Wildfires:

Water Infrastructure and Community Resilience

Andrew J. Whelton, Ph.D.

Purdue University

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

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.

National Interagency Fire Center (www.nifc.gov)

Current National Statistics

69 Incidents
Total Number of Large Fires

2 Total
New Large Fires

41,944 Incidents
Year-to-date Wildfires

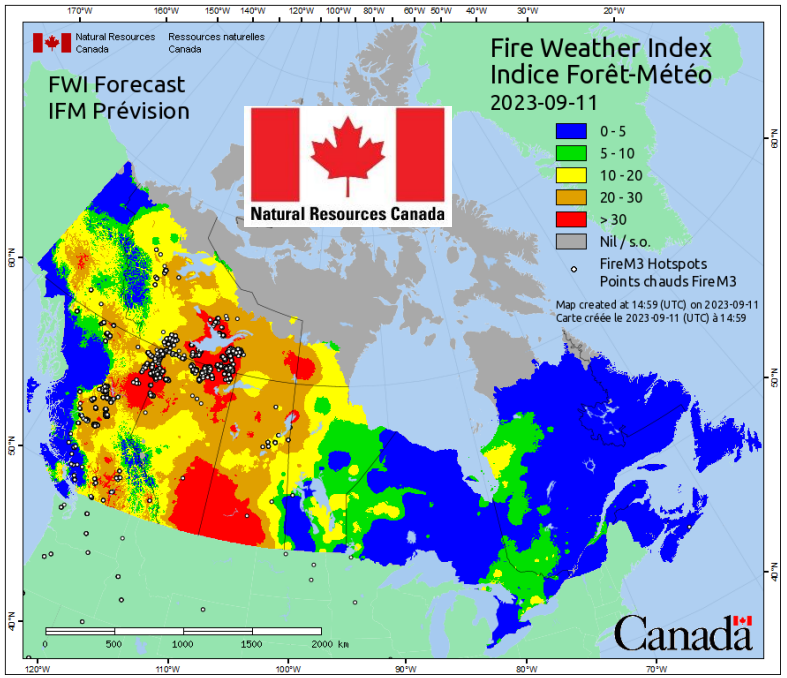
475,924 Acres
Acres Burned on Large Fires

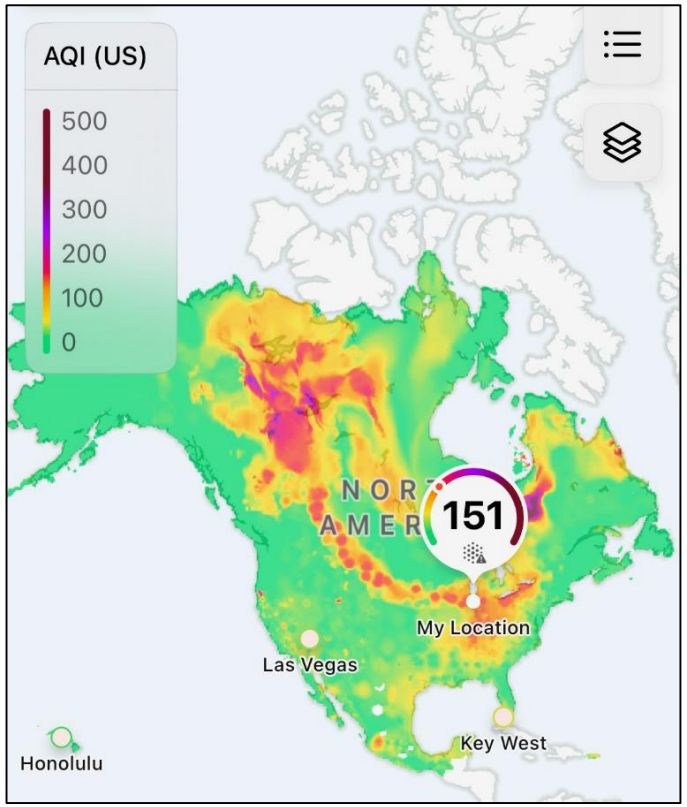
12,391
Personnel Assigned to Wildfires

2,191,140 Acres
Year-to-date Acres Burned

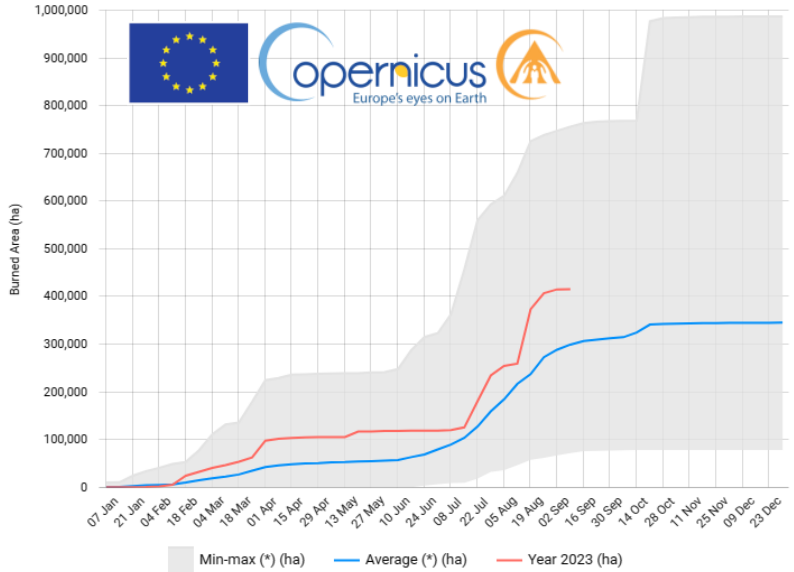
Last Updated: Monday, September 11, 2023 - 08:25

Wildland Fire Information System (nrcan.gc.ca)





European Forest Fire Information System (EFFIS) (europa.eu)



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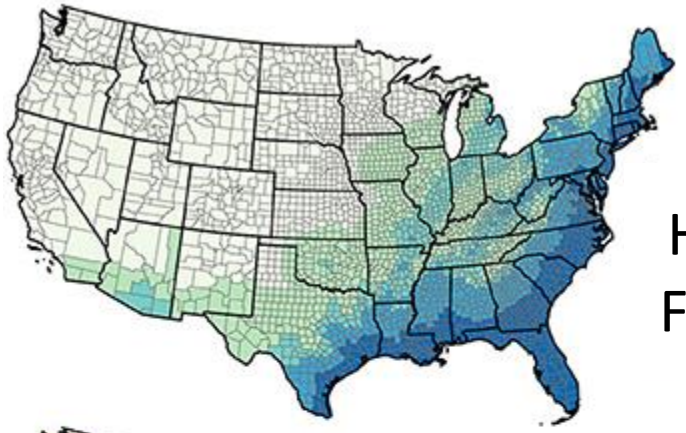
Wildfires cause health and safety risks, and are increasing in intensity as well as the number of acres burned (UNEP 2022)

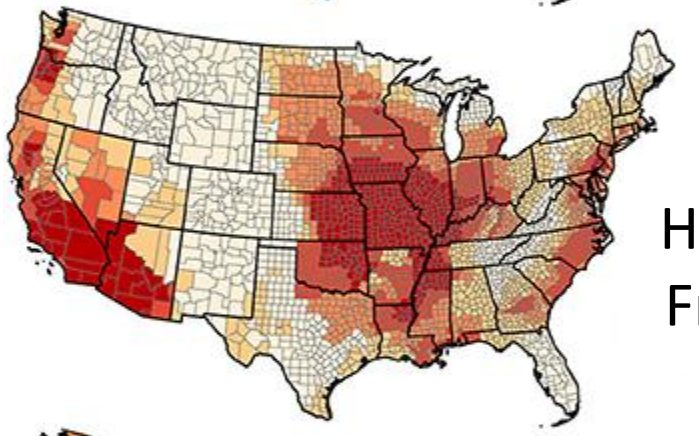
U.S. Fire Administration
Working for a fire-safe America

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

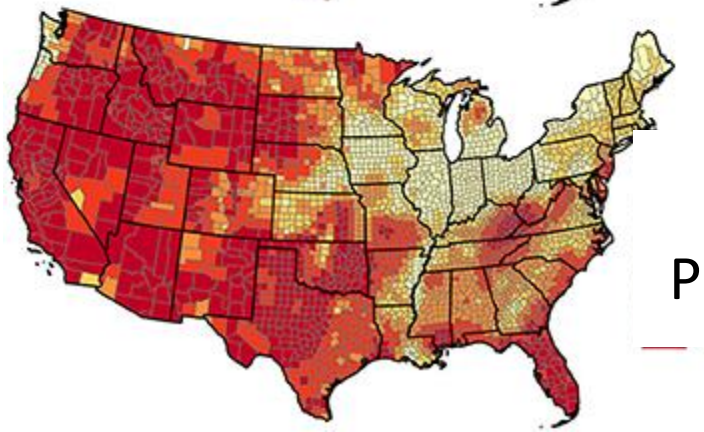
Meanwhile, down south…



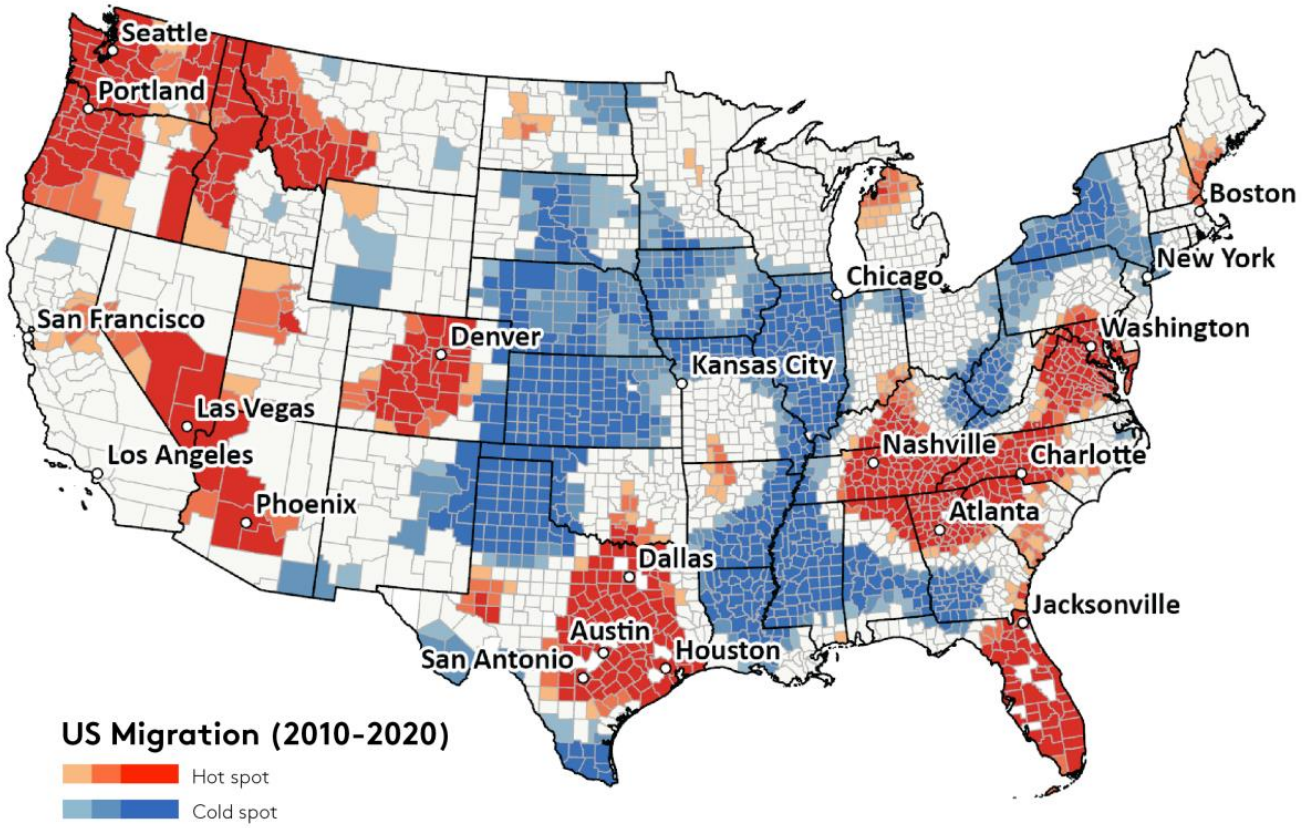
Hurricane Frequency



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

Drinking Water Source

CA Utility 2021

CA Utility 2021

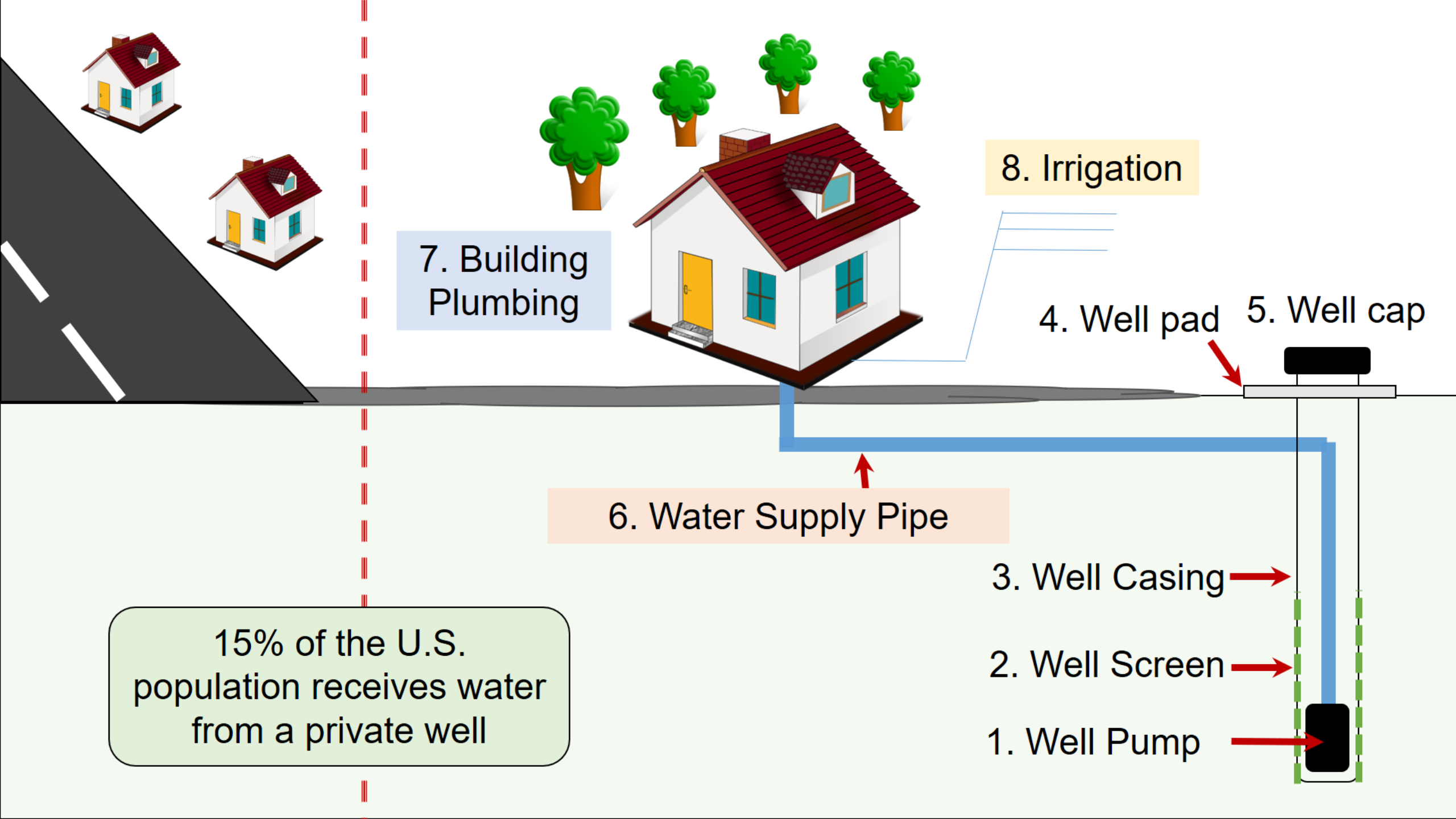
Treatment Facility

Storage Tank

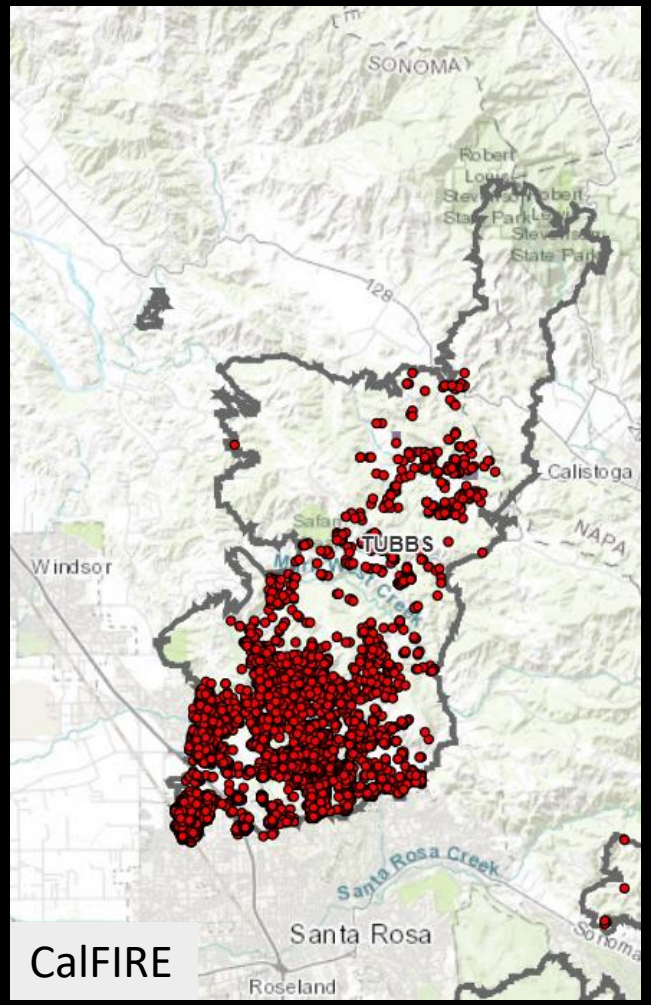
San Francisco Chronicle
9/3/20, Sara Gobets

System Purpose:

- ✓ Fire-fighting
- ✓ Hygiene, sanitation
- ✓ Business
- ✓ Recreation


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 5 ppb 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

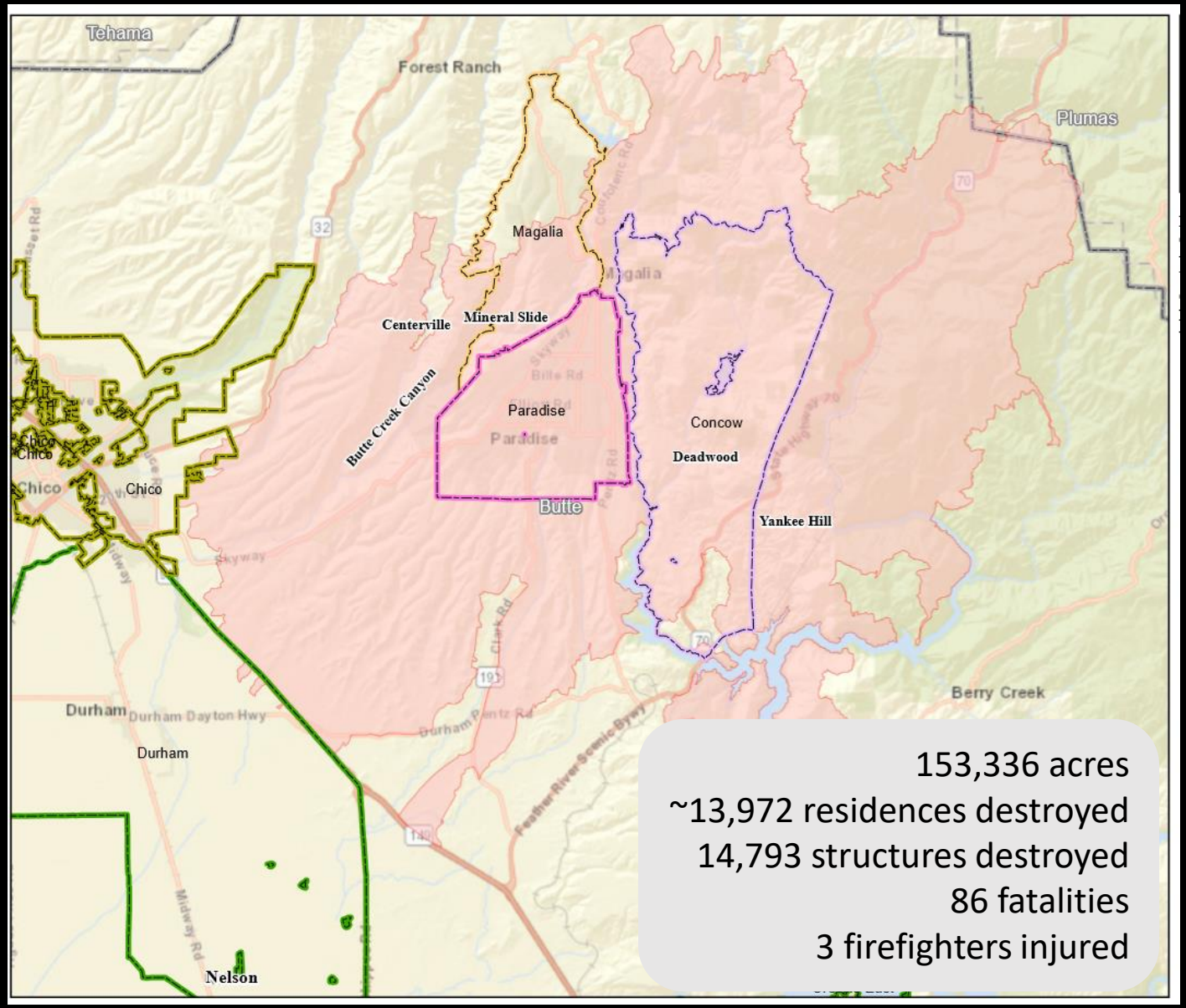
WHEREAS under the provisions of Government Code section 8571, I find that strict compliance with the various statutes and regulations specified in this order would prevent, hinder, or delay the mitigation of the effects of the Camp Fire.

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.

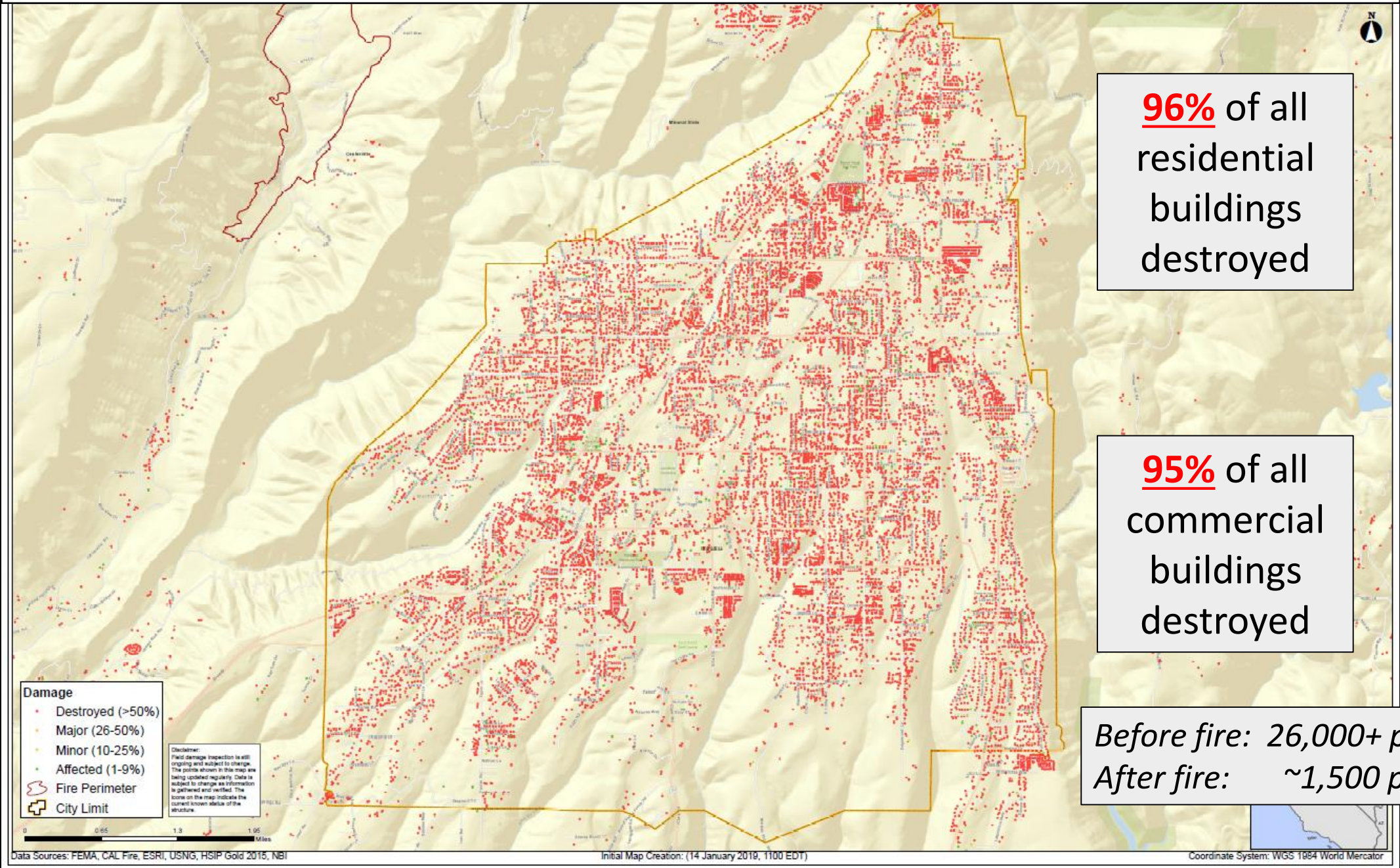
IT IS HEREBY ORDERED THAT:

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



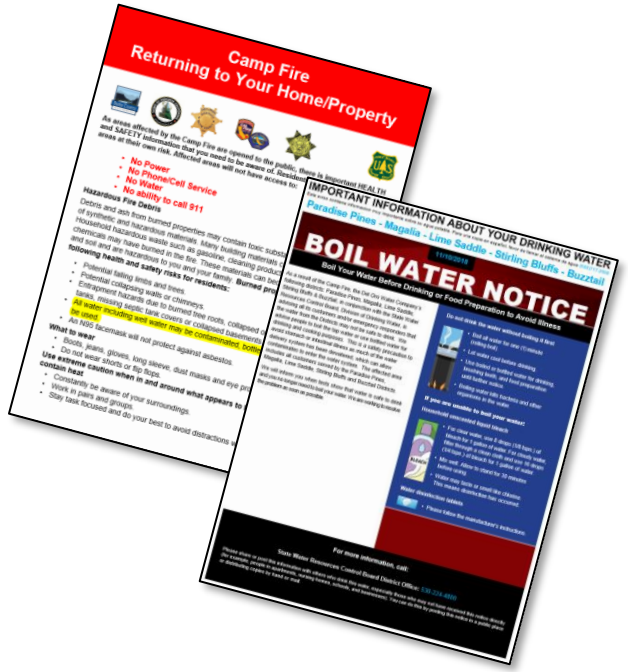
96% of all residential buildings destroyed

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





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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

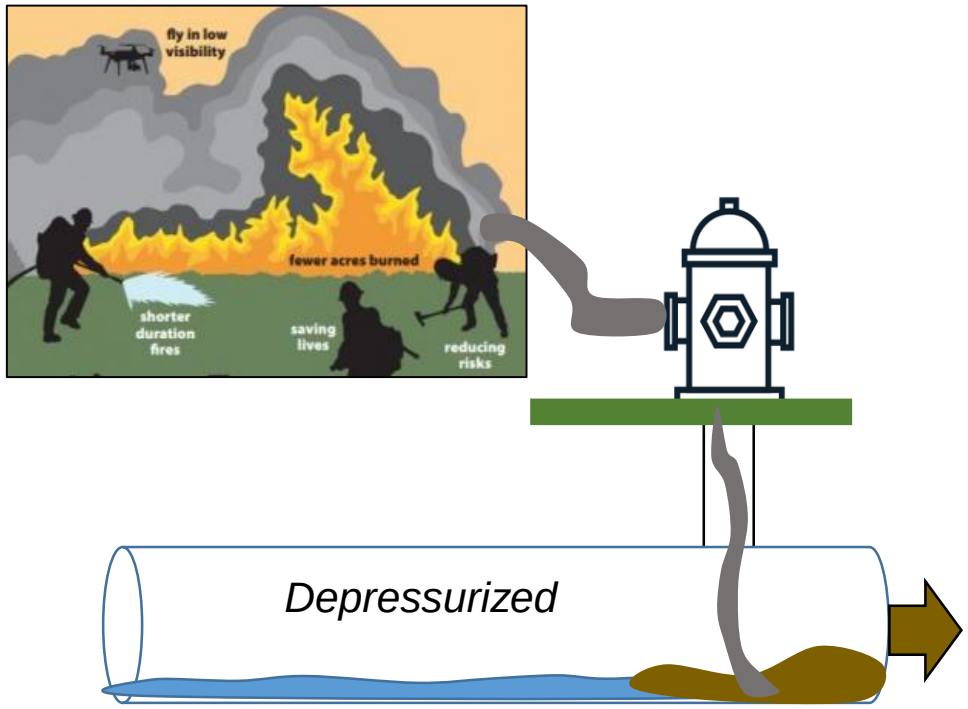
For the Tubbs Fire and Camp Fire, VOCs exceeded *acute* and *chronic* exposure limits

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

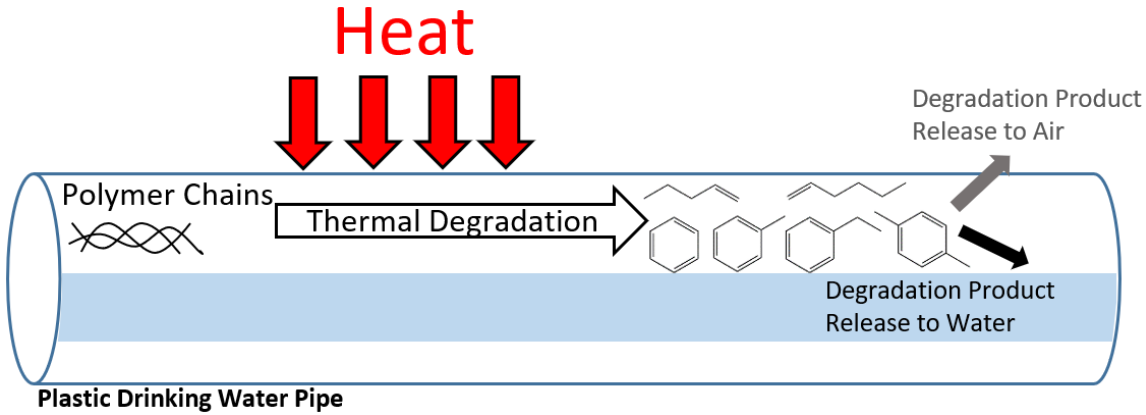
PID used 72 hr stagnation time; DOWC sometimes, but often used 0 hr
p = Utilities did not disclose enough information about their data

Potential PRIMARY Sources

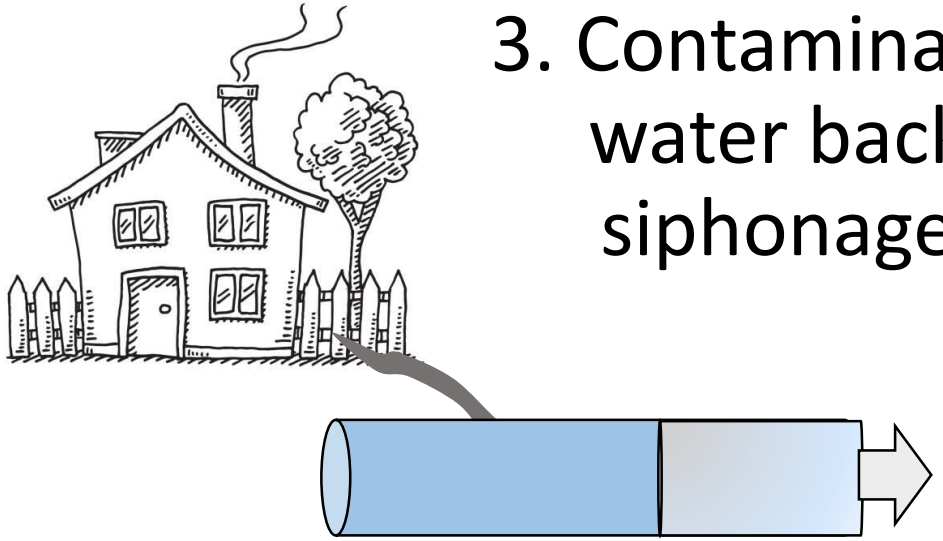
1. Forest biomass or structure combustion



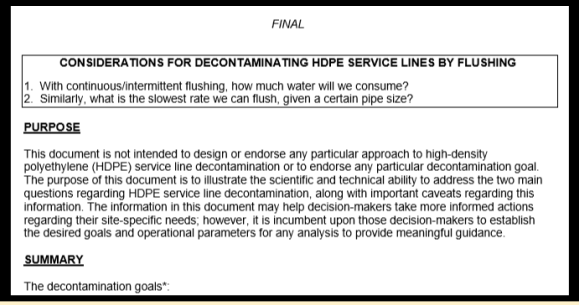
2. Plastic thermal degradation



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

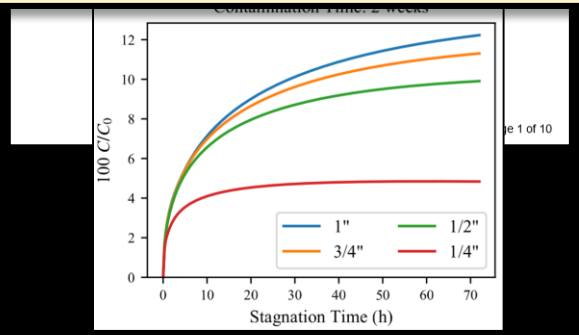
Water Distribution System Decontamination

Collaboration between Us & USEPA

Hydraulics

Polymer Science

Environmental Engineering



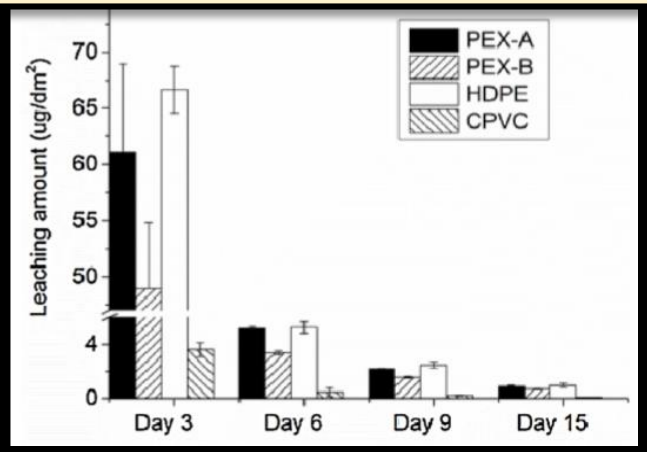
Numerical modeling:

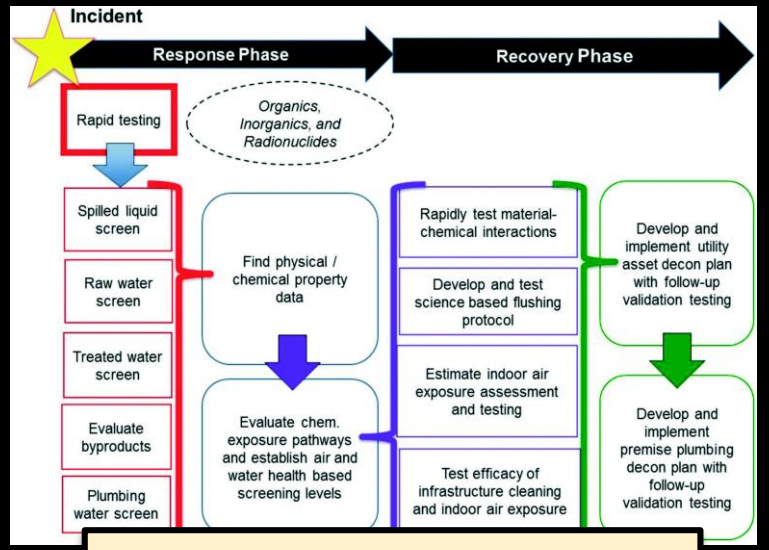
Greater than 286 days vs. less than 64 days of continuous water flushing for 1-inch HDPE service line

(Haupert et al. 2019)

Purdue *(Huang et al. 2017)*

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





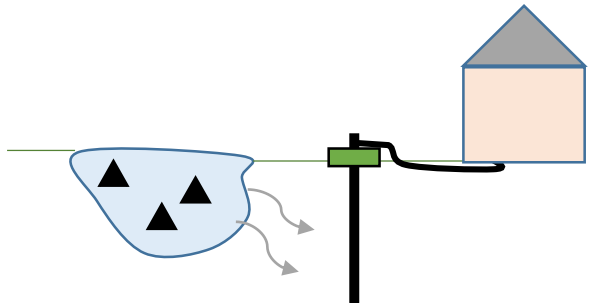
Purdue *(Whelton et al. 2017)*

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

6 Months Later, Households were Largely on their Own

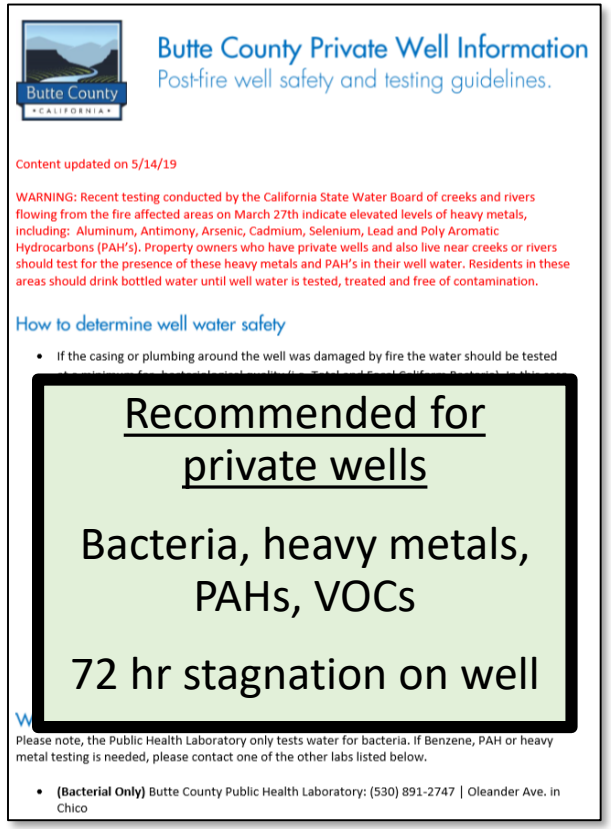
Water use advisories

- 2 water systems contaminated, but had no water advisory
- Some PID customers were not following water advisories



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



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

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

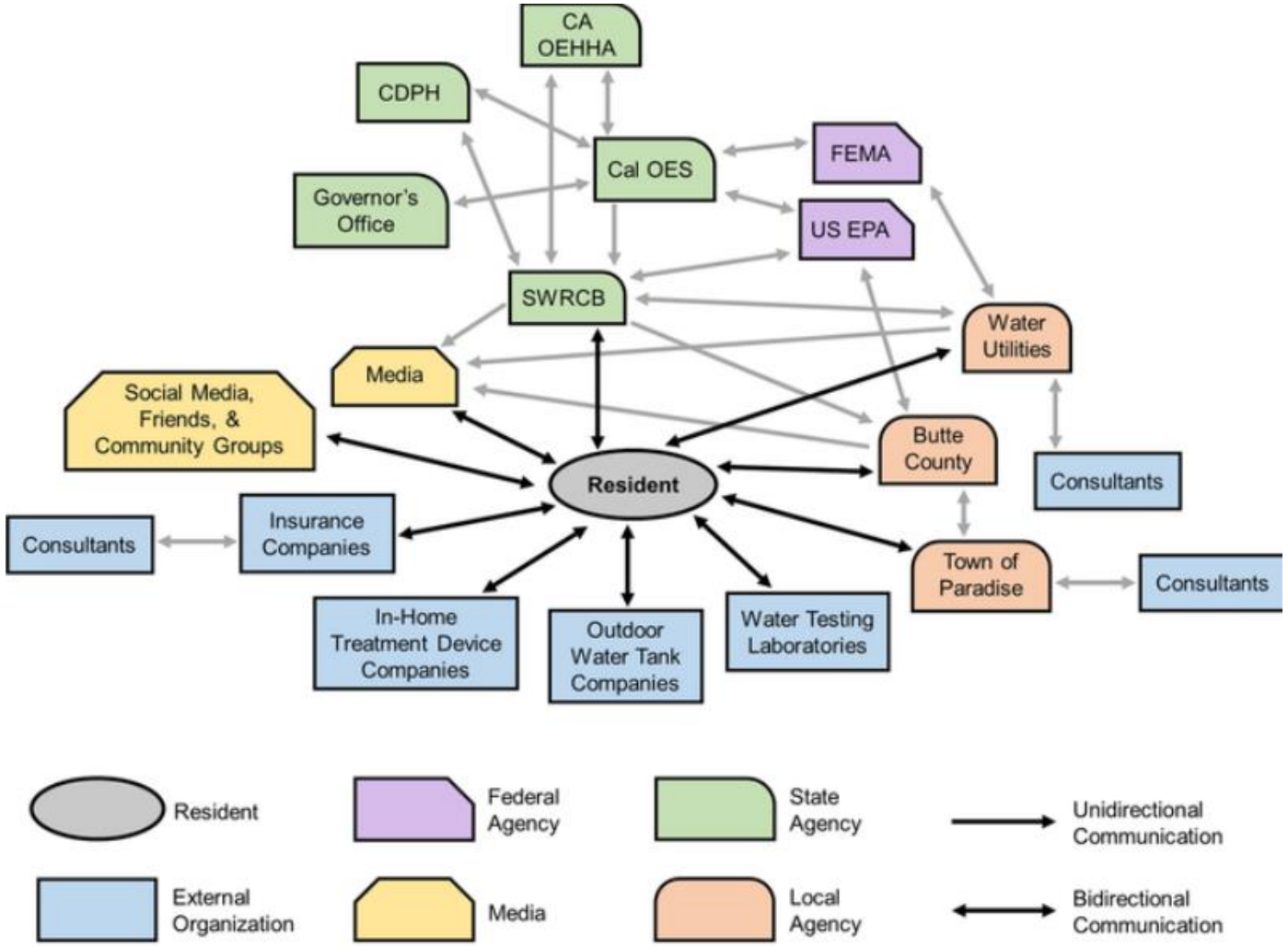
Insurance companies were the in-home treatment deciders

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

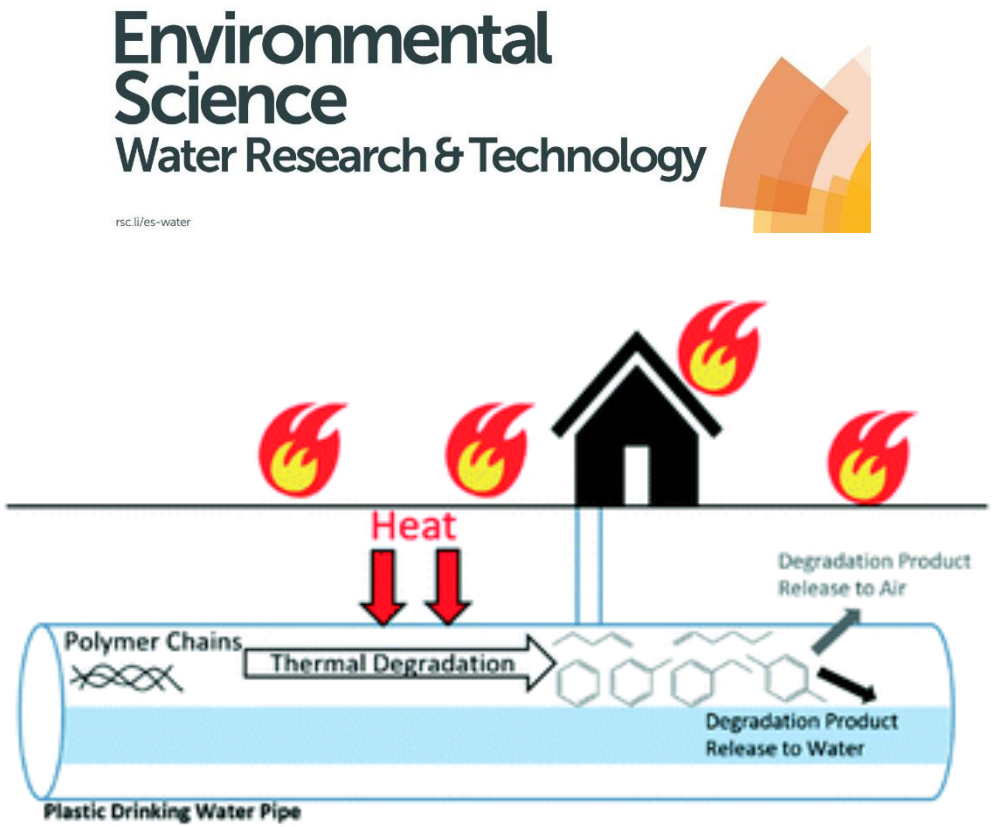
Homeowners:

- 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

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 U.S. 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

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

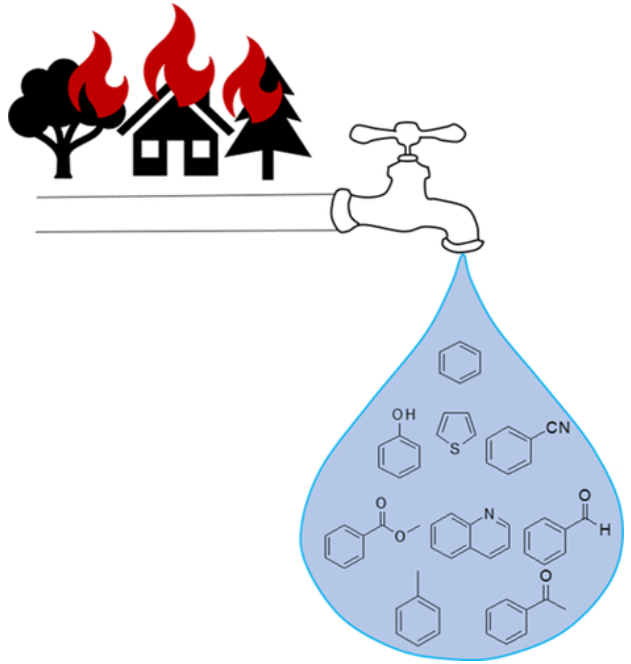
https://doi.org/10.1021/acsestwater.1c00401

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:

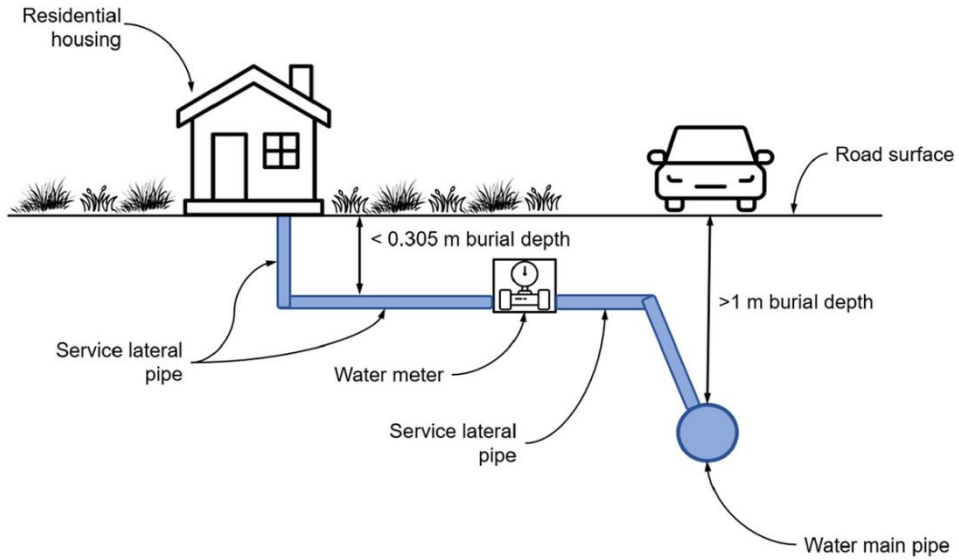
- PVC heating: 32 compounds
- HDPE/PEX heating: 28 compounds
- Service line: 55 compounds associated with uncontrolled burning of biomass and waste materials.



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*

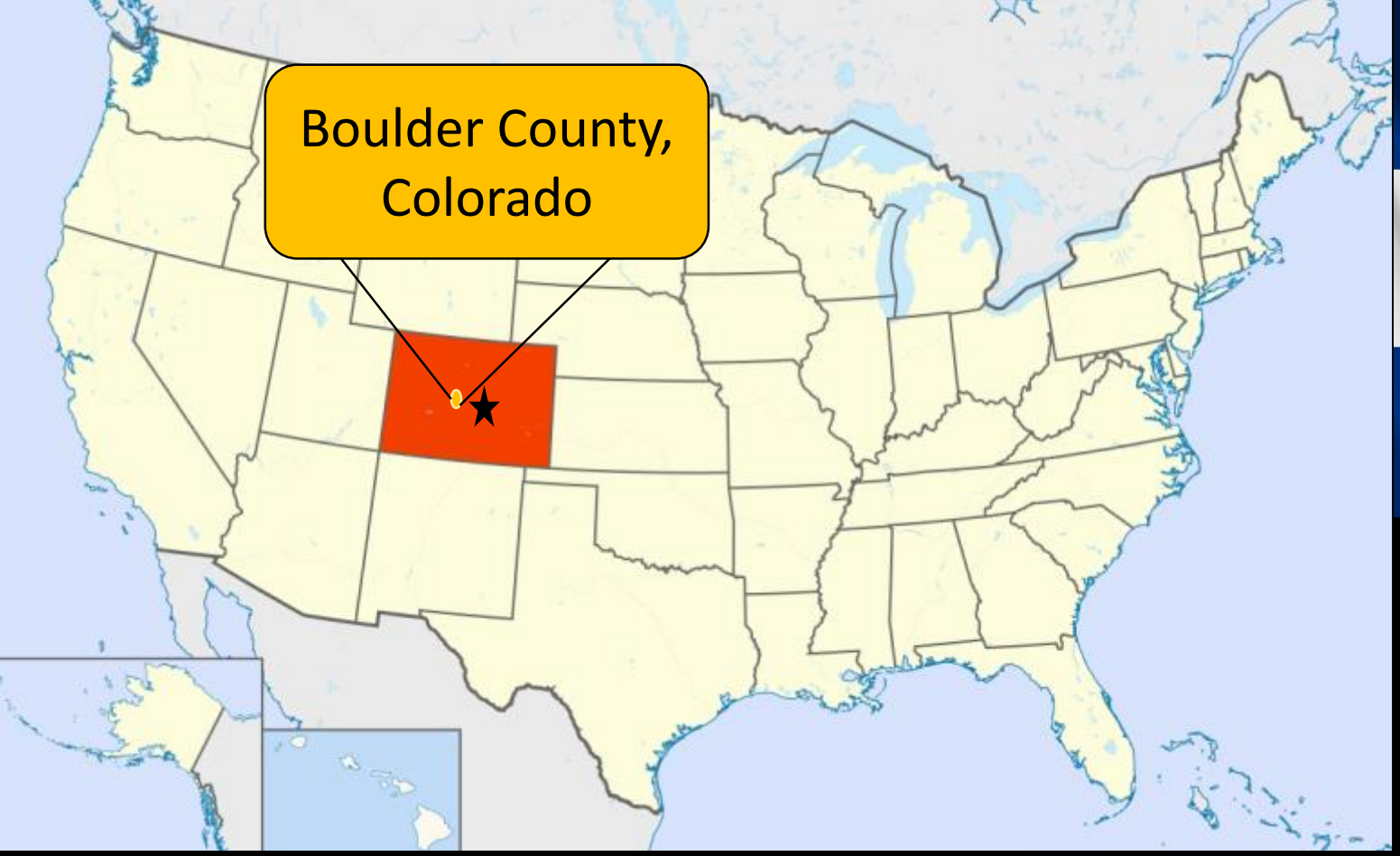
https://doi.org/10.1007/s10694-022-01232-3



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

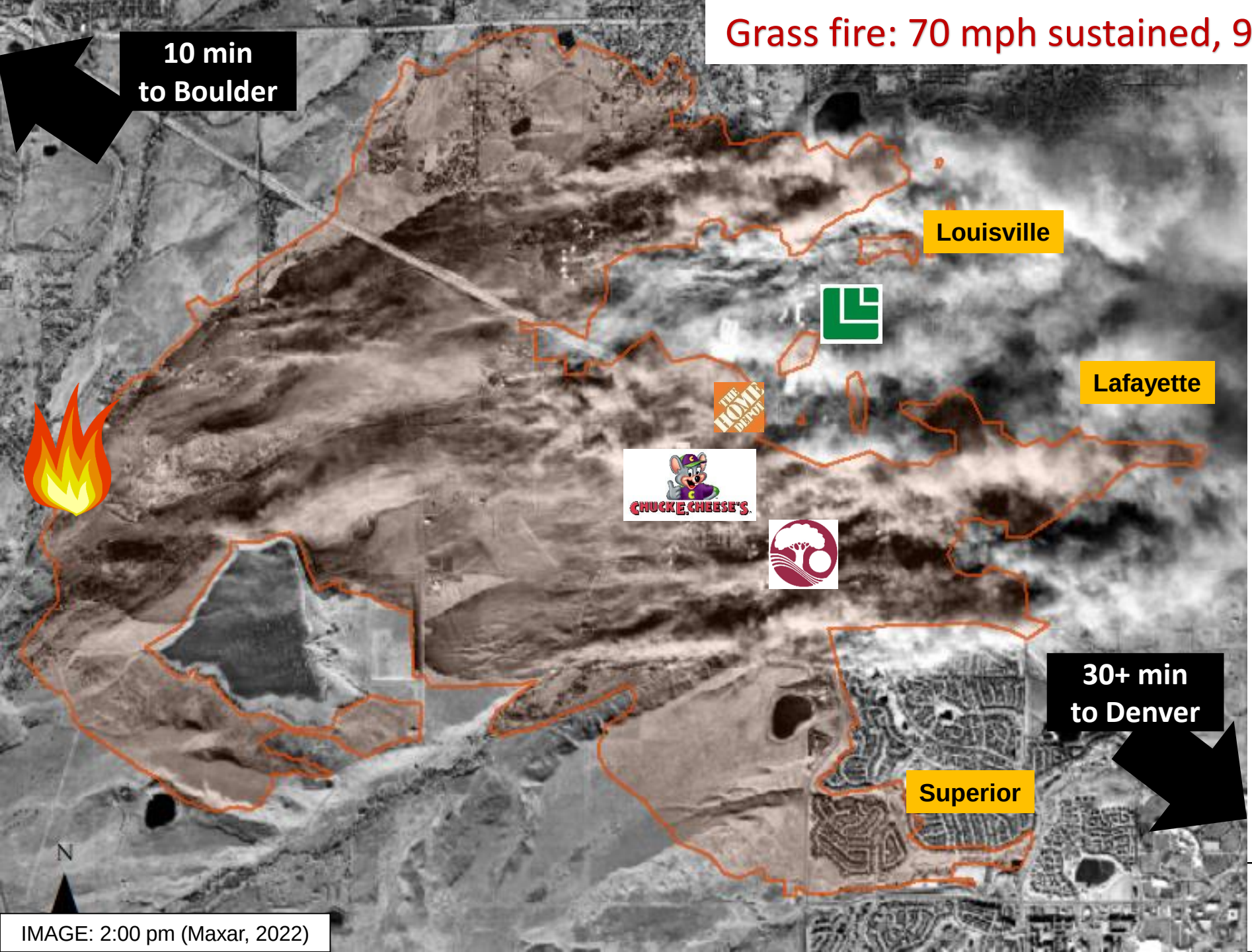
>$1 Billion in damage per NOAA, 6,000+ ac, 40,000+ evacuated

>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



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

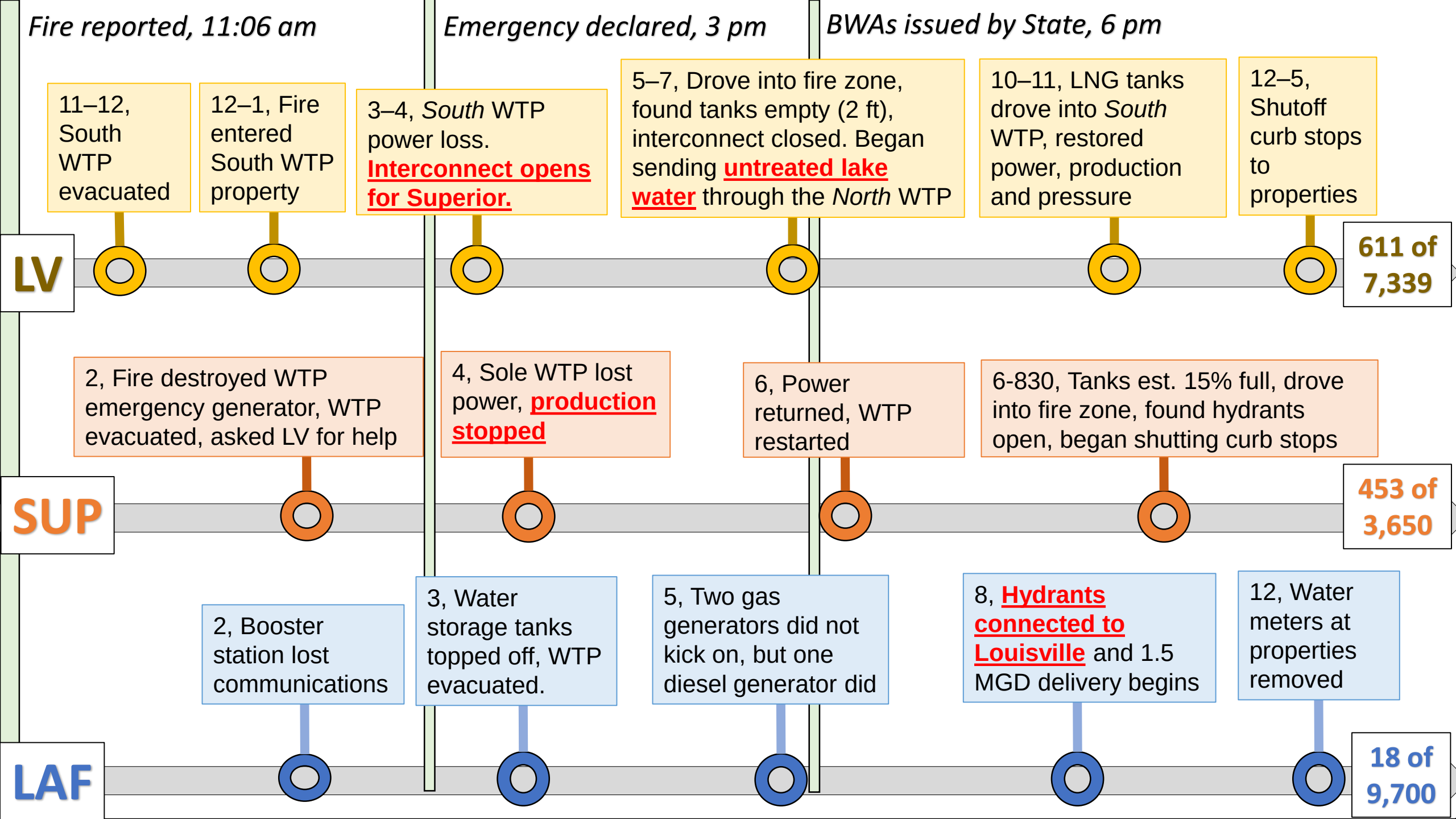
Public Water System (population)	Damaged/ Destroyed Properties	Water Mains, miles	Hydrants	Finished Water Storage, MG	Raw Water
Louisville (20,319)	593	120	1,200	7.5	Surface water
Superior (17,170)	436	50	430	3.4	Surface water
Lafayette (28,700)	~50	177	900	14	Surface water
EBCWD (300)	72 of 137	8	40	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


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

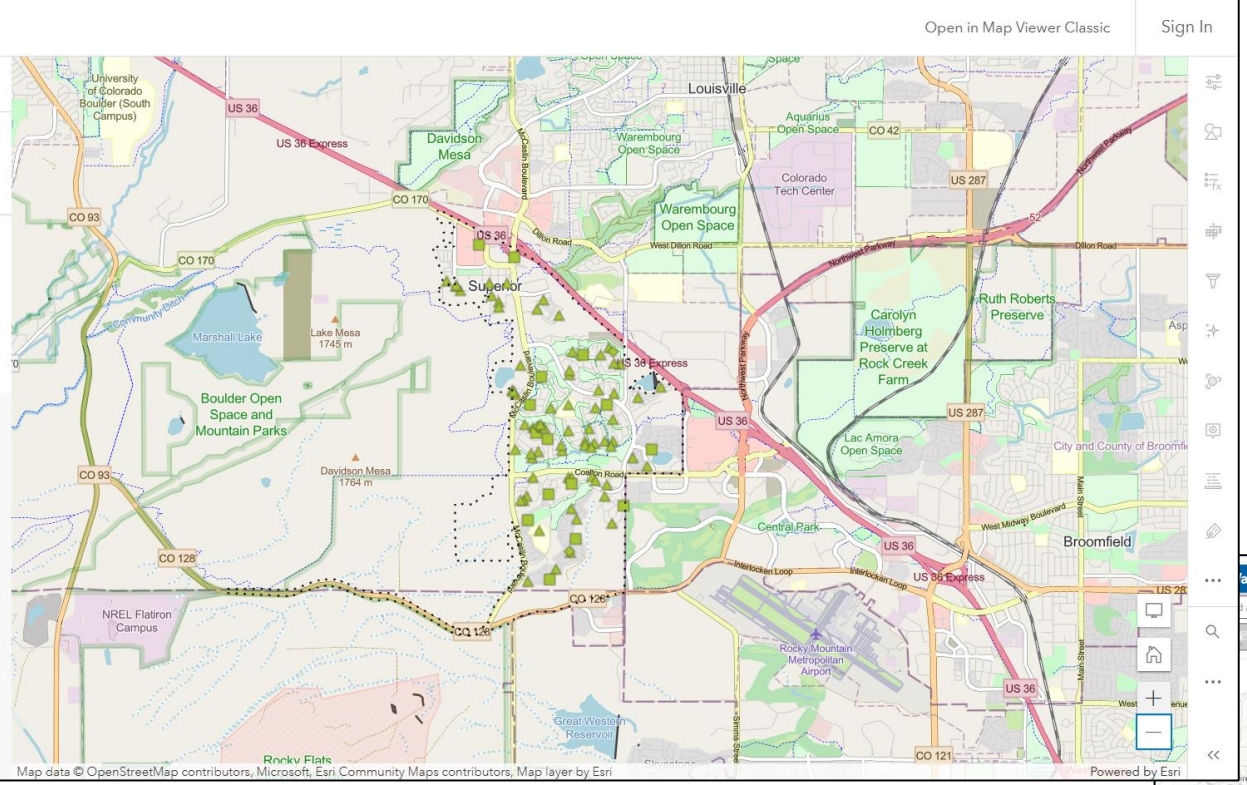

TIM ERLINE
RE PROTECTION
DISTRICT


haley
818

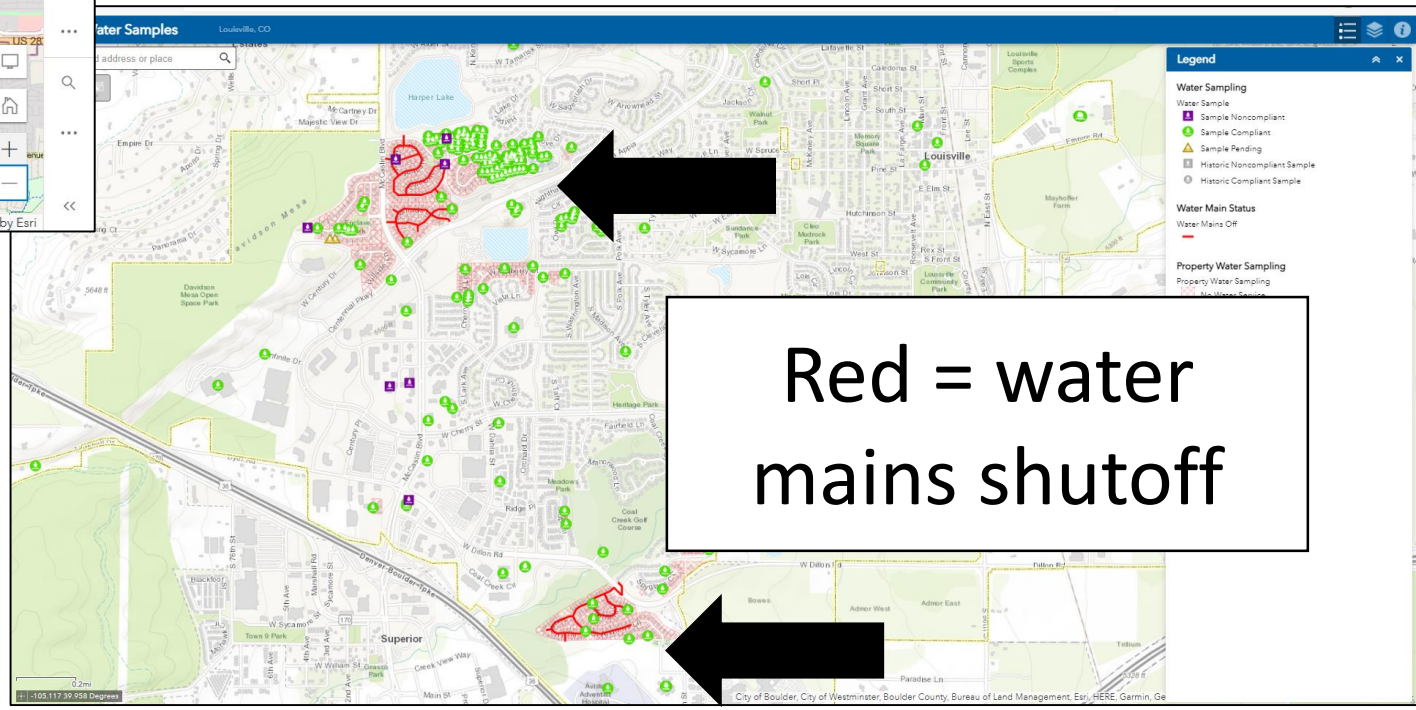
Snowfall helped extinguish the fire and hotspots

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?

--No

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

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

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

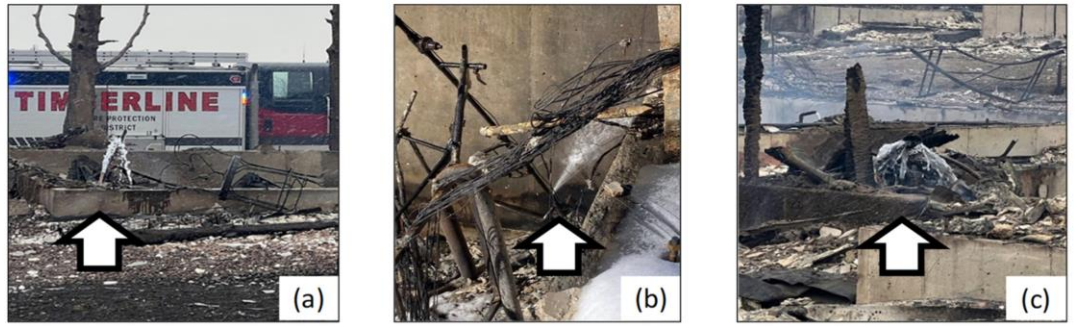
The Marshall Fire: Scientific and policy needs for water system disaster response

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

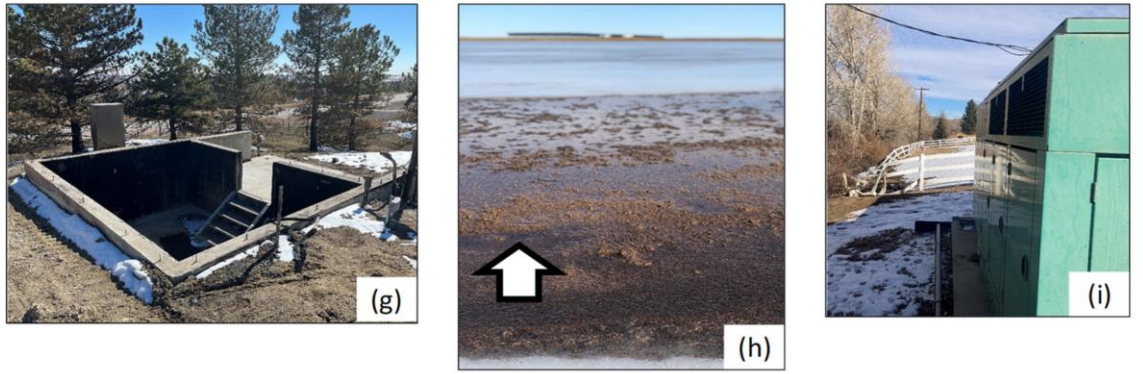
20 scientific and policy needs for improving water system disaster response and recovery

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

Private well testing after wildfire

Evidence was lacking to inform decision making

No published data

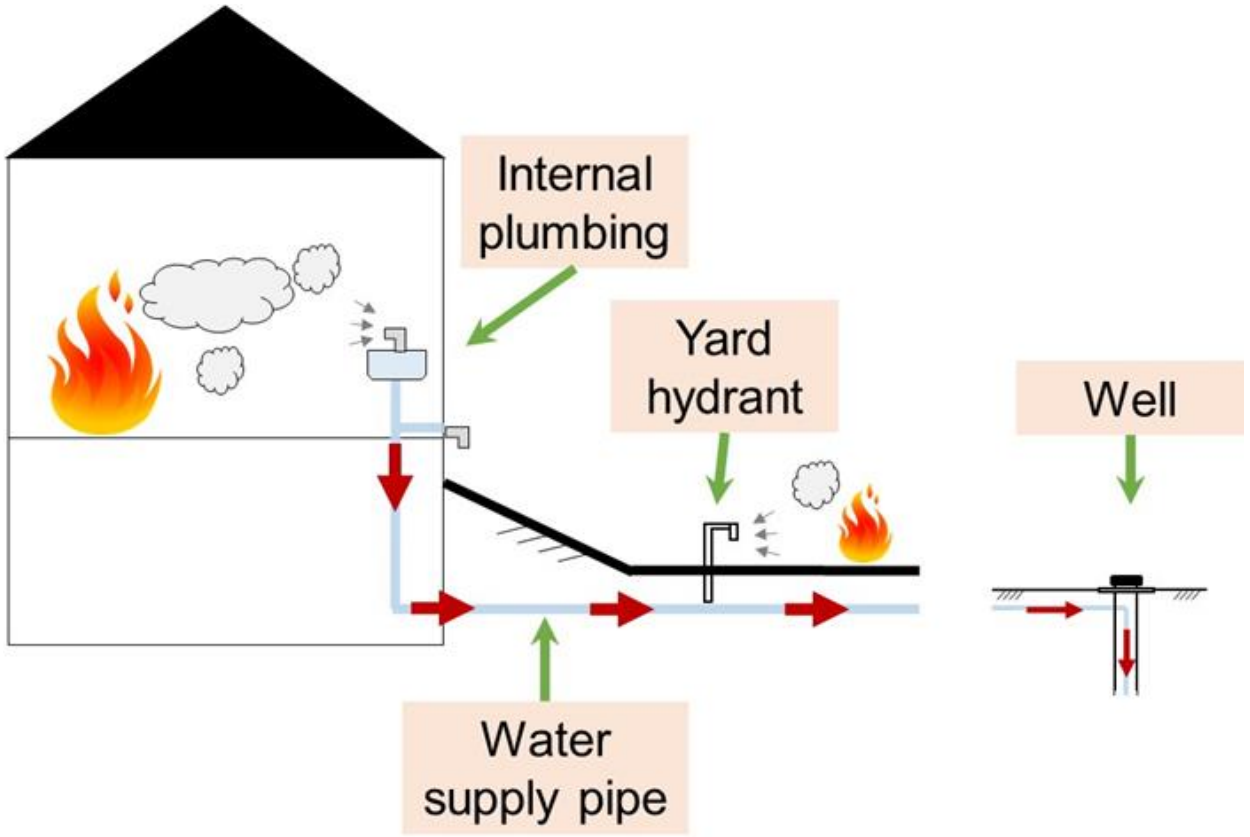
20 different U.S. guidance documents: AK, AZ, CA, CO, KS, MN, NM, MT, OR, WA, CDC, and 2 universities (CO, IN)

- ✓ *Microorganisms (20)*
- ✓ *Nitrate (8), Heavy metals (6)*
- ✓ *VOC: 9 (most said BTEX only)*
- ✓ *SVOC: 4 (some said PAH only)*

Guidance also varied across Canadian agencies

To address this gap, we helped Boulder County and CDPHE after the 2021 Marshall Fire… but more to be done.

Jankowski, Isaacson et al. 2023. *AWWA Wat. Sci.*



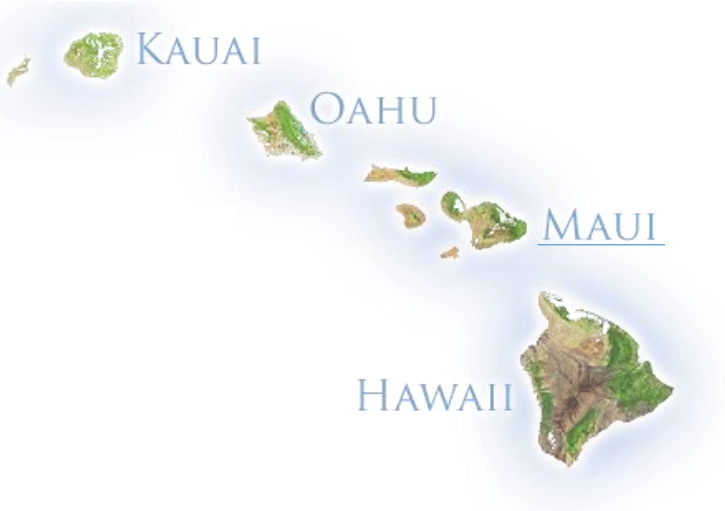
Wildfire damage and contamination to private drinking water wells

AWWA Water Science, January 2023

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

No prior wildfire drinking water well test results available.

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



The Hawaiian archipelago is the most isolated place on earth, more than 2,000 miles from the nearest continent.

2023 Maui Wildfires: August 8, 2023

Hurricane Dora offshore, 60-80 mph gusts onshore

Olinda Fire: 1,081 acres, 2 structures

Kula Fire: 202 acres, 544 structures

Lahaina Fire: 2,170 acres, 2,207 structures

Puelho Fire: 5,300 acres, 0 structures

Deadliest wildfire incident in modern U.S. history: 155 dead, 66+ missing

Lahaina Sys. Pop. 20,065
Elev. 1 ft.
28% White alone
Median income: $80,035
Median-vale home: $0.72M
Seat of Hawaiian Kingdom

County Seat

Kula Sys. Pop. 7,686
Elev. 1,000-3,600 ft.
54% White alone
Median income: $86,938
Median-value home: $1.1M





1. Conduct free in-home drinking water testing for Lahaina, Kula, and Olinda households and survey needs

University of Hawai'i Mānoa

Purdue University

2. Advise Maui County Utilities on how to respond to and recover their damaged water systems

Purdue University

City of Louisville Colorado • Since 1878

ACWA JPIA

PID Serving since 1916

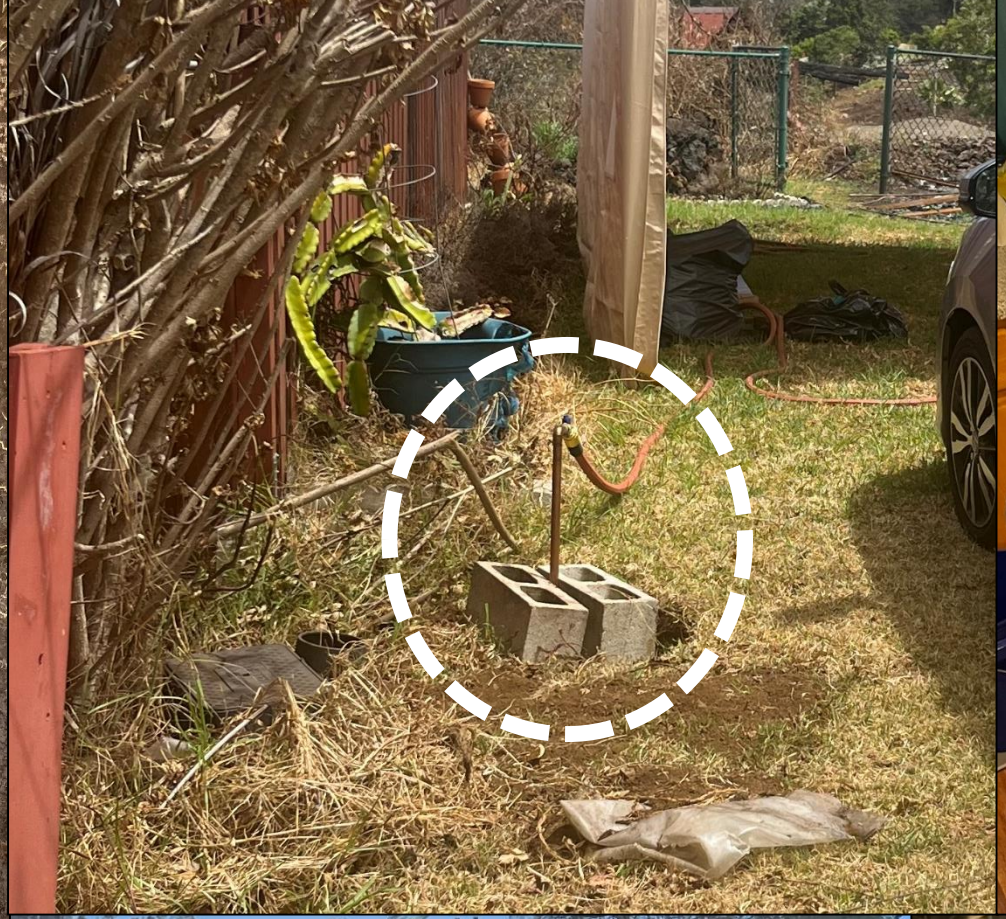
City of Santa Rosa

3. Assist the State of Hawai'i Veterinarian investigate damage and impacts to ranch water systems

Purdue University

University of Hawai'i Mānoa

City of Louisville Colorado • Since 1878




U-HAUL


UNITED STATES
POST OFFICE
LAHAINA, HAWAII
96761
RESERVED
PARKING
VAN


POTABLE WATER
500 GALLONS


FREE
FOOD + WATER
Food
+
Drink
Kula
Strong

Preliminary Results: Rapid Household Survey 2 Weeks after the Wildfires to Ascertain Drinking Water Experiences and Needs

14 households, All in the Unsafe Water Alert zones

- ✓ Water systems: 2 Lahaina, 11 Kula, 1 cistern in Kula
- ✓ Property: 10 owned, 4 rent; All had insurance
- ✓ Average household lived in home for 12 years
- ✓ Average respondent age (51), min (26), max (75)

Findings

- 5 homes were less than 500 ft from a destroyed home; 7 had property damage
- 13 households used water before finding out it was potentially contaminated
- 10 households reported a drinking water taste, odor, color, or clarity problem
- 4 households visited water buffalos - 7 did not because of source/safety concern
- 42 questions - Households wanted officials to answer specific questions
- Cistern owner followed Unsafe Water Alert, no post-fire cistern safety advice
- And more…


STATE OF HAWAII
DEPARTMENT
OF
AGRICULTURE

Looking Ahead

Safe drinking water is critical for the health, safety, and economic vitality of communities

Water Systems Face Multiple Challenges During Wildfire Attack

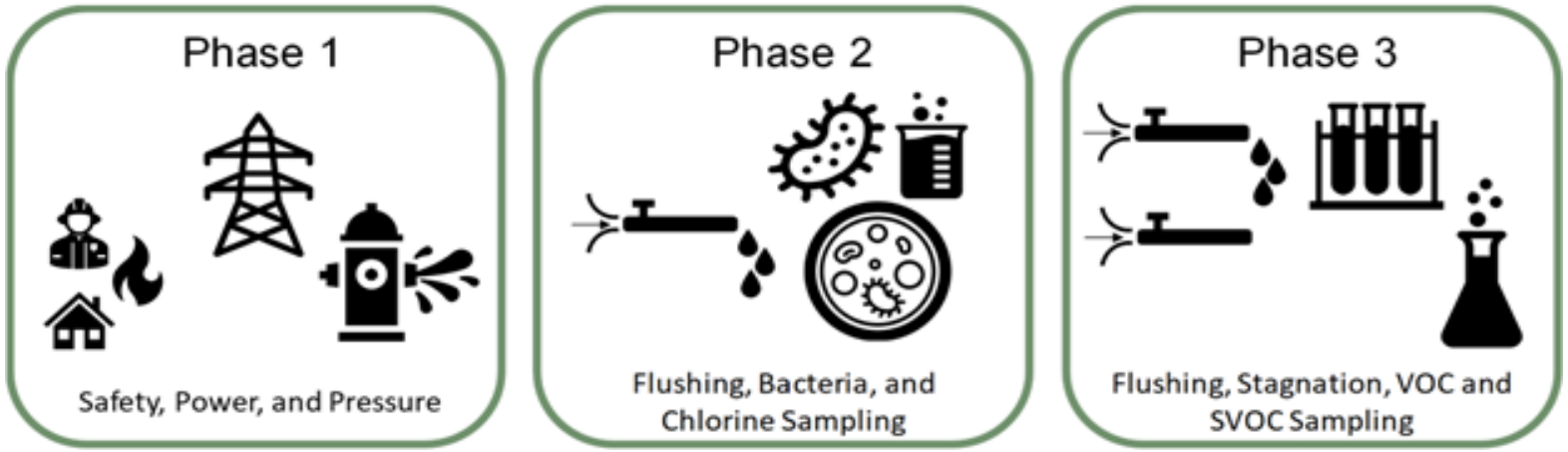
Pressure, utility network and building plumbing: Leaking, destruction

Power: Electric poles down, shutoff by provider, natural gas generators destroyed, lacking fuel

Telecommunications: Outages inhibit tank level, pressure, chemical feed, and pump status monitoring

Personnel: Hazard situations, unable to respond due to staff availability

Contamination: Chemicals and microbiologicals drawn into the water system, immediate health risk



Support firefighting
Isolate damage
Maintain pressure
Water use warnings

Personnel surge
Restore control, pressure
Repeated sampling
Laboratories

Personnel surge
Repeated sampling
Laboratories
Decon, remove, replace

Resilience:
The ability to bounce back from misfortune or change

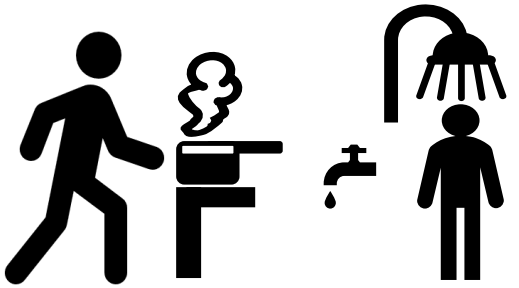
Decisions Needed

Exposure Routes

(i.e., Adults, children, infants, etc.)

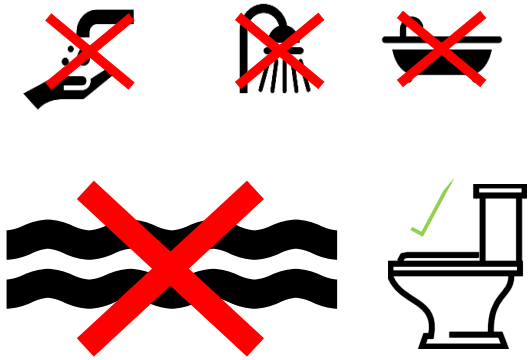
Ingestion

Dermal contact



Inhalation

Water Use Warnings

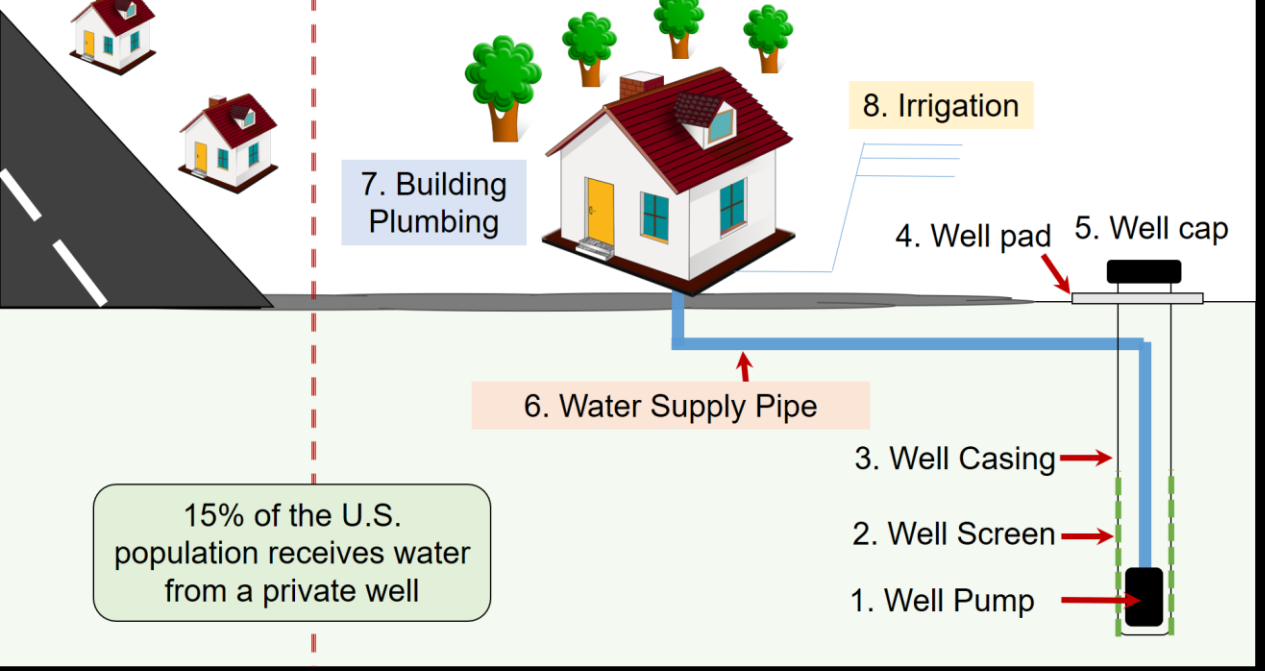


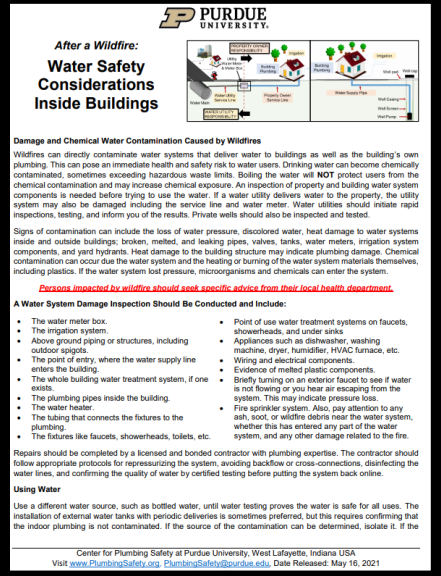
Do Not Use (DNU)

Do Not Drink (DND)

Boil Water Order

If you do not know the range of contamination, it is not advisable to use in-home water treatment devices. Those are NOT rated to make acutely contaminated water safe.





After a Wildfire:

Water Safety Considerations Inside Buildings

Damage and Chemical Water Contamination Caused by Wildfires

Wildfires can directly contaminate water systems that deliver water to buildings as well as the building's own plumbing. This can pose an immediate health and safety risk to water users. Drinking water can become chemically contaminated, sometimes exceeding hazardous waste limits. Boiling the water will **NOT** protect users from the chemical contamination and may increase chemical exposure. An inspection of property and building water system components is needed before trying to use the water. If a water utility delivers water to the property, the utility system may also be damaged including the service line and water meter. Water utilities should initiate rapid inspections, testing, and inform you of the results. Private wells should also be inspected and tested.

Signs of contamination can include the loss of water pressure, discolored water, heat damage to water systems inside and outside buildings; broken, melted, and leaking pipes, valves, tanks, water meters, irrigation system components, and yard hydrants. Heat damage to the building structure may indicate plumbing damage. 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 can enter the system.

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

A Water System Damage Inspection Should Be Conducted and Include:

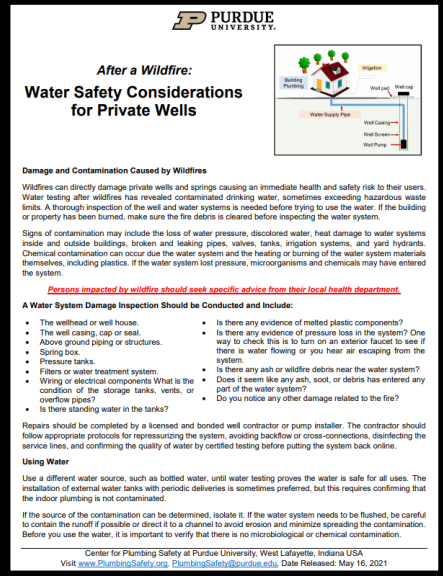
- The water meter box.
- The irrigation system.
- Above ground piping or structures, including outdoor spigots.
- The point of entry, where the water supply line enters the building.
- The whole building water treatment system, if one exists.
- The plumbing pipes inside the building.
- The water heater.
- The tubing that connects the fixtures to the plumbing.
- The fixtures like faucets, showerheads, toilets, etc.
- Point of use water treatment systems on faucets, showerheads, and under sinks
- Appliances such as dishwasher, washing machine, dryer, humidifier, HVAC furnace, etc.
- Wiring and electrical components.
- Evidence of melted plastic components.
- Briefly turning on an exterior faucet to see if water is not flowing or you hear air escaping from the system. This may indicate pressure loss.
- Fire sprinkler system. Also, pay attention to any ash, soot, or wildfire debris near the water system, whether this has entered any part of the water system, and any other damage related to the fire.

Repairs should be completed by a licensed and bonded contractor with plumbing expertise. The contractor should follow appropriate protocols for repressurizing the system, avoiding backflow or cross-connections, disinfecting the water lines, and confirming the quality of water by certified testing before putting the system back online.

Using Water

Use a different water source, such as bottled water, until water testing proves the water is safe for all uses. The installation of external water tanks with periodic deliveries is sometimes preferred, but this requires confirming that the indoor plumbing is not contaminated. If the source of the contamination can be determined, isolate it. If the

Center for Plumbing Safety at Purdue University, West Lafayette, Indiana USA
Visit www.PlumbingSafety.org, PlumbingSafety@purdue.edu, Date Released: May 16, 2021



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.

A Water System Damage Inspection Should be Conducted and Include:

- The wellhead or well house.
- The well casing, cap or seal.
- Above ground piping or structures.
- Spring box.
- Pressure tanks.
- Filters or water treatment system.
- Wiring or electrical components What is the condition of the storage tanks, vents, or overflow pipes?
- Is there standing water in the tanks?
- Is there any evidence of melted plastic components?
- Is there any evidence of pressure loss in the system? One way to check this is to turn on an exterior faucet to see if there is water flowing or you hear air escaping from the system.
- Is there any ash or wildfire debris near the water system?
- Does it seem like any ash, soot, or debris has entered any part of the water system?
- Do you notice any other damage related to the fire?

Repairs should be completed by a licensed and bonded well contractor or pump installer. The contractor should follow appropriate protocols for repressurizing the system, avoiding backflow or cross-connections, disinfecting the service lines, and confirming the quality of water by certified testing before putting the system back online.

Using Water

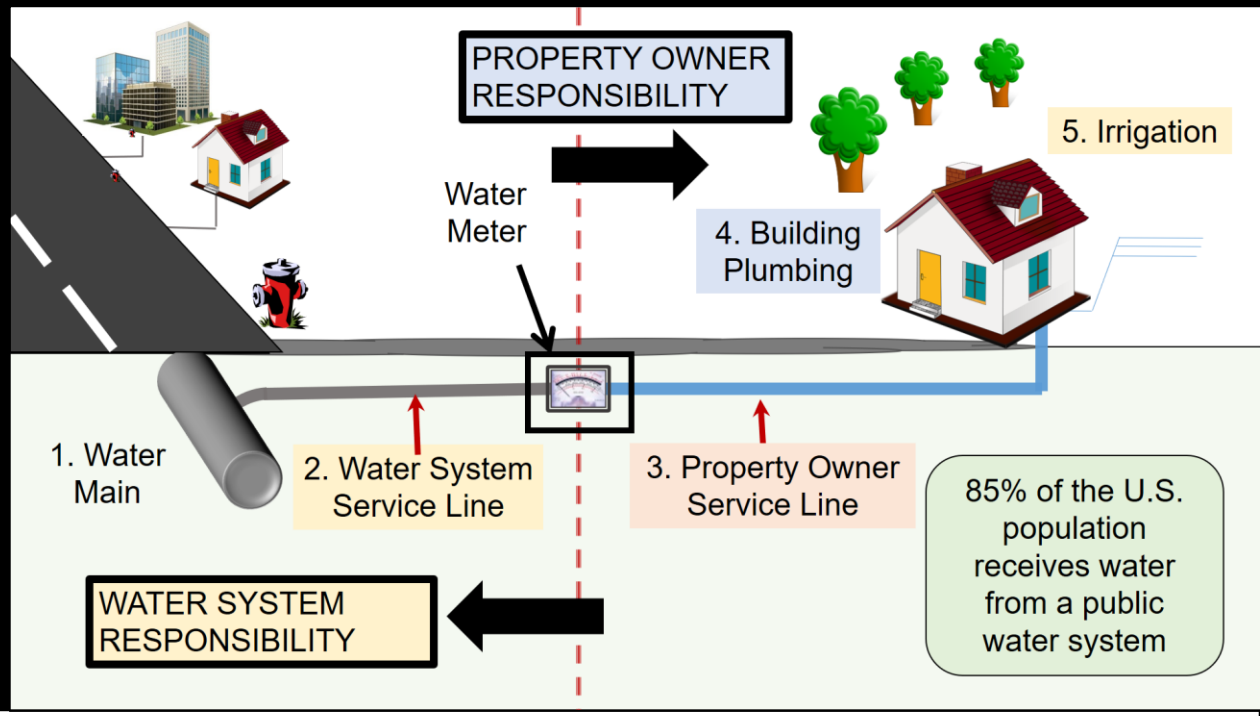
Use a different water source, such as bottled water, until water testing proves the water is safe for all uses. The installation of external water tanks with periodic deliveries is sometimes preferred, but this requires confirming that the indoor plumbing is not contaminated.

If the source of the contamination can be determined, isolate it. If the water system needs to be flushed, be careful to contain the runoff if possible or direct it to a channel to avoid erosion and minimize spreading the contamination. Before you use the water, it is important to verify that there is no microbiological or chemical contamination.

Center for Plumbing Safety at Purdue University, West Lafayette, Indiana USA
Visit www.PlumbingSafety.org, PlumbingSafety@purdue.edu, Date Released: May 16, 2021

We created two 1 page inspection and water testing guidance sheets for private wells and building water systems

Access here ➔ [Click]



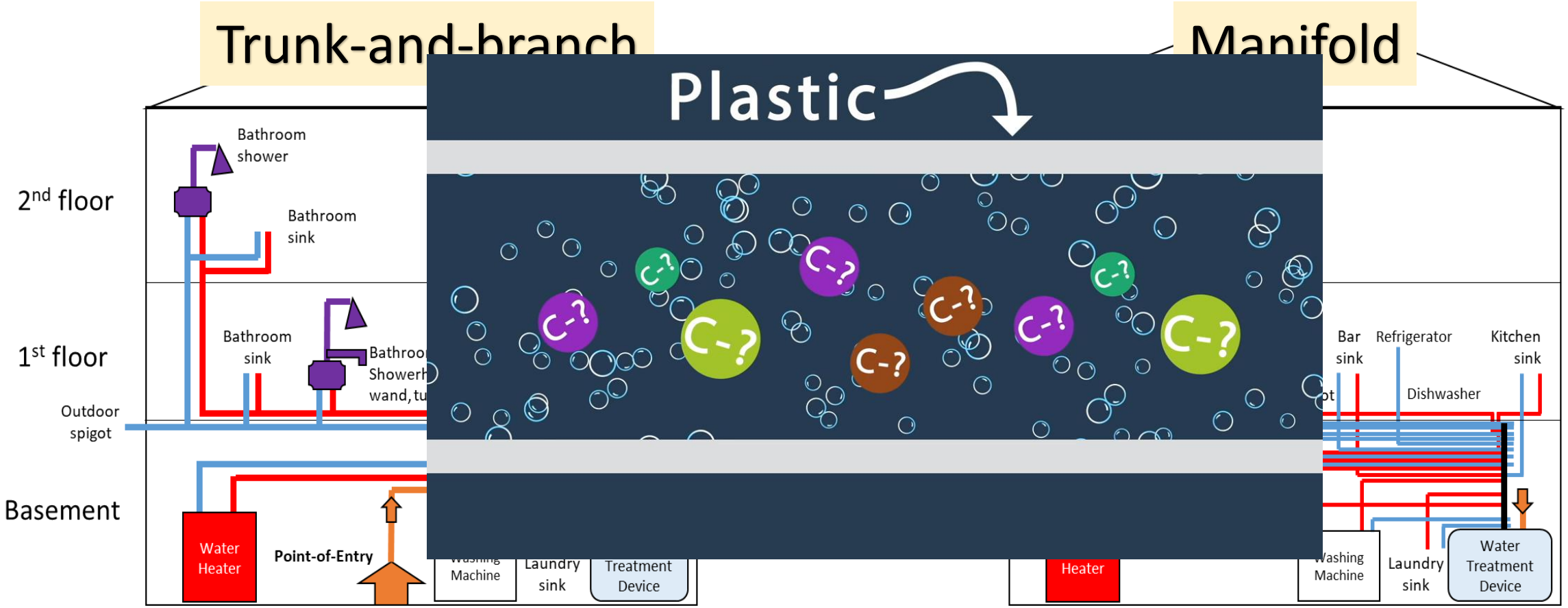
PURDUE UNIVERSITY

In-home treatment devices are not designed for some wildfire water contamination. Know the range, then decide on use.

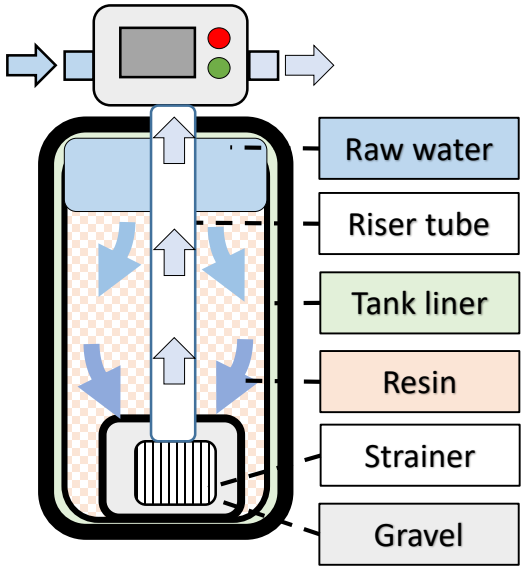
Water Collected and Analyze	Preliminary Results, ppb			
	Benzene	Toluene	Ethyl Benzene	Xylene
Entering the filter	713	911	87	212
Exiting the filter				
1 L	20	15	3	4
1.5 L	33	30	5	9
2 L	47	46	6	11
3 L	64	75	10	21
3.5 L	62	75	10	20
4 L	24	22	4	5
4.5 L	87	98	11	21
5 L	37	37	5	8

In 2019, CA OEHHA concluded that short-term 26 ppb benzene exposure would prompt an increased risk of blood effects in children such as a decrease in lymphocytes and white blood cells; Benzene has a 5 ppb Federal MCL, 1 ppb CA MCL

Where and how you sample (and decon) in plumbing must consider the specific layout and components

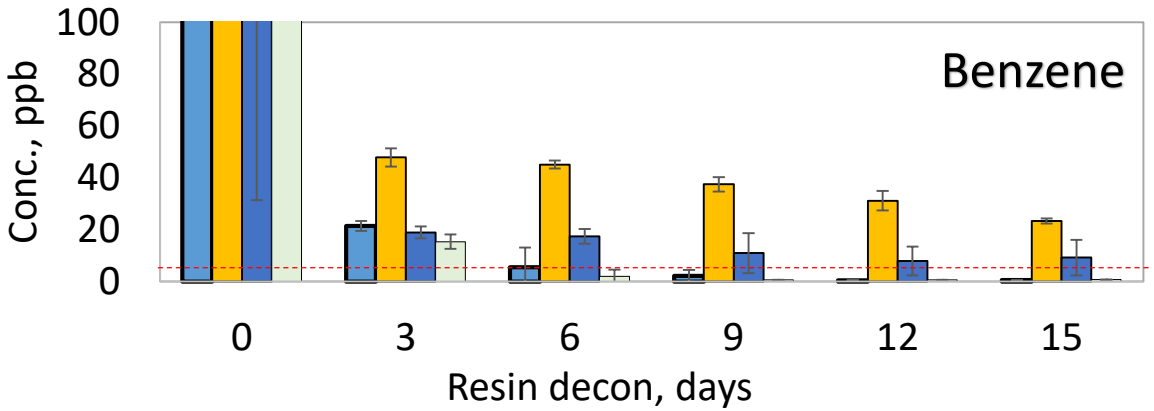


Hydrocarbon Contamination and Decontamination of Water Softeners



Surface area

Resin: 2,800,000+ cm^2
Liner: 9,300 cm^2
Gaskets: 32 cm^2



…. of Water Supply Connectors

After the 2014 West Va. chemical spill, the Health Department recommended discarding tubing at restaurants

Dishwasher connector – PVC

Softener connector – PVC

Ice-maker tubing – PE

Multipurpose tubing – PVC

Faucet supply line – PVC

Ice-maker tubing – PEX

All plastics sorbed 93-100% of the BTEX in 24 hr

9 of 11 materials still exceeded the benzene MCL after 9 days of decon

Washing machine hose – EPDM

Jankowski et al. 2023. *ES&T.*

Isaacson et al. *In Prep.*

Wildfire Water Utility Training

Roles and responsibilities of organizations

Disaster CONOPS – Concept of Operations Plan

Wildfire worker safety, hazards, and PPE

Public notifications and customer engagement

Water sampling, testing and decision-making

Mutual aid/WARN, interdependent utilities

Return to service actions and plan

Recovery lessons (i.e., debris, officials)

Tabletop exercise

Learn from Experience

2017 Tubbs Fire (California)

2018 Camp Fire (California)

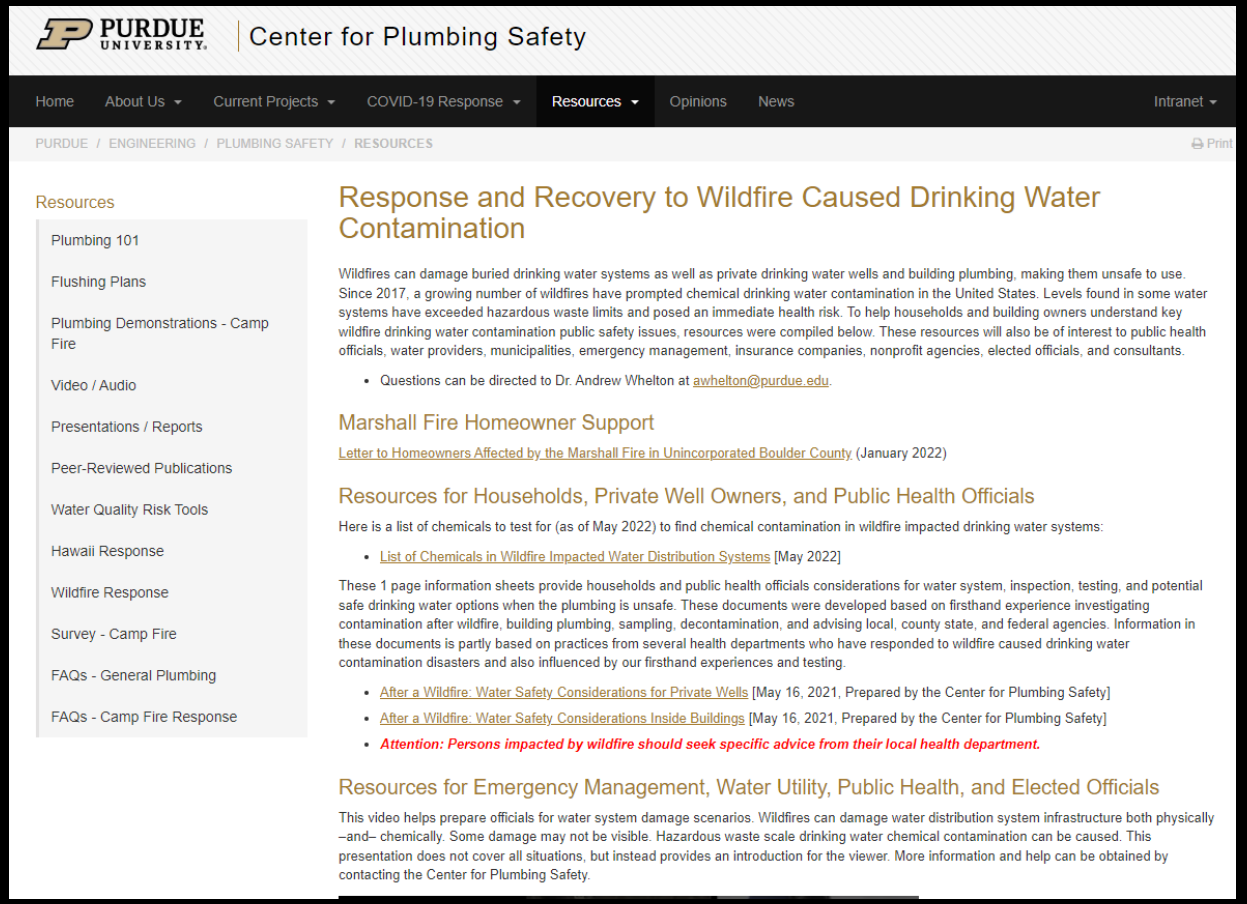
2020 Oregon Fires (Oregon)

2021 Marshall Fire (Colorado)

2022 Calf Canyon/Hermits Peak Fires (New Mexico)

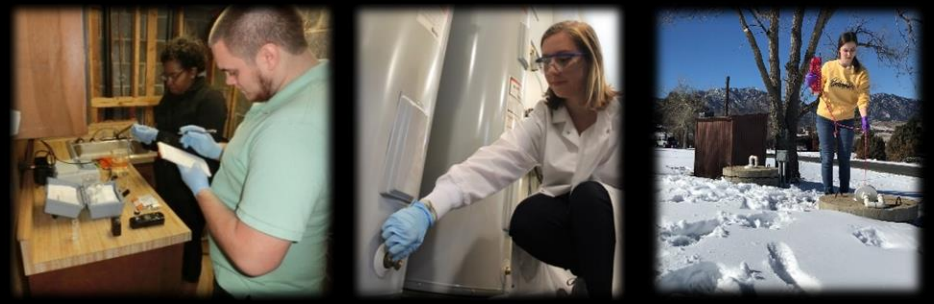
2023 Maui Fires (Hawai'i)

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



More Lessons Coming Soon

www.PlumbingSafety.org



- ✓ Post-fire chemicals to test for
- ✓ Brief videos for emergency managers and health officials
- ✓ Guidance for private well owners
- ✓ Guidance for building owners
- ✓ Federal and state government agency resources
- ✓ FEMA mitigation guidance
- ✓ Other training resources

PURDUE UNIVERSITY

NSF

THE Water Research FOUNDATION

Rotary Club of Paradise, California

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY