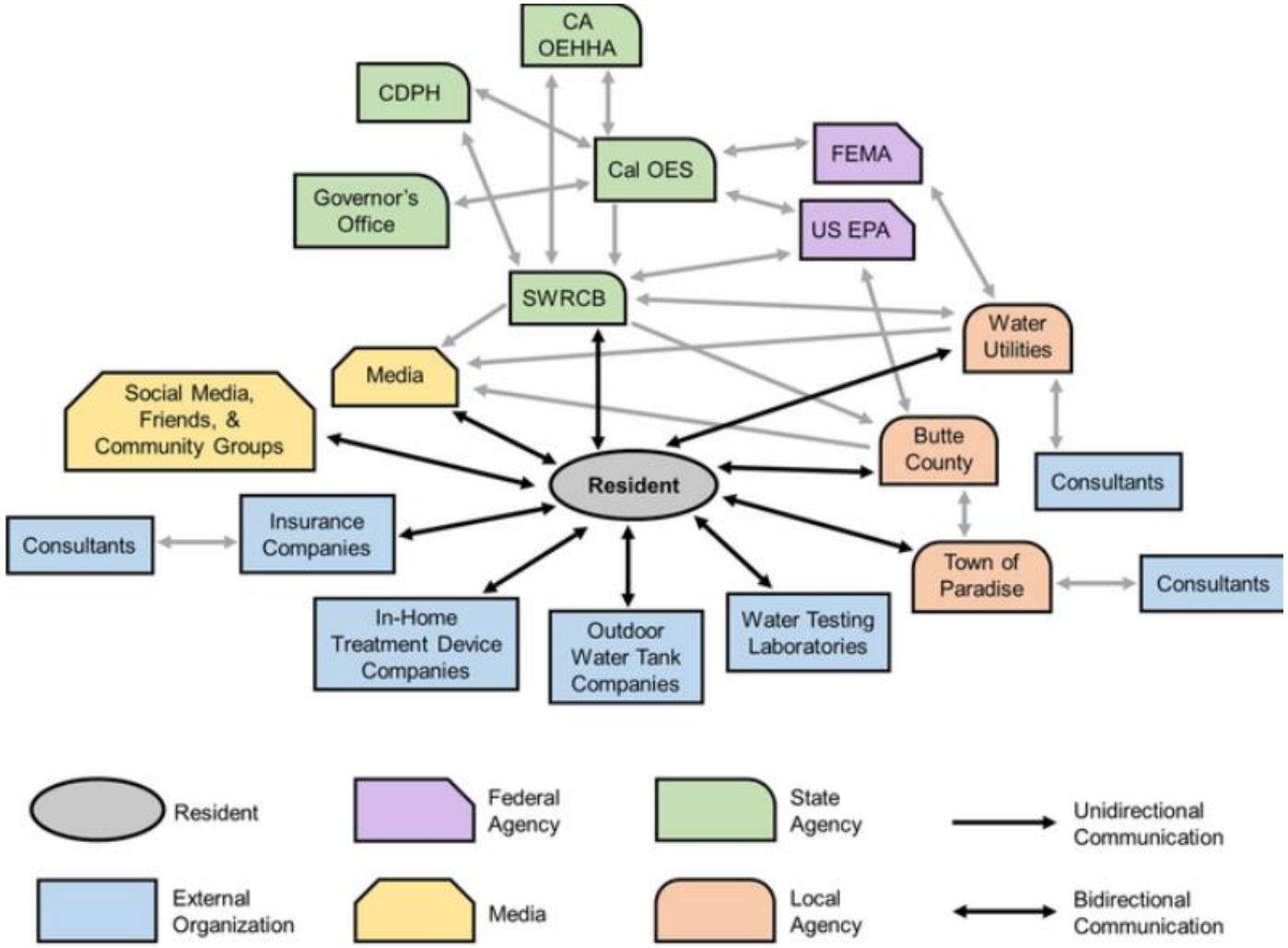
- **(Bacterial Only)** Butte County Public Health Laboratory: (530) 891-2747 | Oleander Ave. in Chico

Water safety attitudes, risk perception, experiences, and education for households impacted by the 2018 Camp Fire

Natural Hazards, Published May 2021 https://doi.org/10.1007/s11069-021-04714-9

Critical Public Health Issues

1) Water use restrictions,
2) **Plumbing** sampling and testing,
3) **Plumbing** decontamination methods and validation,
4) Water tank selection and maintenance,
5) In-home treatment device selection and maintenance, and
6) **Plumbing** design and material selection for property repairs and new construction.



CHICO STATE

PURDUE UNIVERSITY

Butte College
DISTRICT BUTTE - GLENN COMMUNITY COLLEGE

Berkeley
UNIVERSITY OF CALIFORNIA

1 Year After the Fire

Population: Less than 3,000 of 26,000 pre-fire (now certified as rural)

Homes rebuilt: 11 of the 11,000+ homes that were destroyed

Debris removed: 7.3 billion pounds of ash, debris, metal, concrete, and contaminated soil (2x the debris from the 9/11 World Trade Center)

PID water:

- 150 of 172 miles of water main cleared free of contamination
- 47% of meter/service lines 'standing structures' cleared of contamination; Service lines to destroyed structures still need testing, maybe contaminated

Homeowners:

- Responsible for testing THEIR service line and THEIR plumbing – *negligible support*
- Insurance only sometimes covered plumbing testing and not full plumbing
- Many exclusively relied on in-home treatment systems, some on water tanks
- Some stayed, some returned, others left, others uncertain

A few more lessons …

State and 1 private utility said that if water doesn't have an odor, it is safe [WRONG]

Some laboratories incorrectly told survivors how to collect water samples

When benzene not present other VOCs exceeded drinking water exposure limits

California conducted testing on State employees using the contaminated drinking water – and then documented acute chemical exposure symptoms

California found lab reproducibility issue: ± 287% benzene difference in duplicates

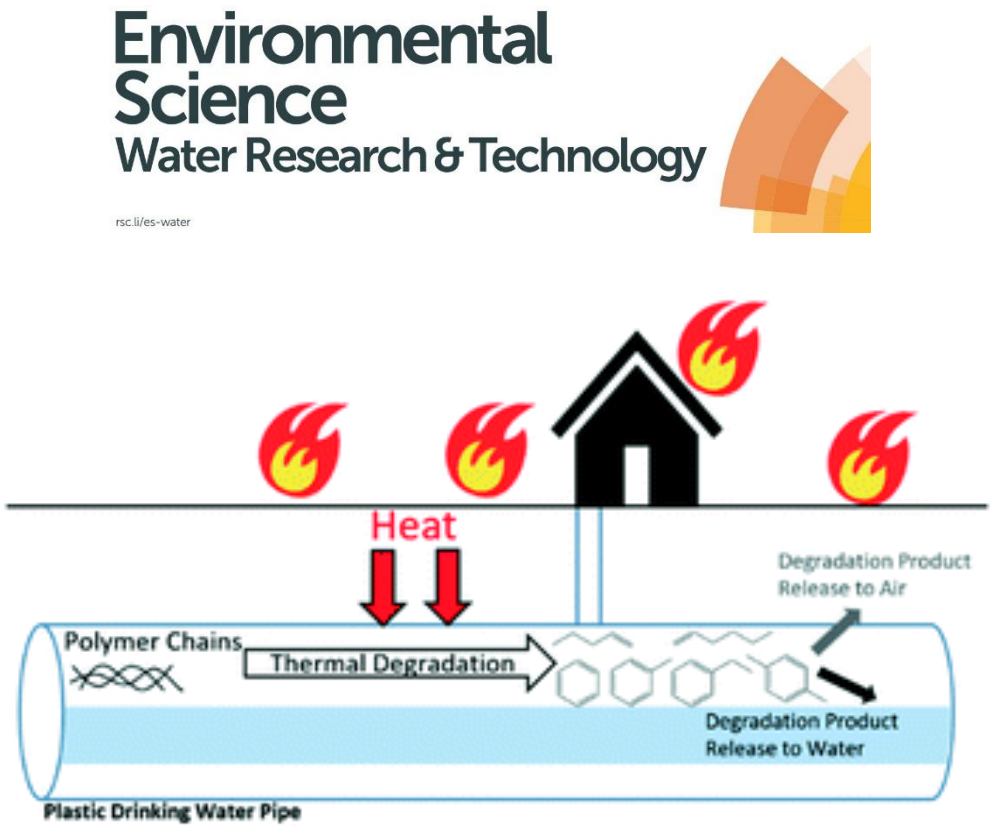
Plumbing testing guidance bungled by State, at least 1 Commercial Lab, some Home Water Treatment Companies, at least 1 Insurance Company

Insurance companies hired "experts". 1 told me they didn't "believe in" stagnation

Max. Benzene, ppb	Event / Location	Pop.	System	Year
5.5	Echo Mountain Fire/ Oregon	120	Whispering Pines Mobile Home Park	2020
11.3	Echo Mountain Fire/ Oregon	362	Hiland WC -Echo Mountain	2020
1.1	Echo Mountain Fire/ Oregon	760	Panther Creek Water District	2020
76.4	Almeda Fire/ Oregon	6,850	City of Talent	2020
44.9	Lionshead Fire/ Oregon	205	Detroit Water System	2020
1.8	CZU Lightning Complex Fire/ California	1,650	Big Basin Water Company	2020
42	CZU Lightning Complex Fire/ California	21,145	San Lorenzo Valley Water District	2020
>2,217	Camp Fire/ California	26,032	Paradise Irrigation District	2018
38.3	Camp Fire/ California	924	Del Oro Water Co.-Magalia	2018
8.1	Camp Fire/ California	1,106	Del Oro Water Co.-Lime Saddle	2018
530	Camp Fire/ California	11,324	Del Oro Water Co.-Paradise Pines	2018
40,000	Tubbs Fire/ California	175,000	City of Santa Rosa	2017

From 2017-2020, more water systems became contaminated by wildfire.

December 2020 Study: Thermally damaged plastic pipes can be a source of water contamination



Drinking water contamination from the thermal degradation of plastics: implications for wildfire and structure fire response, *AWWA Water Science*

Download FREE here:

https://doi.org/10.1039/D0EW00836B

Heating new HDPE, PEX, PVC, CPVC, and PP pipes < T_{deg} generated VOCs *and* SVOCs

Benzene generated by heating all pipes except PP

Once plastic cooled, chemicals leached into water

200-400˚C	Confirmation of BTEX Components in Water				Number of TICs in extract[a]	
Material	B	T	E	X	Water	*n*-Hexane
Cold water pipes						
PVC	✓	✓	–	–	4	41
HDPE	✓	✓	✓	✓	14	100
Hot and cold water pipes						
CPVC	✓	–	–	–	3	32
PEX-a1-a	✓	✓	✓	✓	19	123
PEX-a1-b	✓	✓	✓	✓	16	122
PEX-a2	✓	✓	✓	✓	22	117
PEX-b	✓	✓	✓	✓	18	127
PEX-c1-a	✓	✓	✓	✓	19	133
PEX-c1-b	✓	✓	✓	✓	17	134
PEX-c1-EVOH	✓	✓	✓	✓	20	109
PP	–	✓	–	–	6	95

Fires are often >200˚C, but ground temperature can be >100˚C for hrs

Chemistry:

Polymer chain scission

Aromatization

The role of additives

The role of temperature

The role of RH

The role of O_2

Partitioning after generation

*Building codes never considered damaged plastic water system materials becoming a 1˚ or 2˚ source of drinking water contamination. (est. 300,000 structure fires per year in the U.S. - **NFPA**)*

Organic Chemical Contaminants in Water System Infrastructure Following Wildfire, *ES&T Water*

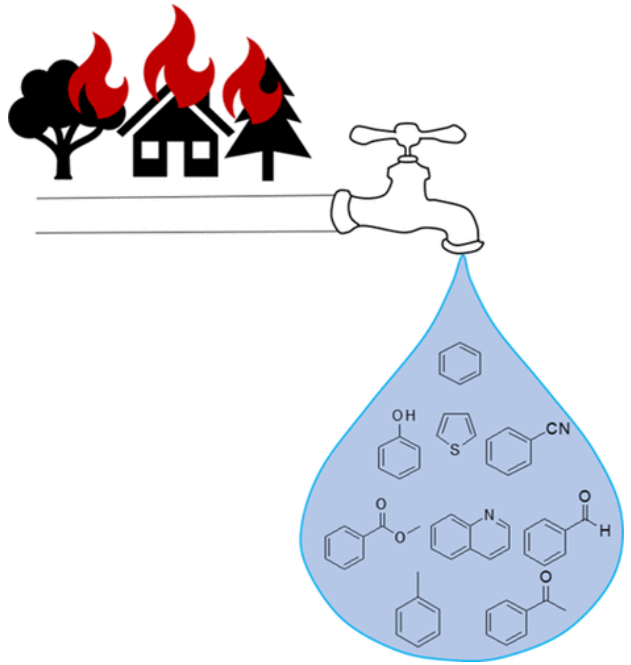
https://doi.org/10.1021/acsestwater.1c00401

Characterized target and nontarget VOCs and SVOCs in water from **1** contaminated service line after the Camp Fire.

PVC, PEX, and HDPE pipe **heating experiments** conducted

Results:

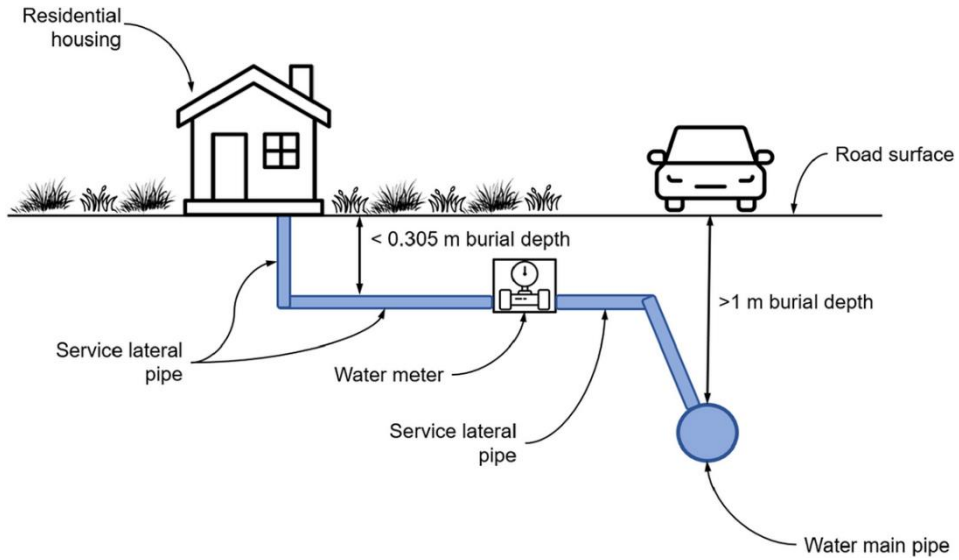
- PVC heating: 32 compounds
- HDPE/PEX heating: 28 compounds
- Service line: 55 compounds associated with uncontrolled burning of biomass and waste materials.



Findings support hypotheses that wildfires can contaminate drinking water systems both by thermal damage to plastic pipes and intrusion of smoke.

Simulation of Heat Transfer Through Soil for the Investigation of Wildfire Impacts on Buried Pipelines, *Fire Technology*

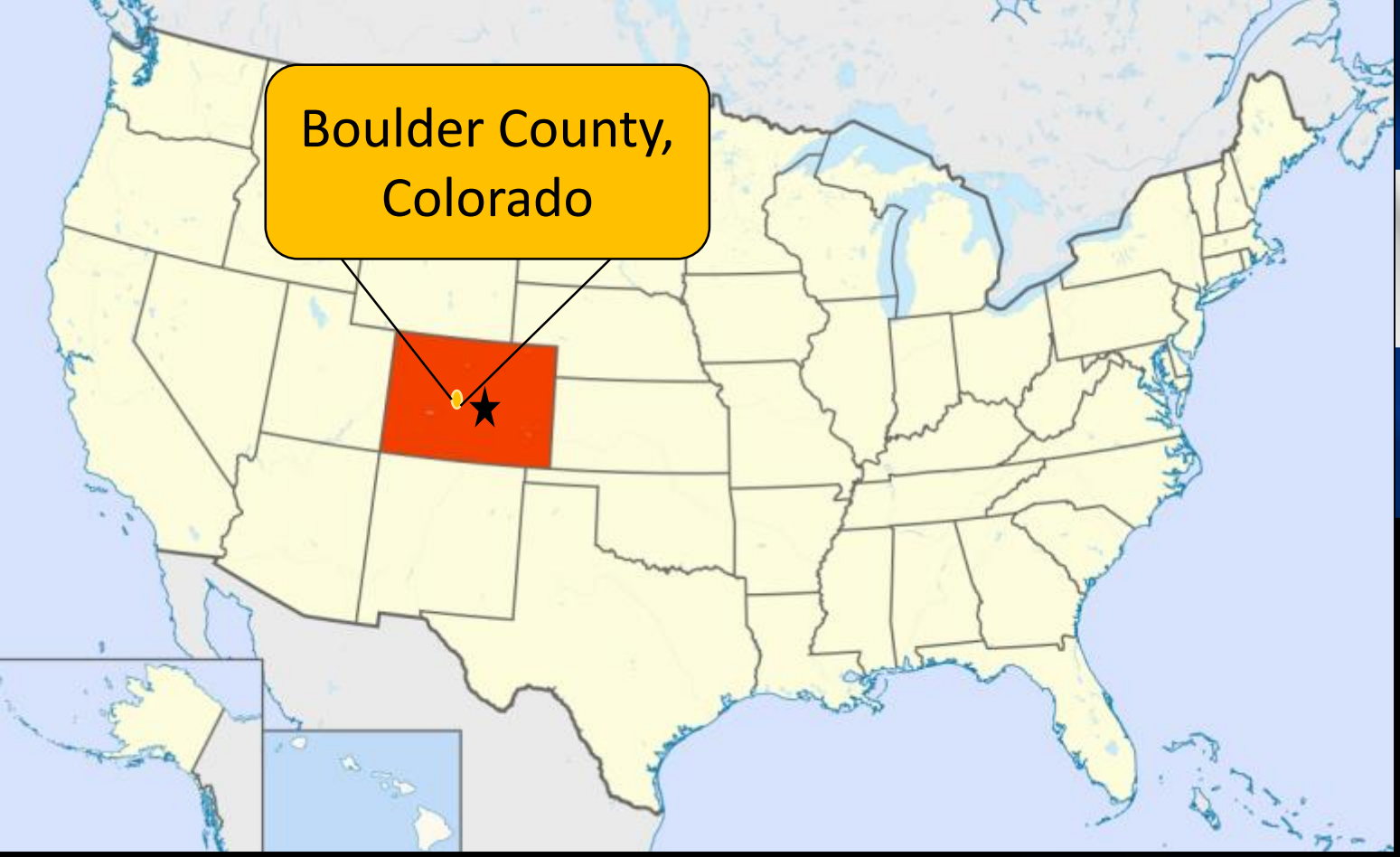
https://doi.org/10.1007/s10694-022-01232-3



Mathematical Modeling Results:

- The upper limit temperature for pressure service of the pipelines was exceeded at depths up to 0.45 m (1.5 ft).
- The upper limit temperature will be exceeded at least 50% of the time at depths up to 0.19 m (0.6 ft).

Buried depth will impact thermal vulnerability



2021

		$$$		
U.S. pop	331,893,745	$62,843	$217,500	32.1%
Boulder Co., CO	**330,758**	**$127,292**	**$592,000**	**62.1%**
Butte Co., CA	208,309	$51,566	$49,000	26.0%

The Marshall Fire, December 30, 2021

Most expensive and destructive in Colorado history

>$1 Billion in damage per NOAA, 6,000+ ac, 40,000+ evacuated

>100 mph winds

- ❑ 553 destroyed in Louisville, 45 damaged
- ❑ 332 destroyed in Superior, 60 damaged
- ❑ 106 destroyed in unincorporated Boulder County, 22 damage

❑ Chemical contamination found in 2 of 6 public water systems

Grass fire: 70 mph sustained, 90 to 102 mph wind gusts

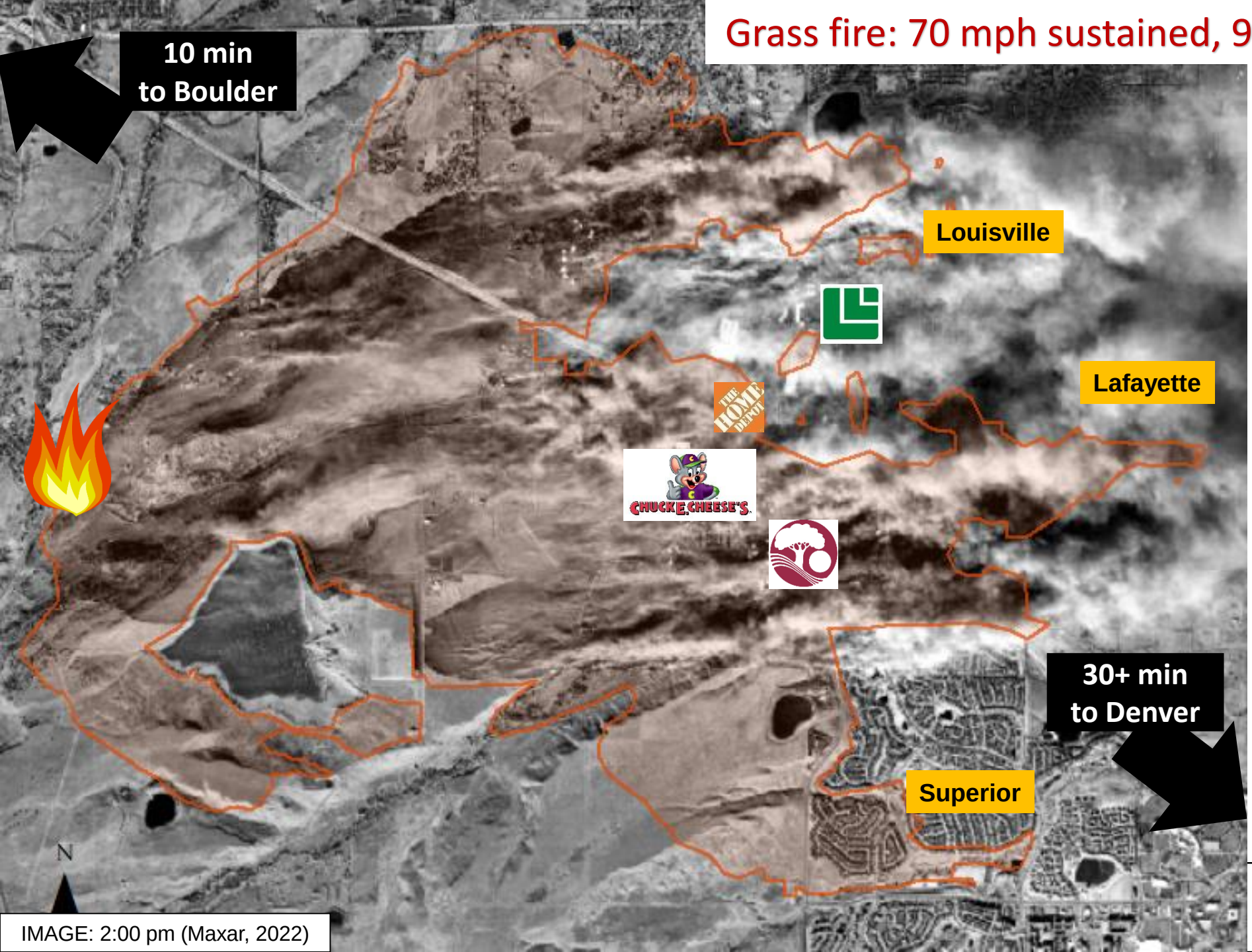


IMAGE: 2:00 pm (Maxar, 2022)

December 30, 2021

11:06 am, Fire in Boulder Co.
12:10 pm, Fire in Superior
12:50 pm, Fire in Louisville
1:00 pm, 1,000 acres

40,000+ evacuation ordered

The 3 largest communities
Lafayette: 30,411
Louisville: 21,266
Superior: 13,094

The 6 public water systems impacted served about 60,000 people

Public Water System (population)	Damaged/ Destroyed Properties	Water Mains, miles	Hydrants	Finished Water Storage, MG	Raw Water
Louisville (20,319)	593	120	1,200	7.5	Surface water
Superior (17,170)	436	50	430	3.4	Surface water
Lafayette (28,700)	~50	177	900	14	Surface water
EBCWD (300)	72 of 137	8	40	0.1	Lafayette
Eldorado Artesian Spring (259)	0	<1	0	None	2 Wells, 1 Spring
S.S. Mobile Home Park (150)	3, wind	<1	0	None	1 Well


7493

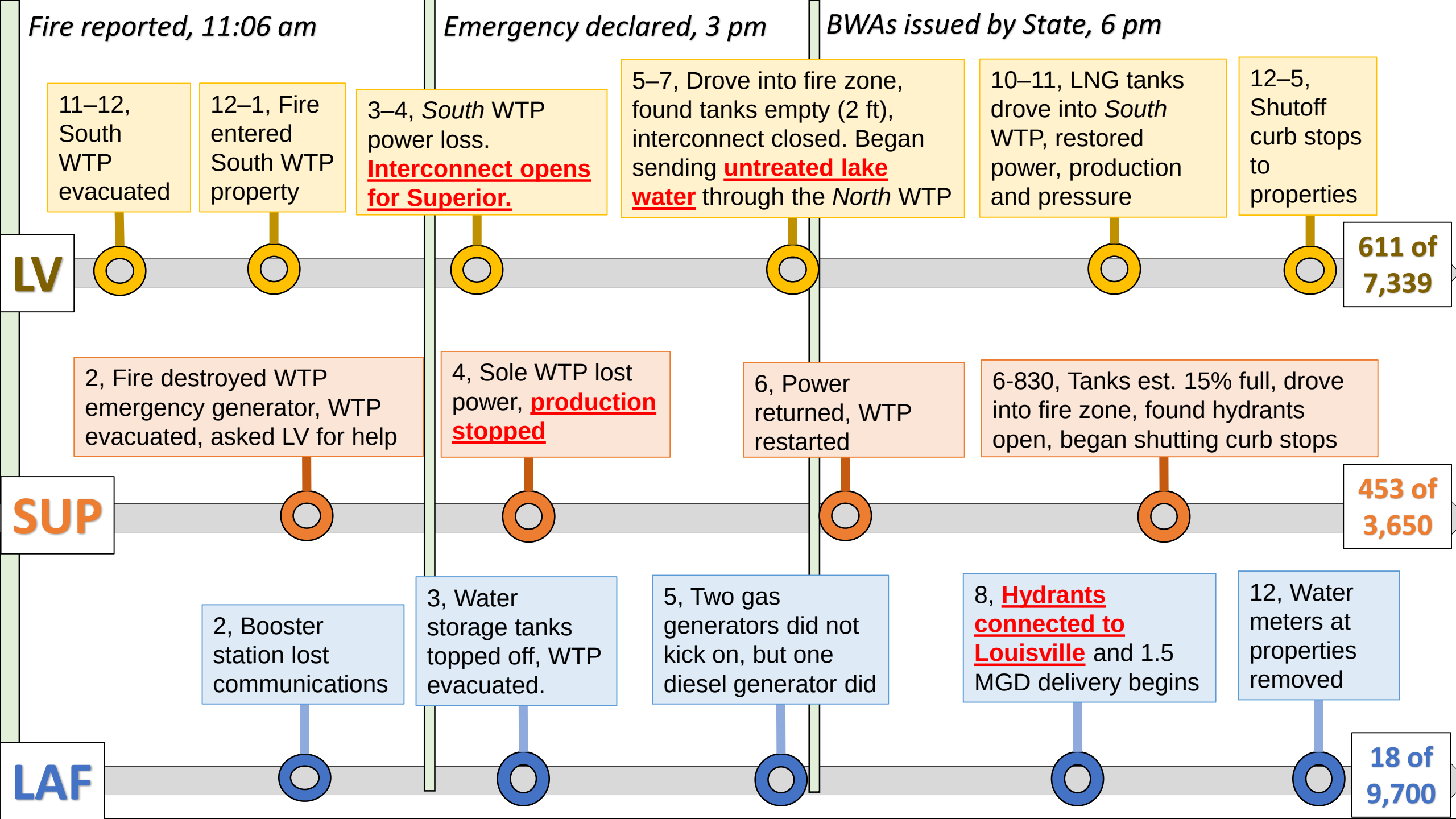

1783
ELDORADO
NATURAL SPRING WATER


Town of
SUPERIOR


City of
Lafayette
PUBLIC WORKS


City of
Louisville
Public Works

The first 24 hours


Fire reported, 11:06 am
Emergency declared, 3 pm
BWAs issued by State, 6 pm
11–12, South WTP evacuated
12–1, Fire entered South WTP property
3–4, South WTP power loss. Interconnect opens for Superior.
5–7, Drove into fire zone, found tanks empty (2 ft), interconnect closed. Began sending untreated lake water through the North WTP
10–11, LNG tanks drove into South WTP, restored power, production and pressure
12–5, Shutoff curb stops to properties
LV
611 of 7,339
2, Fire destroyed WTP emergency generator, WTP evacuated, asked LV for help
4, Sole WTP lost power, production stopped
6, Power returned, WTP restarted
6-830, Tanks est. 15% full, drove into fire zone, found hydrants open, began shutting curb stops
SUP
453 of 3,650
2, Booster station lost communications
3, Water storage tanks topped off, WTP evacuated.
5, Two gas generators did not kick on, but one diesel generator did
8, Hydrants connected to Louisville and 1.5 MGD delivery begins
12, Water meters at properties removed
LAF
18 of 9,700


TIM ERLINE
RE PROTECTION
DISTRICT


haley
818

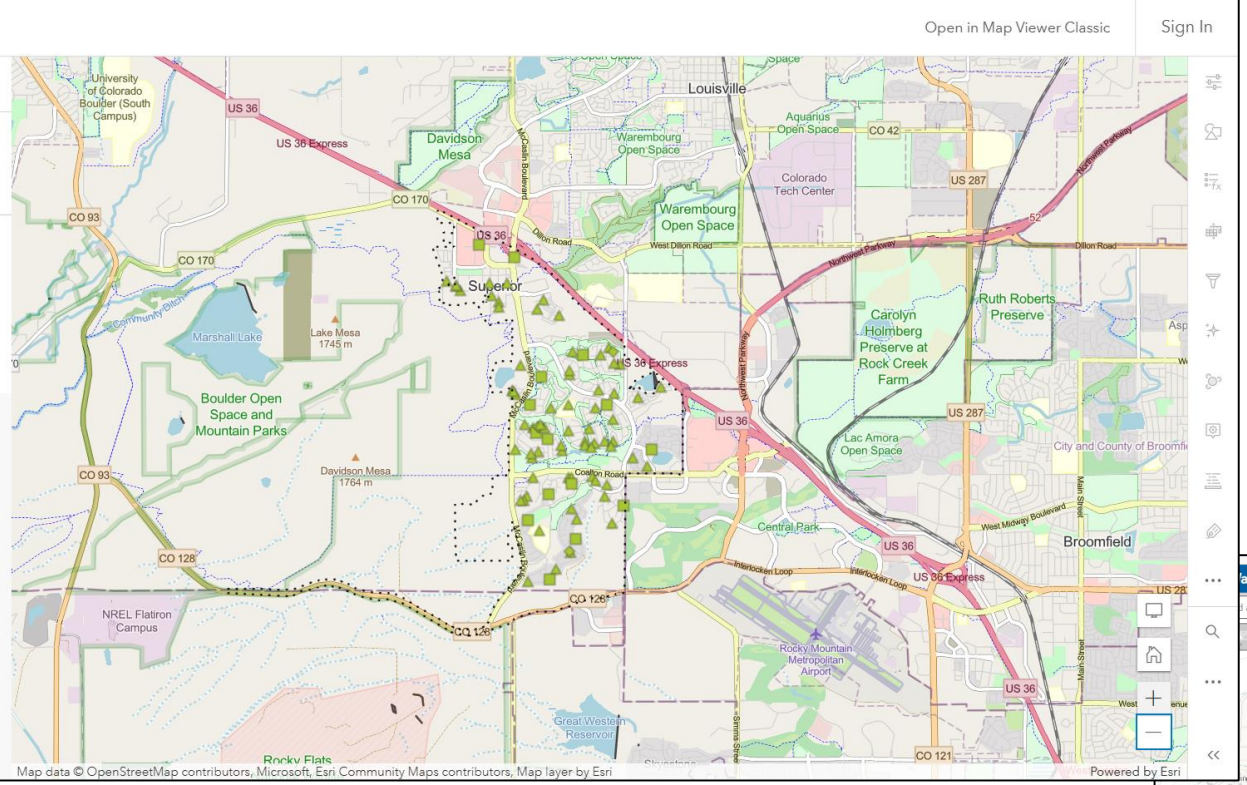

Emergency Response Team
commercial property restoration
srmcat.com


WE ARE
TEMPORARILY
CLOSED
DUE TO NO
ACCESS TO
CLEAN WATER.
SEE YOU SOON!

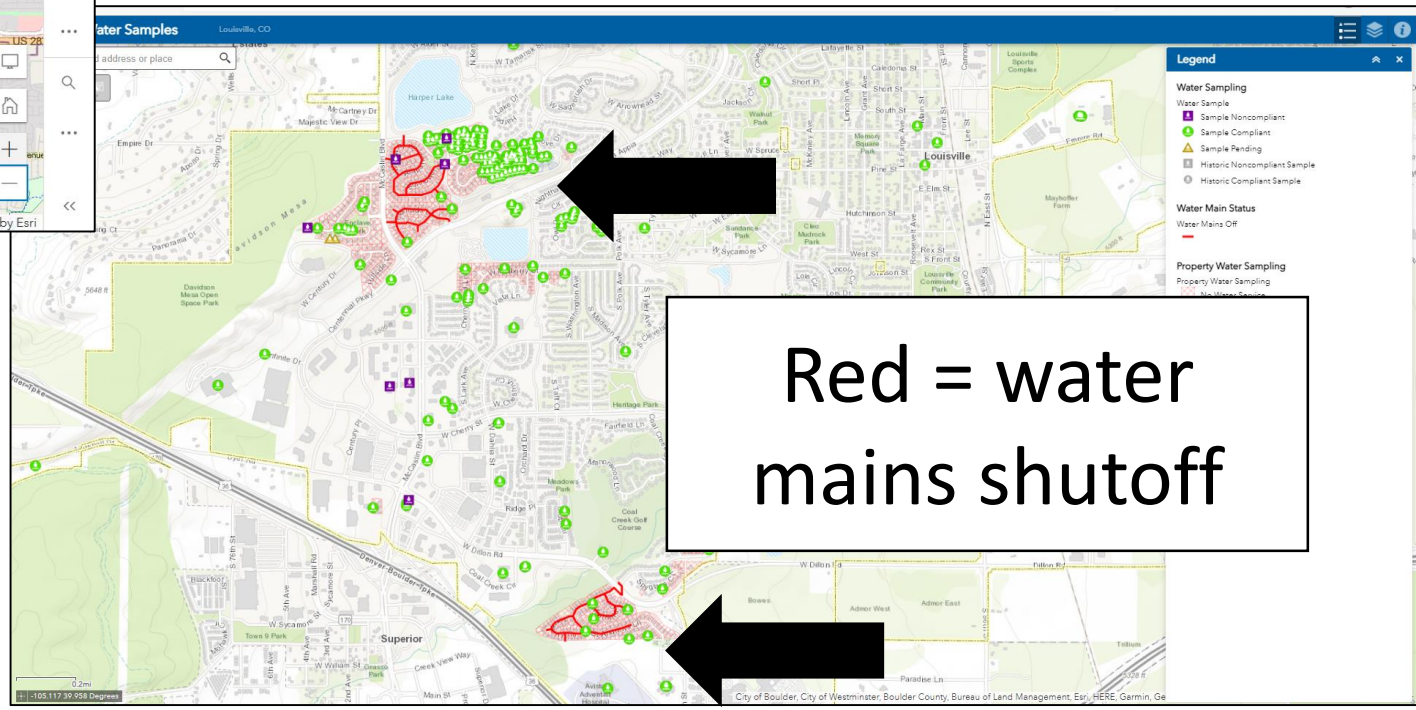
Snowfall helped extinguish the fire and hotspots

Internal leadership, exceptional staff, and requests for aide helped utilities stabilize

<u>Helpful neighbors:</u>
Boulder, Ft. Collins, Erie, Westminster, South Adams County, Broomfield, Longmont, more…



Technology was critical to Louisville and Superior in finding valves, isolating systems, flushing, and identifying sampling locations to restore pressure.



Red = water mains shutoff

Each utility moved at a different pace with different challenges

1st focus: Pressure, bacteria and chlorine

Next: Fire caused VOCs

And then: Fire caused SVOCs

Is ***benzene*** THE indicator of contamination?

--No

Is ***BTEX*** THE indicator of contamination?

--No

Is ***VOC*** THE indicator of SVOC contamination?

--Probably not, untested theory

Oregon 2021: MEK (138 ppm) exceeded the USEPA 1-day health advisory in the absence of benzene

No shortcuts to chemical contamination decisions

To expedite contamination testing, we reviewed all literature and compiled a "fire package" list of chemicals

Acetonitrile
Acetone
Acrolein
Acrylonitrile
Benzene
Bromochloromethane
Bromodichloromethane
Bromoform
n-Butylbenzene
sec-Butylbenzene
tert-Butylbenzene
Carbon disulfide
Carbon tetrachloride
Chlorobenzene
Chlorodibromomethane
Chloromethane
4-Chlorotoluene
Dibromochloromethane
1,2-Dichlorobenzene
1,4-Dichlorobenzene
1,1-Dichloroethane
1,2-Dichloroethane
1,1-Dichloroethene
cis-1,2-Dichloroethene
trans-1,2-Dichloroethylene
1,2-Dichloropropane
Ethanol
Ethylbenzene
Ethyl-*tert*-butyl ether (ETBE)
Iodomethane
Isopropylbenzene
Methylene chloride
Methyl ethyl ketone (MEK)
Methyl iso butyl ketone (MIBK)
Methyl-*tert*-butyl ether (MTBE)
Naphthalene
Styrene
***tert*-Butyl alcohol (TBA)**
Tetrachloroethylene
Tetrahydrofuran (THF)
Toluene
1,2,3-Trichlorobenzene
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethylene
Trichloromethane
1,2,4-Trimethylbenzene
1,3,5-Trimethylbenzene
Vinyl chloride
ortho-Xylene
meta-Xylene
para-Xylene

Look for SVOCs too.

10,000 ft view of the Marshall Fire water distribution system contamination

Zero systems found bacteria during their return to service

No fire damage: S.S. Mobile Home Park and Eldorado Artesian Springs

The Mobile Home Park lost power for 4 days: no generator, no storage tank

Lafayette, Louisville, and Superior flushed to bring chlorine residual back

Lafayette shutdown the small area (22 homes) affected and did not find VOC contamination

Louisville had isolated depressurized areas; Found VOC and SVOC contamination

Superior found a different type of VOC contamination

Paint thinner odor was reported at the East Boulder County Water District so they flushed and sampled (no stagnation), but did not find contamination; 3 weeks later (with stagnation) they found 5.1 ppb benzene

In Louisville, chemical contamination was found above short-term drinking water exposure limits in isolated, shutoff sections

Sample → Flush → Sample → Stagnate 72 hr → Sample → Repeat

Chemical	Max	>Limit?	Odor?
Benzene	**221**	**Y**	
Toluene	511		**Y**
Ethylbenzene	160		**Y**
Xylenes	5		
Styrene	**1,900**	**Y**	**Y**
Naphthalene	11		**Y**
Acrolein	24		**Y**

3 EPA Methods (524.2, 524.4, and 8260C) and >4 laboratories used

Locations with VOC exceedances were not returned to service until results were below health limits

Majority of samples had no detections

SVOCs were present too

Others: 1,1-DCP, 1,2,4-TMB, 1,2-Dichloroethane, 4-Chlorotoluene, Acetone, Acetonitrile, Acrylonitrile, DEHP, Carbon disulfide, Chlorobenzene, Chloromethane, IPB, MEK, MTBE, *N*-Butylbenzene, *N*-Propylbenzene

Smoky, Ash Tray, Camp Fire Flavored Water

Superior received 300+ complaints in a day

Community concerns:

- ✓ Present at 1 household and not the neighbors
- ✓ Present in hot water only, not cold water
- ✓ Water heaters were contaminated
- ✓ The depressurized system sucked in chemicals
- ✓ Contamination was trapped in parts of the system

Smoke flavor after ‘03, ‘13, ‘16 wildfires assumed to be caused by drinking water source ash contamination.

Food science literature: Caused by phenols, *o*-cresol, *p*-cresol, *m*-cresol, guaiacol

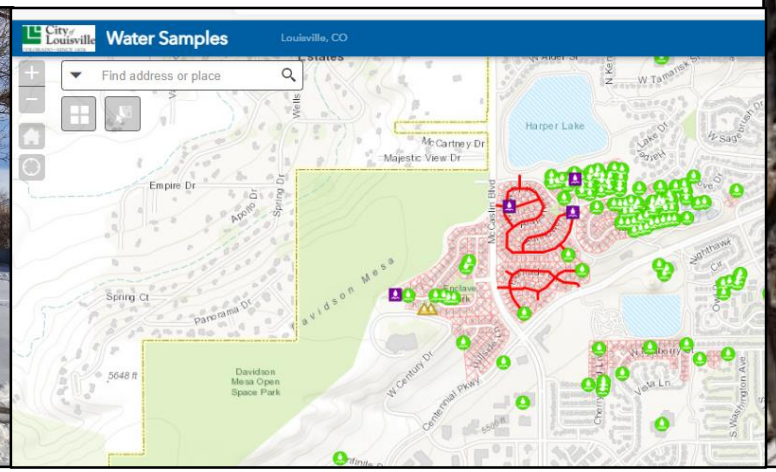
CSU Dr. Omur-Ozbek confirmed the flavor was originating from the source water (lake) –*and*– in the treatment plant –*and*– in the water distribution system

CU Boulder Dr. Thurman, Dr. Ferrer, and Corona identified and attributed a tricarboxylic benzoic acid and a dicarboxylic benzoic acid as the “smoky flavor” agents at ppb (Ferrer et al. 2021)

They stated chemicals identified were not known to be a health risk at levels found

Lessons from the 2021 Marshall Fire

1. Internal leadership and commitment
2. Worker safety, power, and water pressure
3. Damage containment
4. Rapid neighbor/mutual aide support
5. Rapid water contamination support
6. Communications



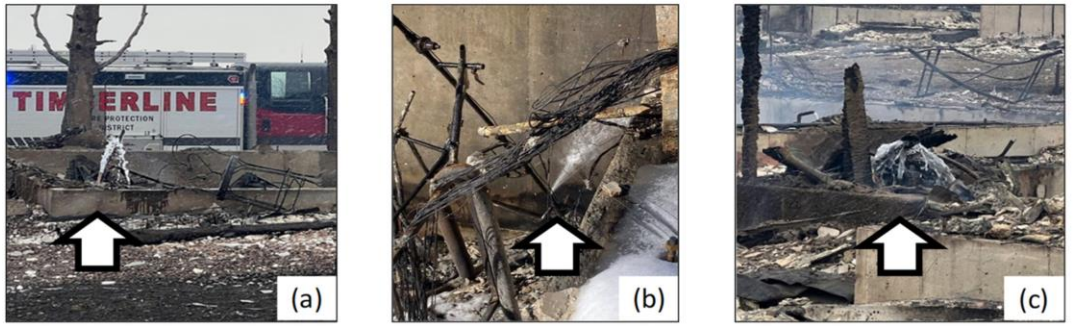
The Marshall Fire: Scientific and policy needs for water system disaster response

AWWA Water Science, Published January 2023
https://doi.org/10.1002/aws2.1318

1) Loss of power jeopardized fire-fighting and caused worker risks
2) Local/external resources were critical
3) SOPs for post-fire sampling, analysis, and rapid external labs are needed
4) Contamination seemed to be related to depressurization and property damage, but more work is needed
5) Clarification on public health risks and water use conditions is needed

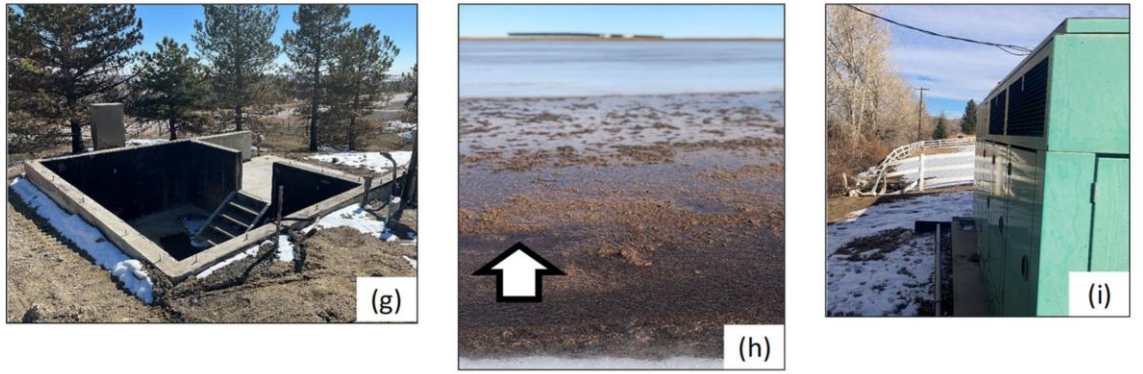
20 scientific and policy needs for improving water system disaster response and recovery

Water Distribution System Damage



Service lines, hydrants, and plumbing were damaged and leaking (a,b,c,d). Some hydrants were left open, fire-fighting equipment was left behind (f). Water meters to properties with destroyed structures were removed (e).

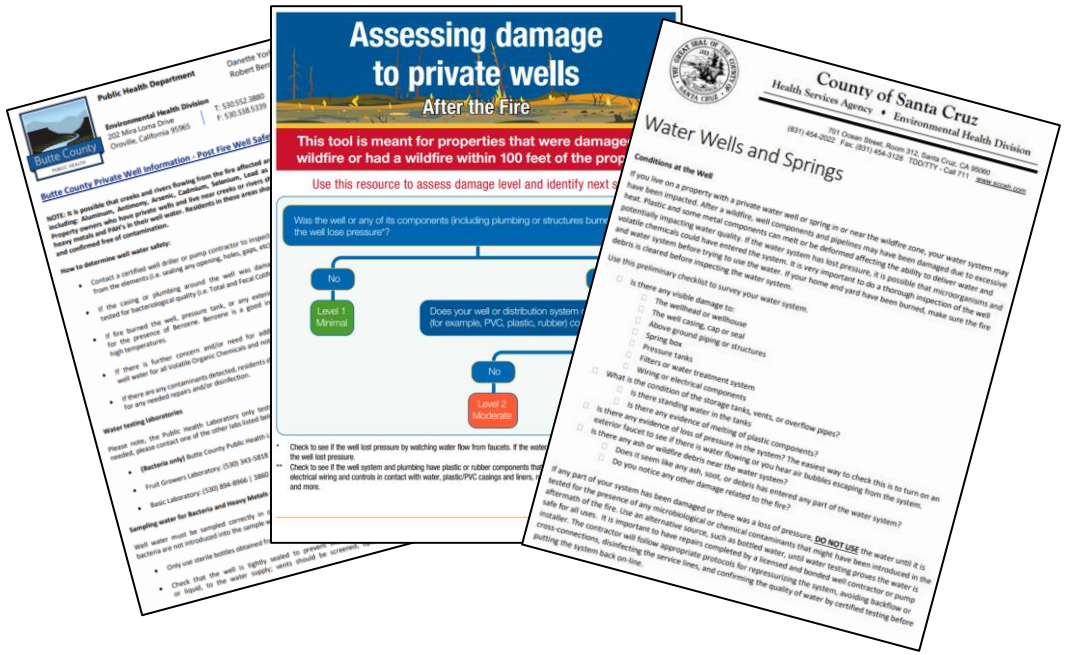
Damage on Facility Property



Ash was visible around and in the Superior reservoir (h), and the water treatment plant emergency generator was destroyed by fire (g). The EBCWD emergency generator air intake was clogged with debris and could not operate because of the gas shutoff (i).

Private drinking water wells and the buildings they supply can be damaged by fire

More than 20 different guidance documents!



BCHD: Bacteria, Al, As, Cd, Pb, Sb, Se, PAH's

CDC: Bacteria, NO_3^-; BTEX; local contaminants

WaDOH: Coliform bacteria

SCCHD: Coliform bacteria, turbidity, pH, conductivity, color, NO_3^-; VOCs, SVOCs

OHA: Coliform bacteria, As, Pb, NO_3^-; BTEX

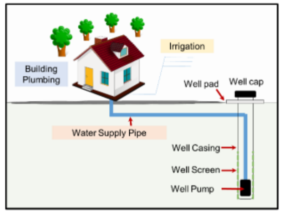
We reached out to help those served by private wells.

Boulder County

PURDUE UNIVERSITY

After a Wildfire:

Water Safety Considerations for Private Wells

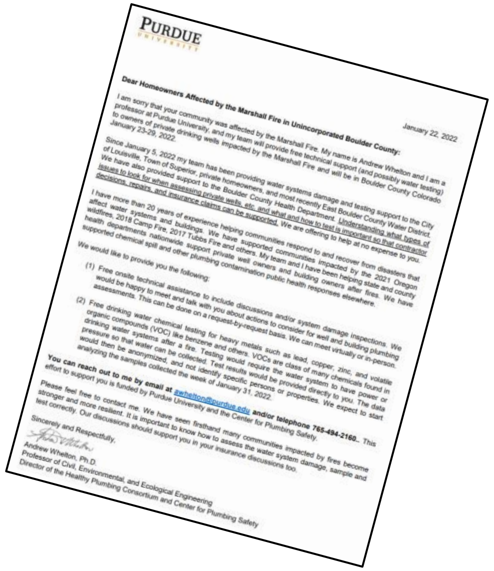


Damage and Contamination Caused by Wildfires

Wildfires can directly damage private wells and springs causing an immediate health and safety risk to their users. Water testing after wildfires has revealed contaminated drinking water, sometimes exceeding hazardous waste limits. A thorough inspection of the well and water systems is needed before trying to use the water. If the building or property has been burned, make sure the fire debris is cleared before inspecting the water system.

Signs of contamination may include the loss of water pressure, discolored water, heat damage to water systems inside and outside buildings, broken and leaking pipes, valves, tanks, irrigation systems, and yard hydrants. Chemical contamination can occur due the water system and the heating or burning of the water system materials themselves, including plastics. If the water system lost pressure, microorganisms and chemicals may have entered the system.

Persons impacted by wildfire should seek specific advice from their local health department.



PURDUE UNIVERSITY

January 22, 2022

Dear Homeowners Affected by the Marshall Fire in Unincorporated Boulder County:

I am sorry that your community was affected by the Marshall Fire. My name is Andrew Whelton and I am a professor at Purdue University, and my team will provide free technical support (and possibly water testing) to owners of private drinking wells impacted by the Marshall Fire and will be in Boulder County Colorado January 23-29, 2022.

Since January 5, 2022 my team has been providing water systems damage and testing support to the City of Louisville, Town of Superior, private homeowners, and most recently East Boulder County Water District. We have also provided support to the Boulder County Health Department. Understanding what types of issues to look for when assessing private wells, etc. and what and how to test is important so that contractor decisions, repairs, and insurance claims can be supported. We are offering to help at no expense to you.

I have more than 20 years of experience helping communities respond to and recover from disasters that affect water systems and buildings. We have supported communities impacted by the 2021 Oregon wildfires, 2018 Camp Fire, 2017 Tubbs Fire and others. My team and I have been helping state and county health departments nationwide support private well owners and building owners after fires. We have supported chemical spill and other plumbing contamination public health responses elsewhere.

We would like to provide you the following:

(1) Free onsite technical assistance to include discussions and/or system damage inspections. We would be happy to meet and talk with you about actions to consider for well and building plumbing assessments. This can be done on a request-by-request basis. We can meet virtually or in-person.

(2) Free drinking water chemical testing for heavy metals such as lead, copper, zinc, and volatile organic compounds (VOC) like benzene and others. VOCs are class of many chemicals found in drinking water systems after a fire. Testing would require the water system to have power or pressure so that water can be collected. Test results would be provided directly to you. The data would then be anonymized, and not identify specific persons or properties. We expect to start analyzing the samples collected the week of January 31, 2022.

You can reach out to me by email at awhelton@purdue.edu **and/or telephone 765-494-2160.**. This effort to support you is funded by Purdue University and the Center for Plumbing Safety.

Please feel free to contact me. We have seen firsthand many communities impacted by fires become stronger and more resilient. It is important to know how to assess the water system damage, sample and test correctly. Our discussions should support you in your insurance discussions too.

Sincerely and Respectfully,

Andrew Whelton, Ph.D.
Professor of Civil, Environmental, and Ecological Engineering
Director of the Healthy Plumbing Consortium and Center for Plumbing Safety


PURDUE
Boilermakers

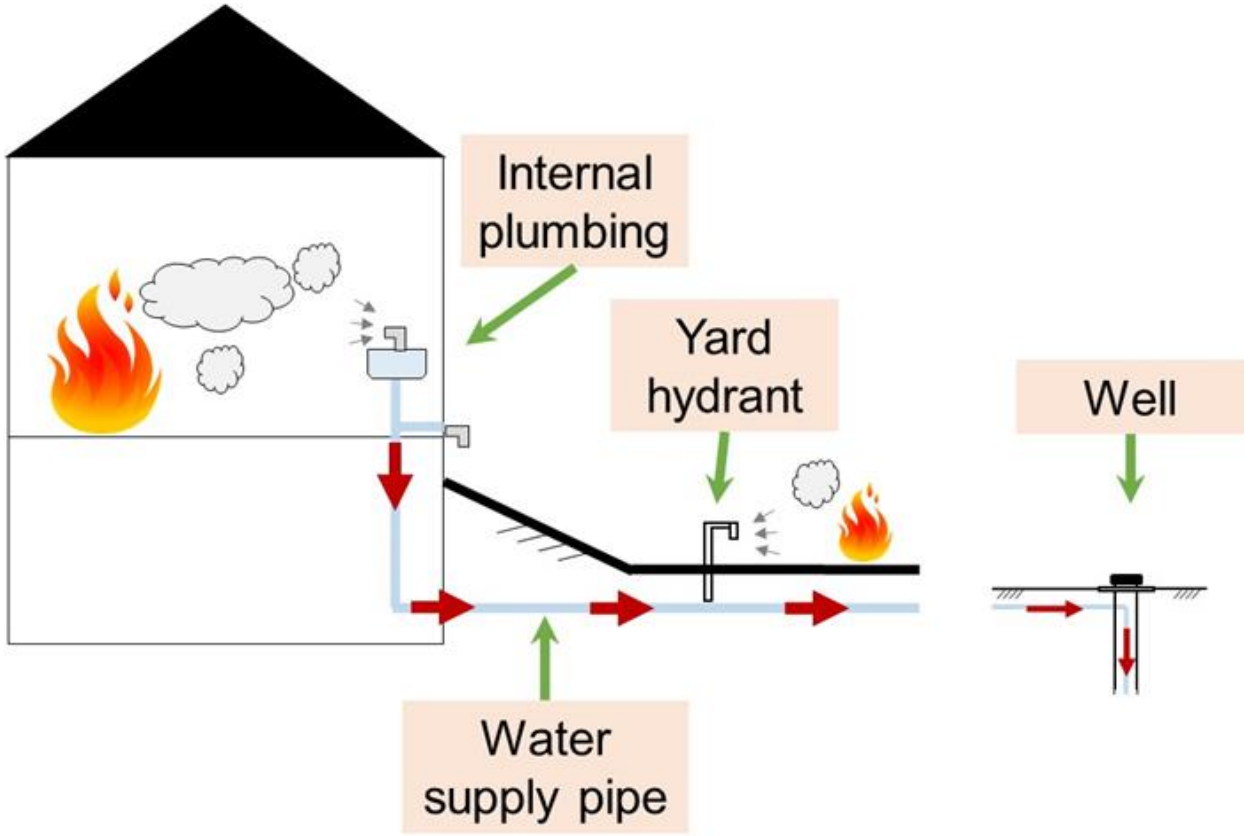

mL 0
±5%
300 mL
±5%
400 mL
PYREX®
Made in Germany
50
250
100
200
No. 1000
200
100
250

Other wells had structures that were destroyed, debris was blown into them for more than 12 hr

PURDUE UNIVERSITY

11:45am Dec. 30, 2022

8 customers, not an HOA
1 well, 1 chlorinator, flow, pressure monitoring
2 concrete cisterns
780 ft HDPE (3”) water main
No hydrants
No water meters, no curb stops
1” HDPE service lines
160 ft max length



Wildfire damage and contamination to private drinking water wells

AWWA Water Science, Published January 2023

https://doi.org/10.1002/aws2.1319

More than 20 different water testing guidance documents, some disagreed with each other

1) Debris near wells had VOCs and SVOCs
2) Debris was found in some wells
3) SVOCs detected
4) Small water system 11 months without pressure.
5) Recommendations for
   - How to inspect
   - Water use considerations
   - What chemicals to look for
   - Repair considerations
   - Future research

Looking back since the 2017 Tubbs Fire…

- ❑ Wildfires have been contaminating drinking water for years, but no one tested.
- ❑ Government officials had a hard time understanding and making policy.
- ❑ Most people tried to do the right thing, and wanted the information.
- ❑ Knowledge sharing with utilities and officials is needed.
- ❑ More resilient system construction needed. Worker safety training needed.
- ❑ Chemical contamination, exposures, and removal for plumbing not understood.

Research needed to improve decisions that impact resilience

Contamination sources, scale and entry pathways to water systems
Distribution network and plumbing decontamination technologies
The role of structure fires on plumbing and utility contamination
Decision making

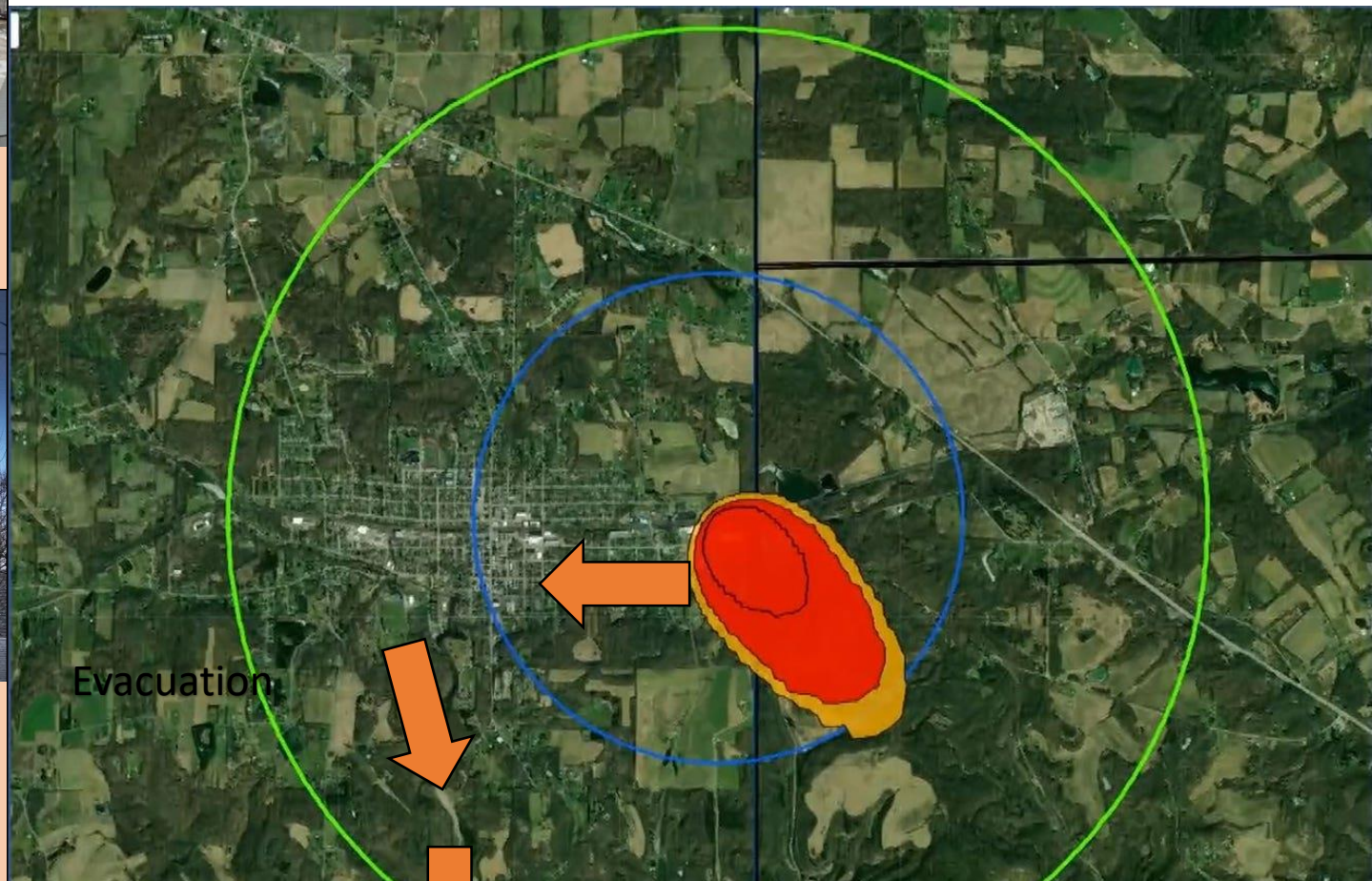
East Palestine, Ohio Chemical Spill and Chemical Fires

Feb 3. wreck

Feb 6 “controlled” burn

149 rail cars, 38 derailed

11 derailed were combustible liquids, flammable liquids, and flammable gas.



More than 43,000 aquatic animals are dead near Ohio train derailment

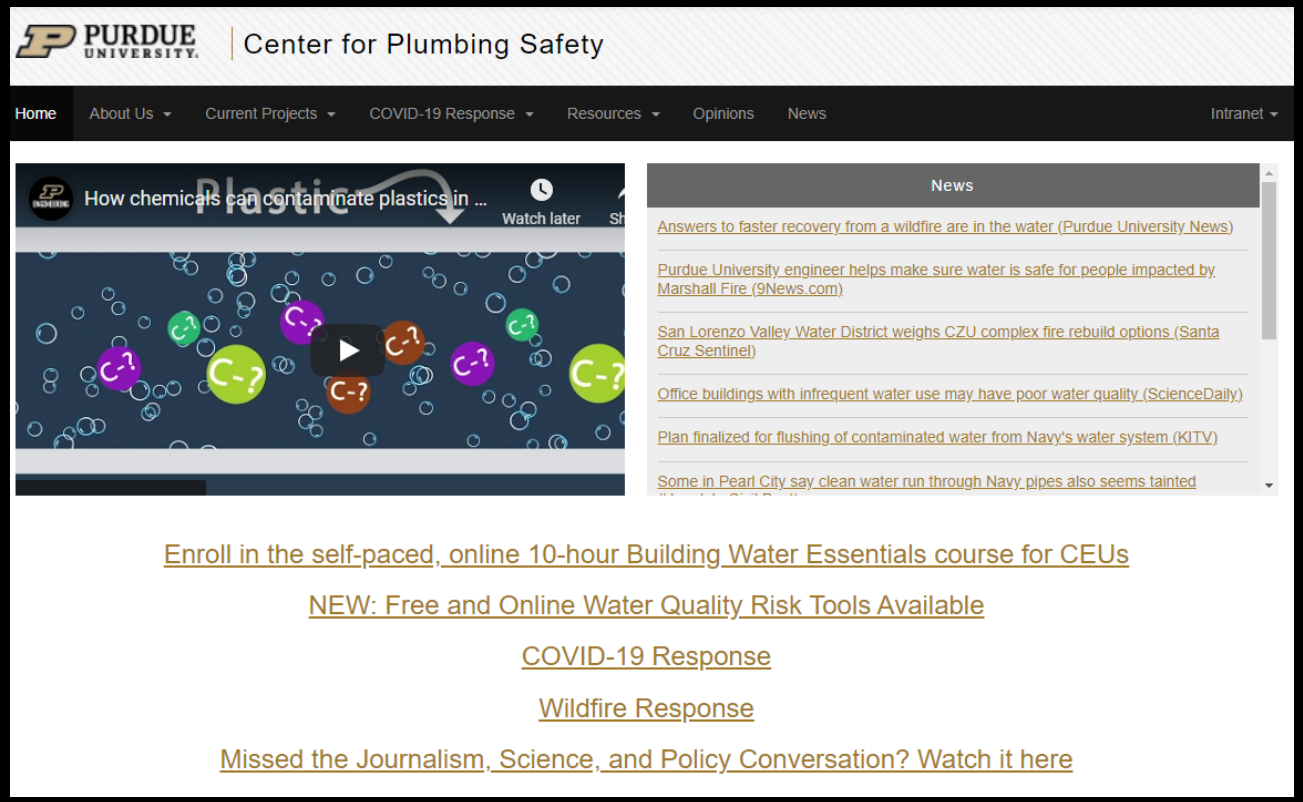
Union rep: Employees reporting illness after working on cleanup for East Palestine derailment

What's on the train and caught fire?

Ethylhexyl acrylate	Propyl glycol
EGMBE	Diethylene glycol
Vinyl chloride	Petro oil, NEC
Butyl acrylate	Petroleum lube oil
PVC resin	Semolina
PE resin	Balls
Frozen vegetables	Powder flakes

Questions?

Andrew Whelton, Ph.D. awhelton@purdue.edu



Funded by:

2214580 RAPID: Drinking Water System Contamination Response & Recovery Following the 2021 Colorado Fires

Learn more at:

www.CIPPSafety.org www.PlumbingSafety.org

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