The Marshall Fire

Andrew Whelton, Ph.D.

April 12, 2022

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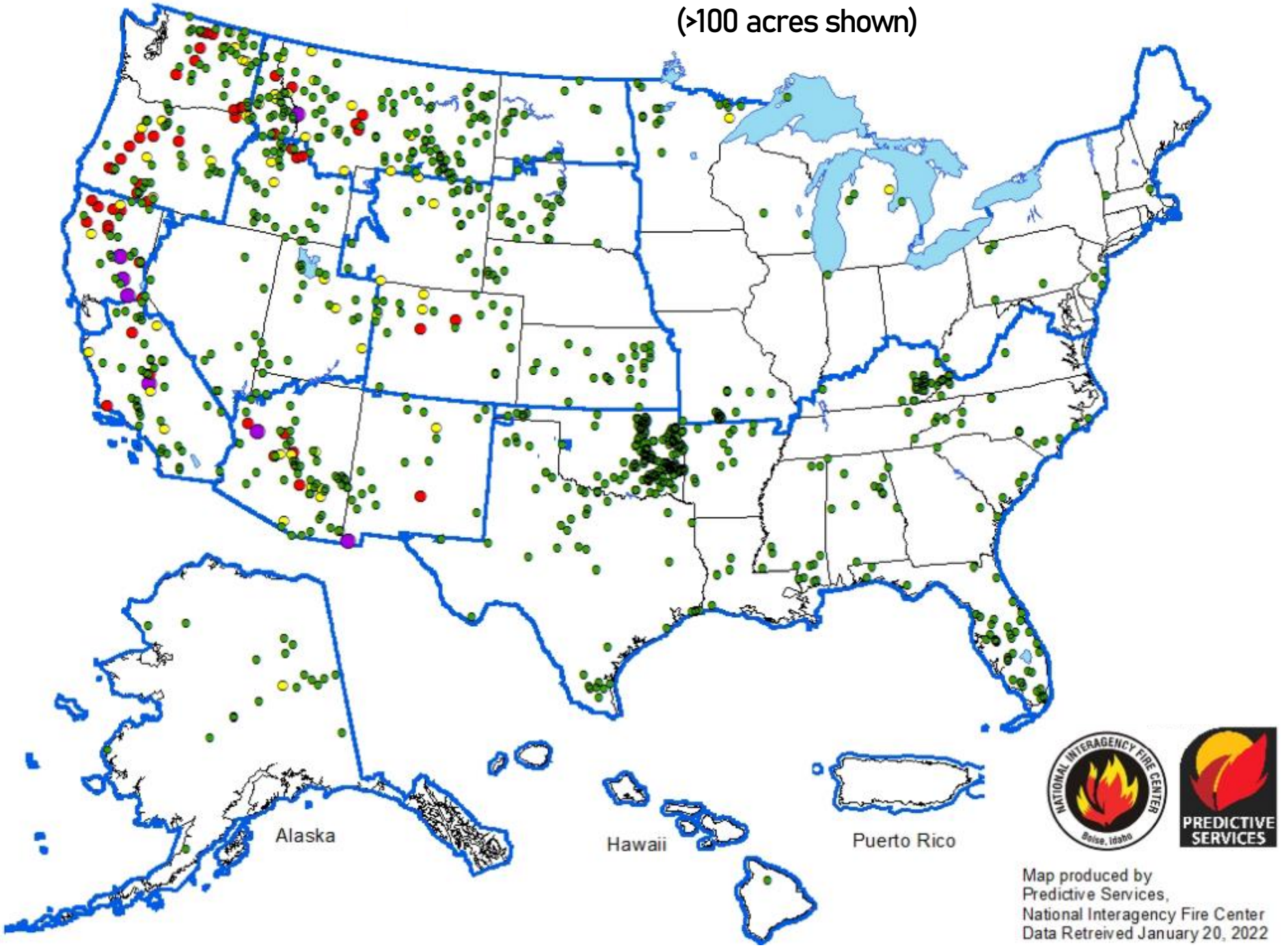
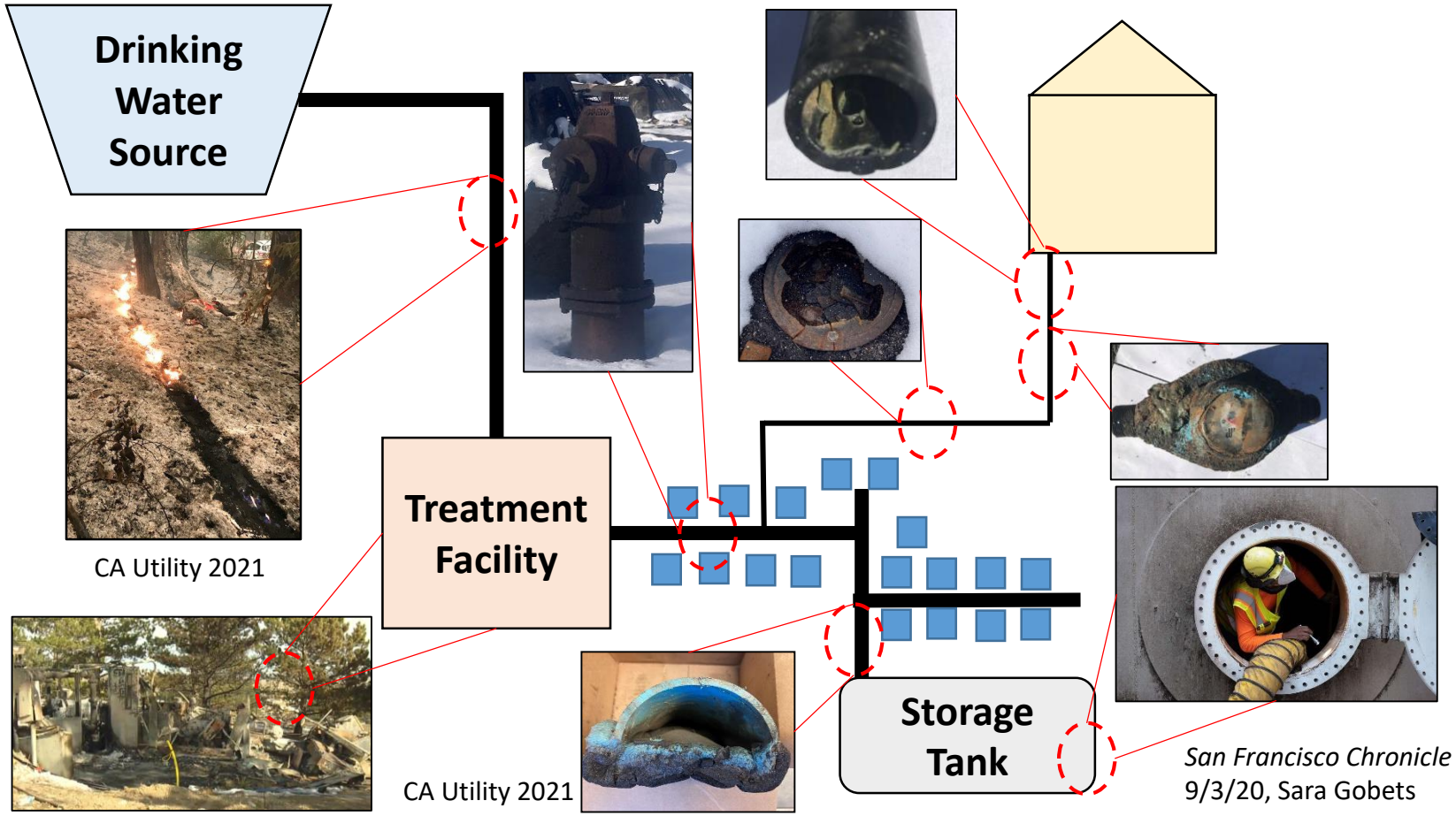


In 2021, wildfires occurred in all 50 states...

Large fires didn't just occur out West

Public water systems and private drinking water wells 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

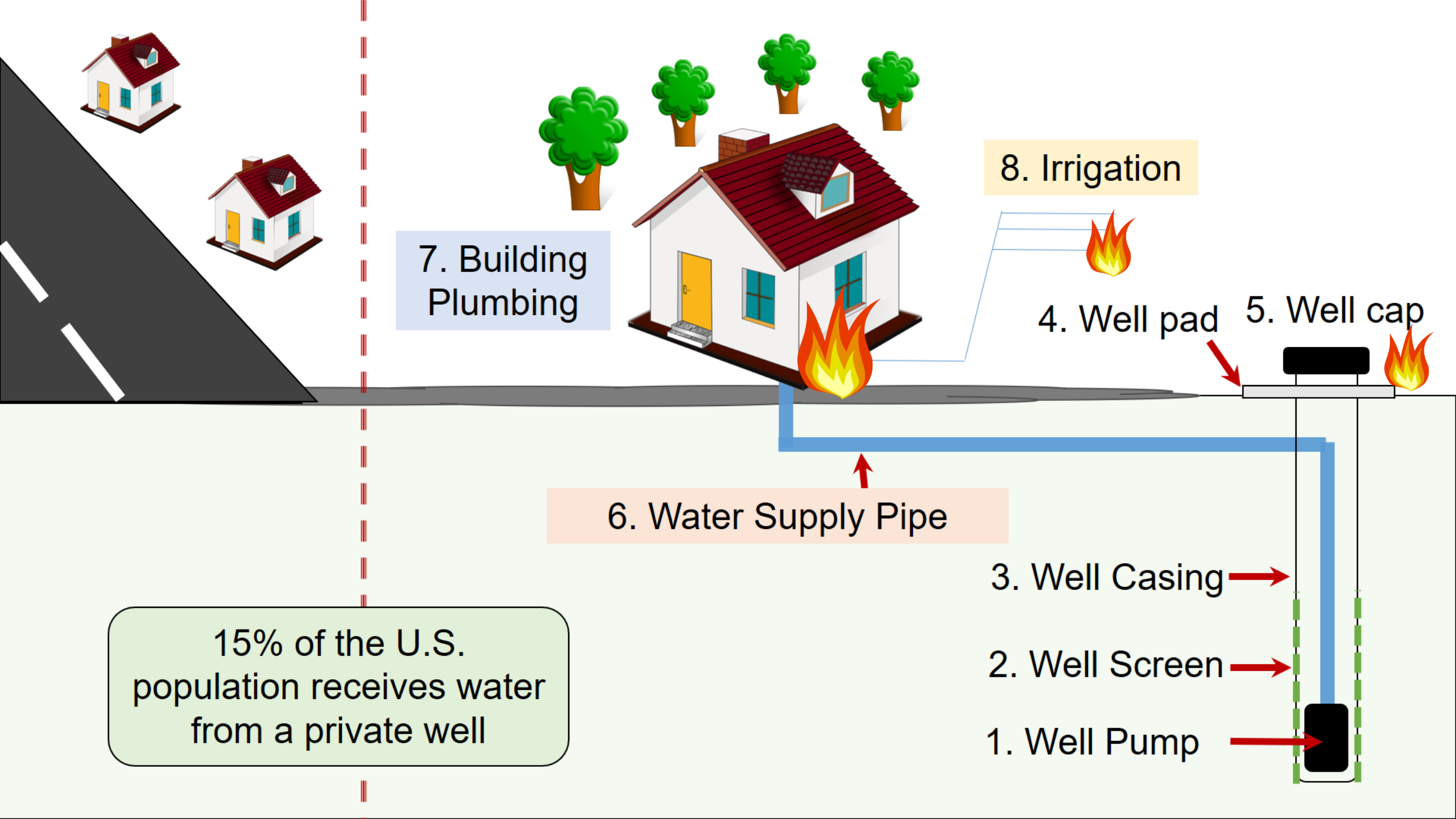
Possible Primary VOC & SVOC Sources

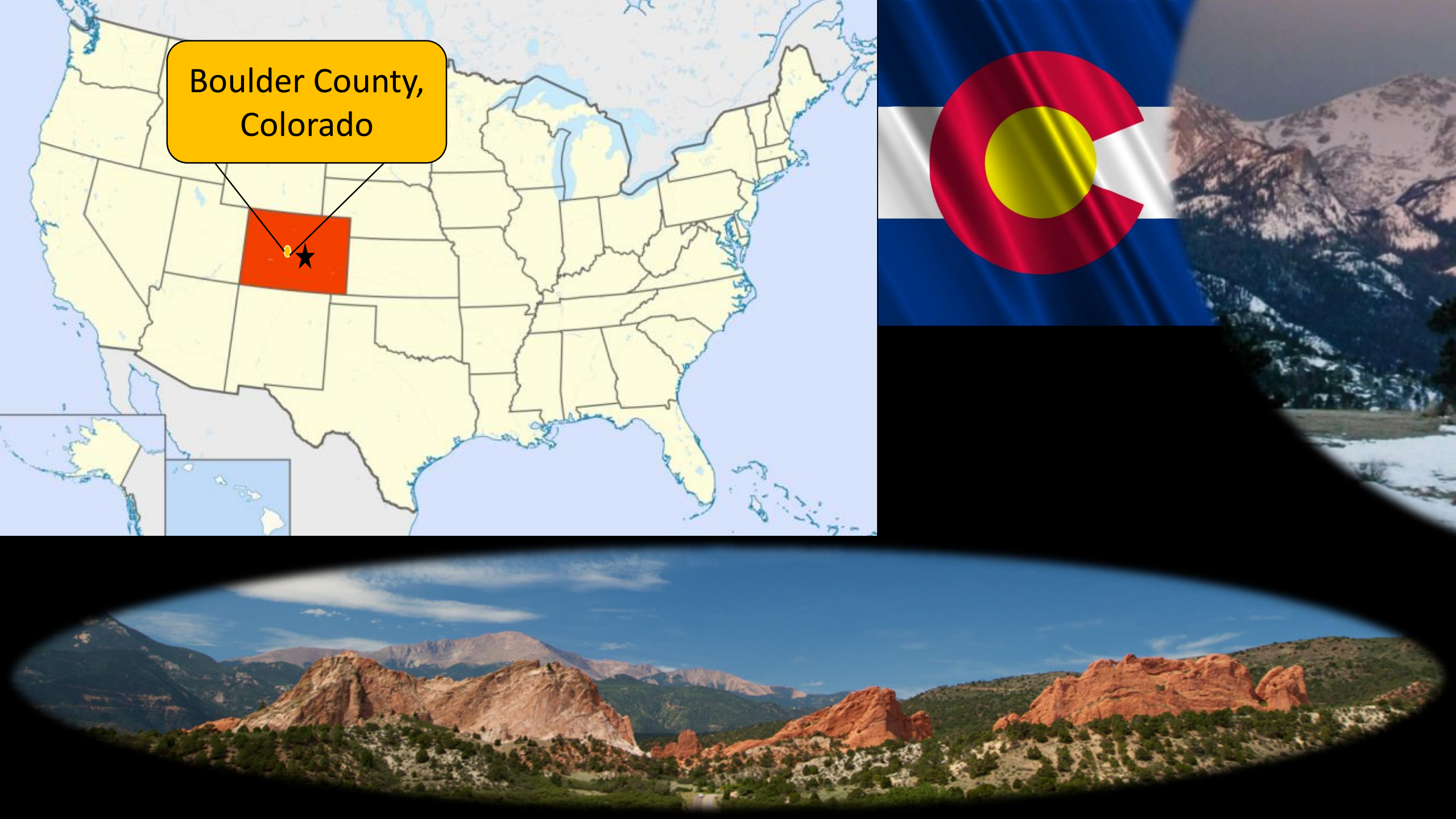
1. *In-situ* plastic thermal decomposition (PVC pipes, HDPE pipes, PB pipes, gaskets, meter components, etc.)
2. Contaminated air/materials drawn into depressurized system
3. Contaminated water from building plumbing drawn into compromised distribution system

Confirmed Secondary Sources

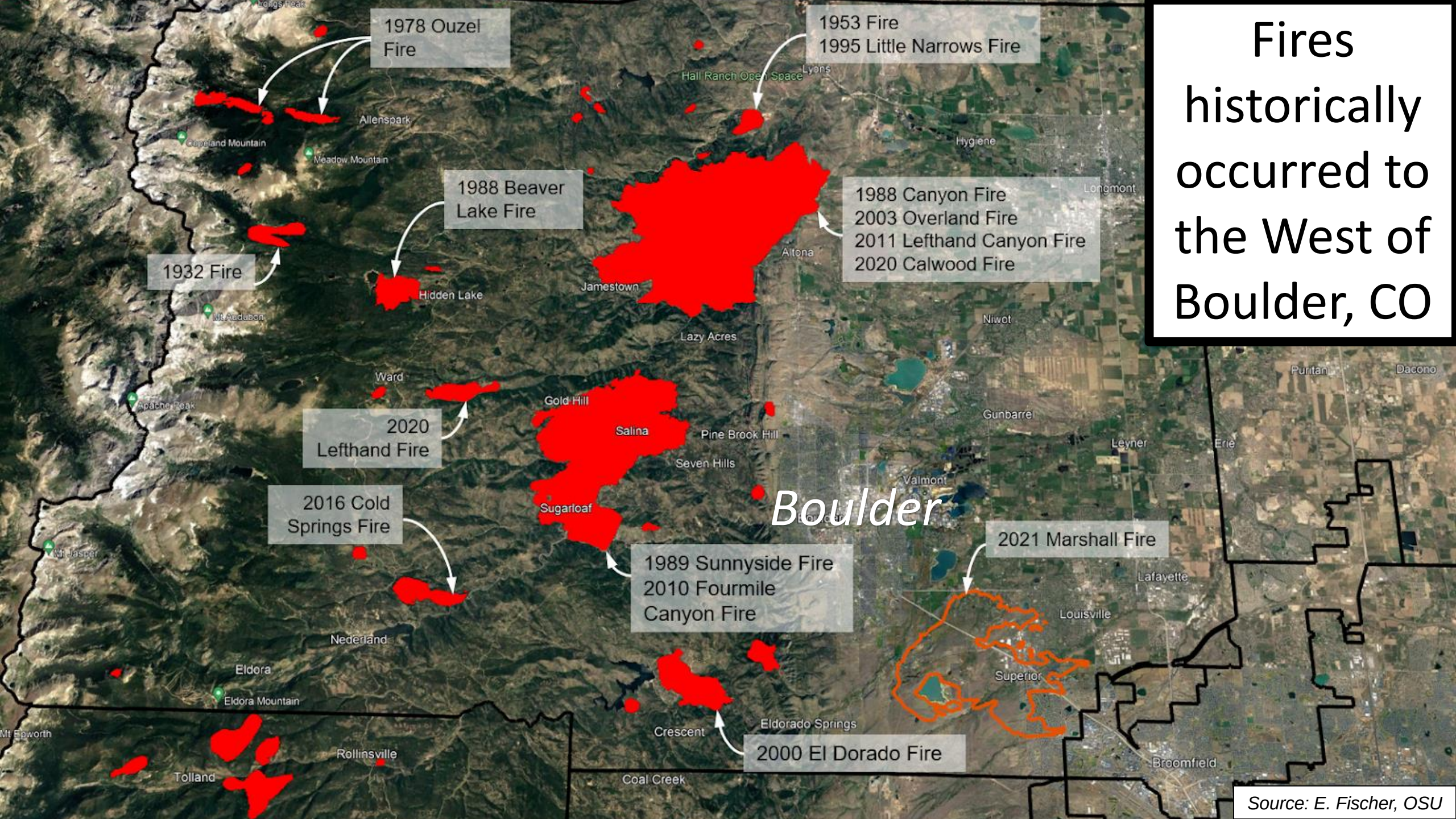
Partitioning/Adsorption/Absorption:
Water ←→ Material

See video at
www.PlumbingSafety.org

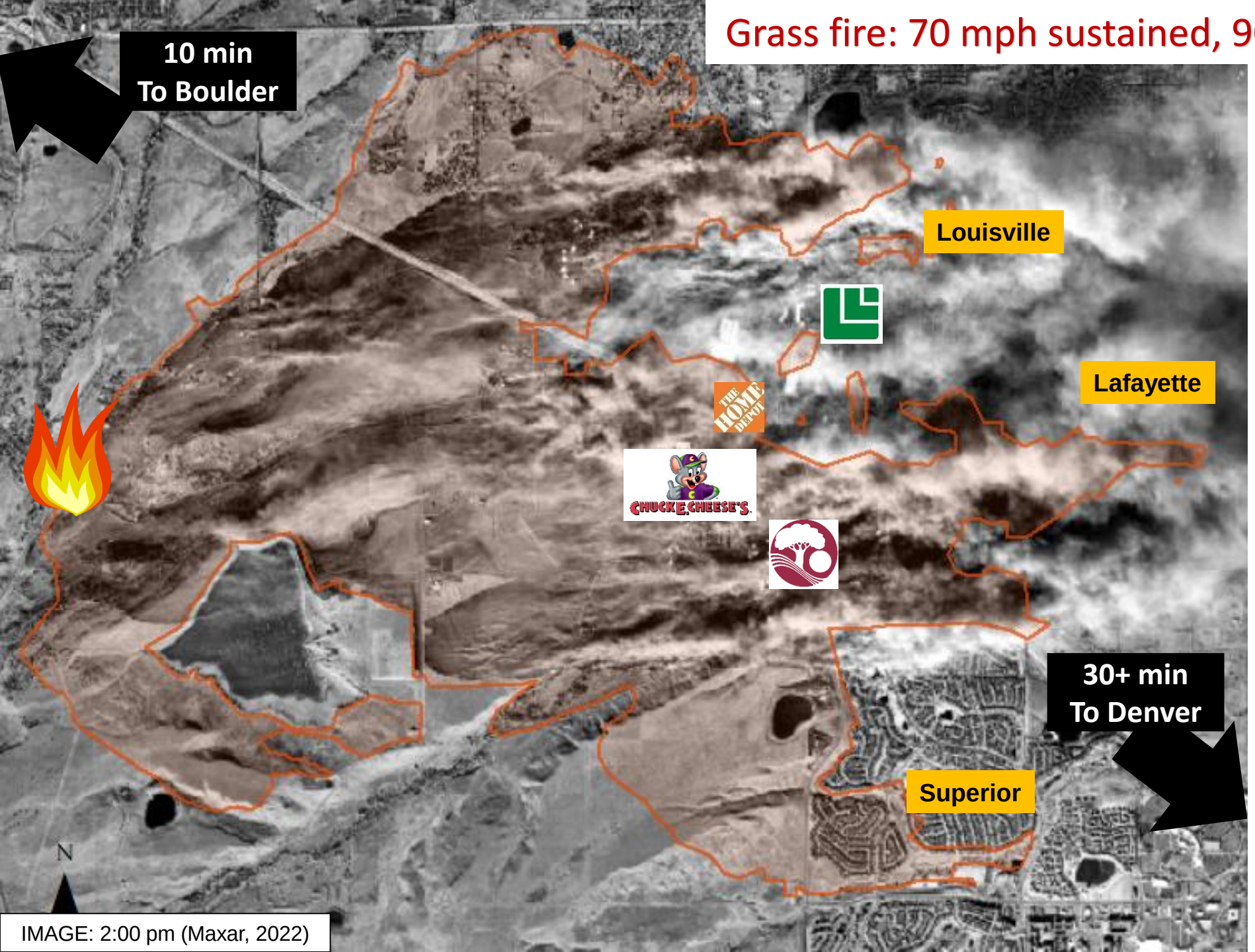

8. Irrigation
7. Building Plumbing
4. Well pad
5. Well cap
6. Water Supply Pipe
3. Well Casing
2. Well Screen
1. Well Pump
15% of the U.S. population receives water from a private well


Boulder County, Colorado

		$$$		
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%


1978 Ouzel Fire
1953 Fire
1995 Little Narrows Fire
1988 Beaver Lake Fire
1988 Canyon Fire
2003 Overland Fire
2011 Lefthand Canyon Fire
2020 Calwood Fire
1932 Fire
2020 Lefthand Fire
2016 Cold Springs Fire
1989 Sunnyside Fire
2010 Fourmile Canyon Fire
2021 Marshall Fire
2000 El Dorado Fire
Boulder
Fires historically occurred to the West of Boulder, CO
Source: E. Fischer, OSU

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



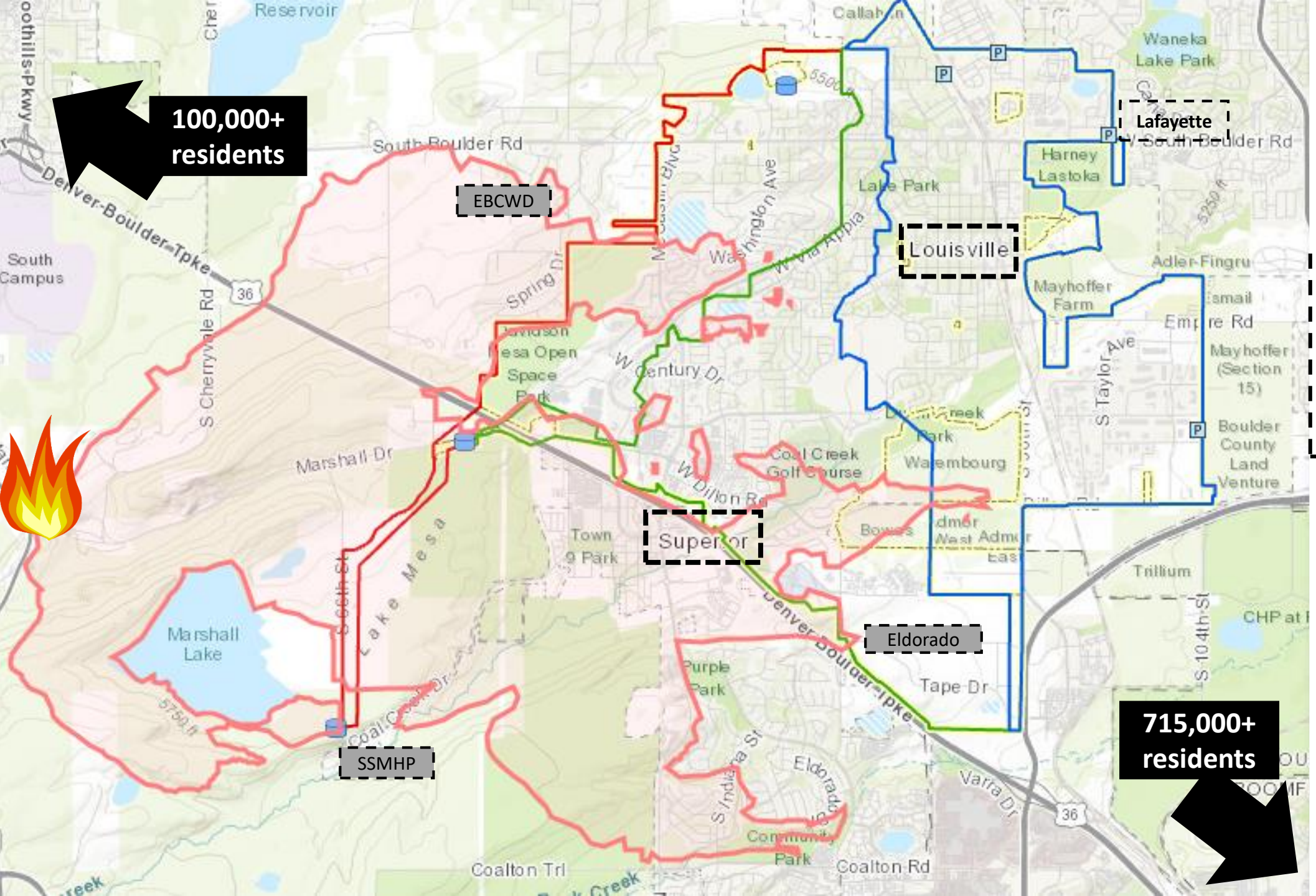
December 30, 2021

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

Source: Fischer & Wham et al. GEER. The 2021 Marshall Fire, Boulder County, CO.



6 public water systems were in the burn area

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

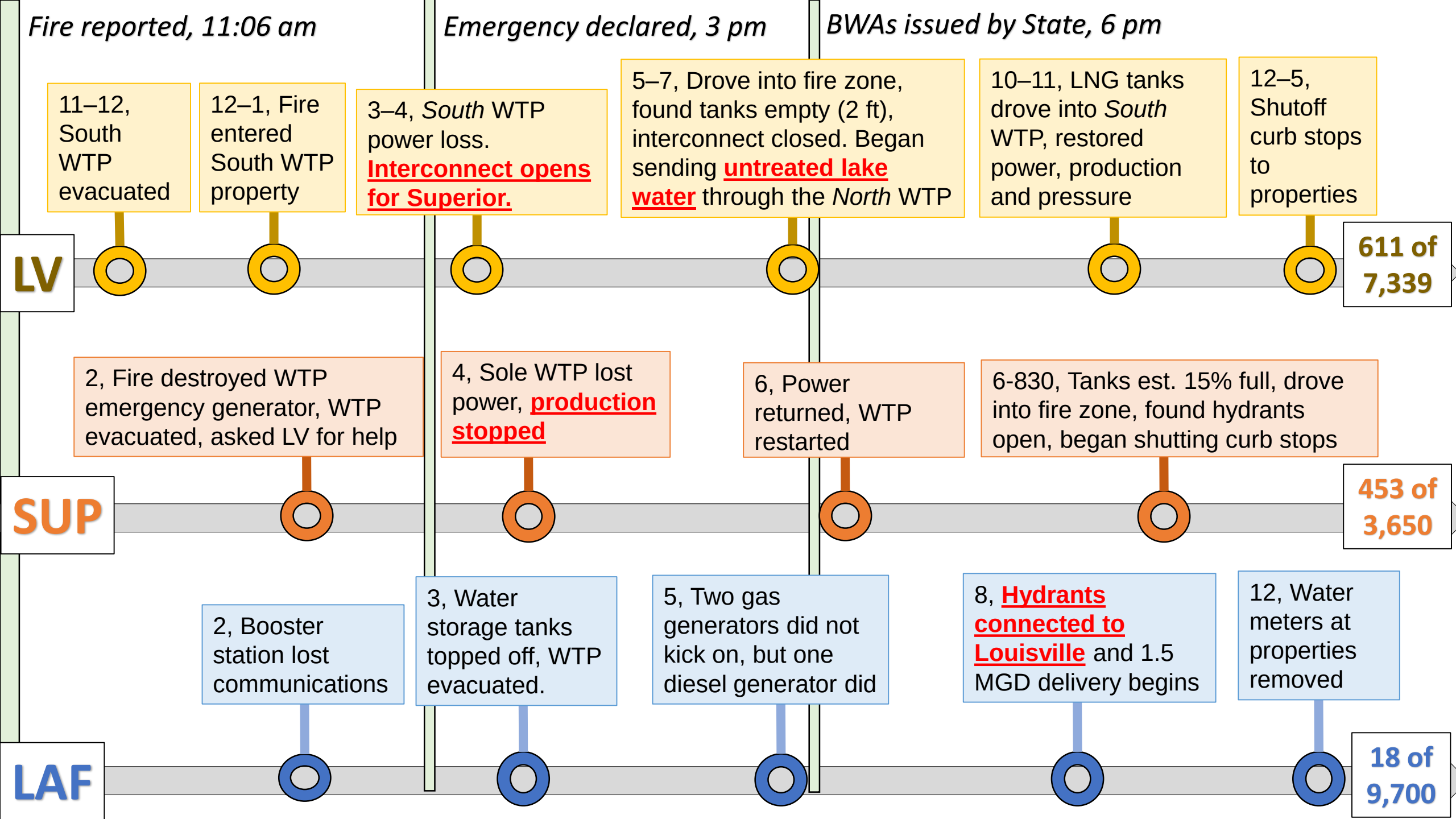

1783
ELDORADO
NATURAL SPRING WATER


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

Source: B. Wham, CU Boulder

After 24 hours

Snowfall helped extinguish the fire and hotspots

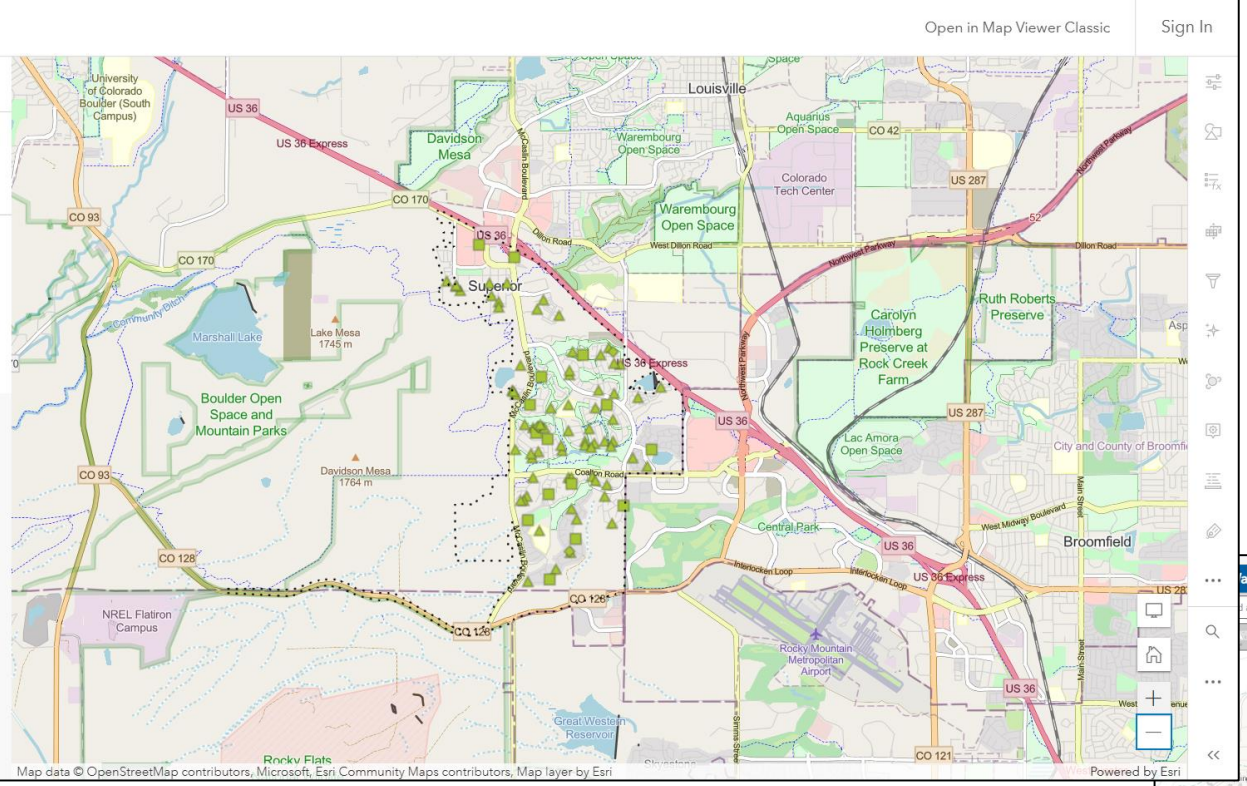

Louisville
Superior
NEXT RIGHT


Emergency Response Team
commercial property restoration
srmcat.com

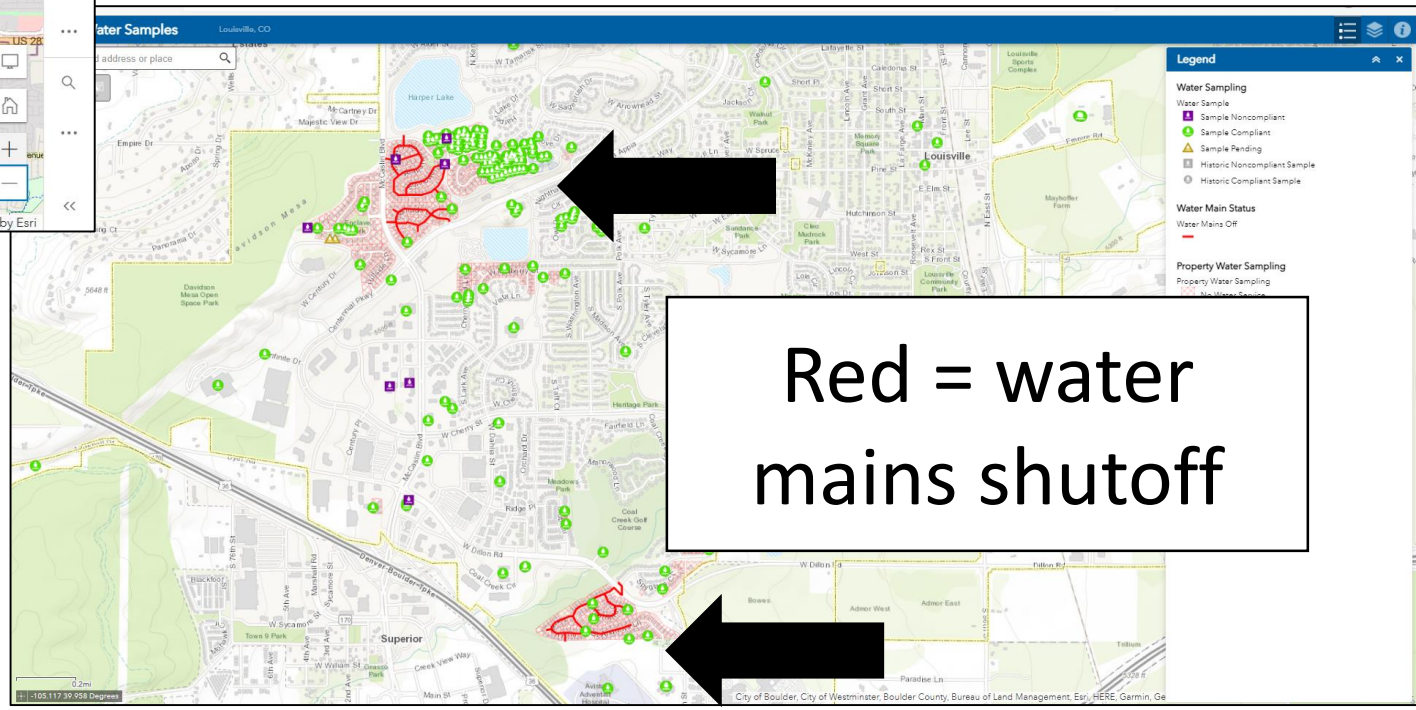

WE ARE
TEMPORARILY
CLOSED
DUE TO NO
ACCESS TO
CLEAN WATER.
SEE YOU SOON!

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: Bacteria and chlorine

Next: Fire caused VOCs

And then: Fire caused SVOCs

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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, CO, 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.

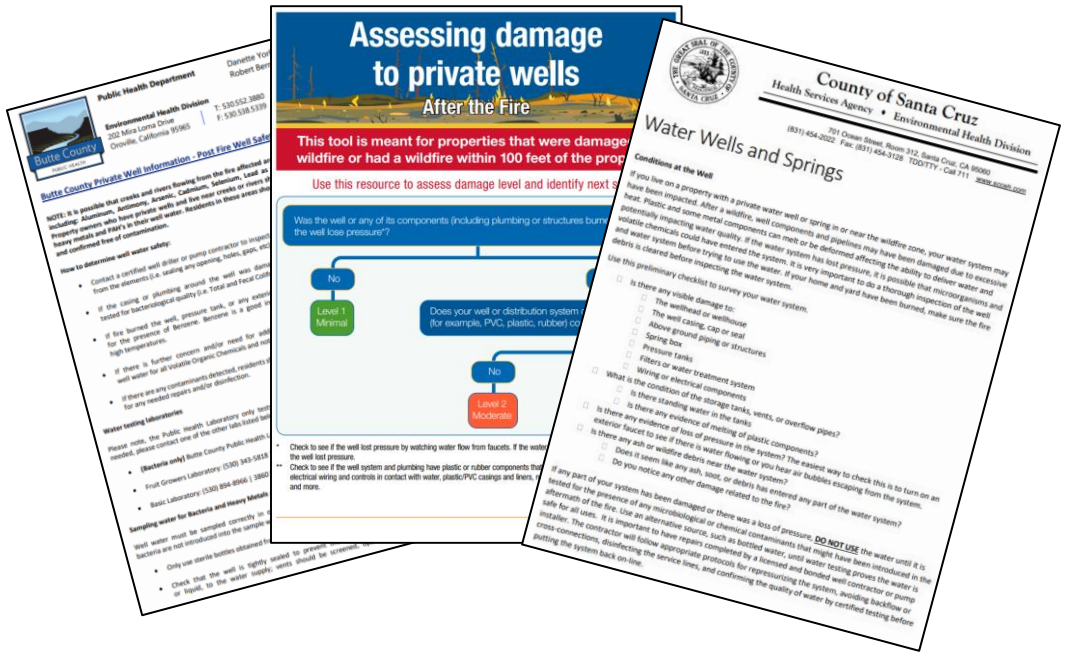
Food science literature: Caused by phenols, *o*-cresol, *p*-cresol, *m*-cresol, guaiacol

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

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



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.

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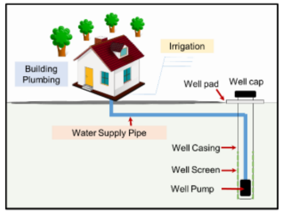
After a Wildfire:

Water Safety Considerations for Private Wells

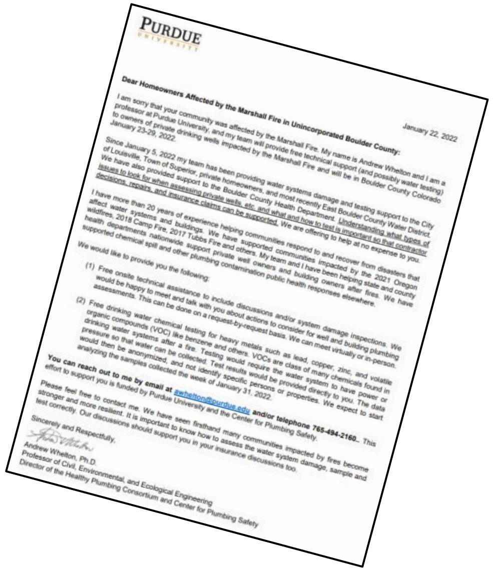


Damage and Contamination Caused by Wildfires

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.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January 22, 2022

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


PURDUE
Boilermakers


mL 0
±5%
300 mL
±5%
400 mL
PYREX®
Made in Germany
50
250
100
200
150
50
200
100
No. 1000
250

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

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Contaminant	W7 (surface)	W7 (3-4 ft)	W13	W5
Azobenzene	-	-	-	0.3
2-Nitrophenol	0.15	0.11	-	-
1,2,3-Trichlorobenzene	0.14	0.16	-	-
Naphthalene	0.15	0.19	-	-
2-Methylnaphthalene	0.10	0.08	-	-
1-Methylnaphthalene	0.16	0.18	-	-
2-Nitroaniline	-	0.10	-	-
Acenaphthylene	0.19	0.23	-	-
1,2-Dinitrobenzene	0.14	0.11	-	-
Fluorene	0.10	0.13	-	-
4-Nitroaniline	0.10	-	-	-
Phenanthrene	0.14	0.25	-	-
Di-*n*-butylphthalate	5.9	0.48	-	-
Fluoranthene	0.13	1.0	0.19	-
Pyrene	0.14	0.19	-	-
Bis(2-ethylhexyl)adipate	9.3	4.9	-	-
Chrysene	0.12	0.12	-	-
Bis(2-ethylhexyl)phthalate	3.6	3.0	-	-
Anthracene	-	-	0.11	-

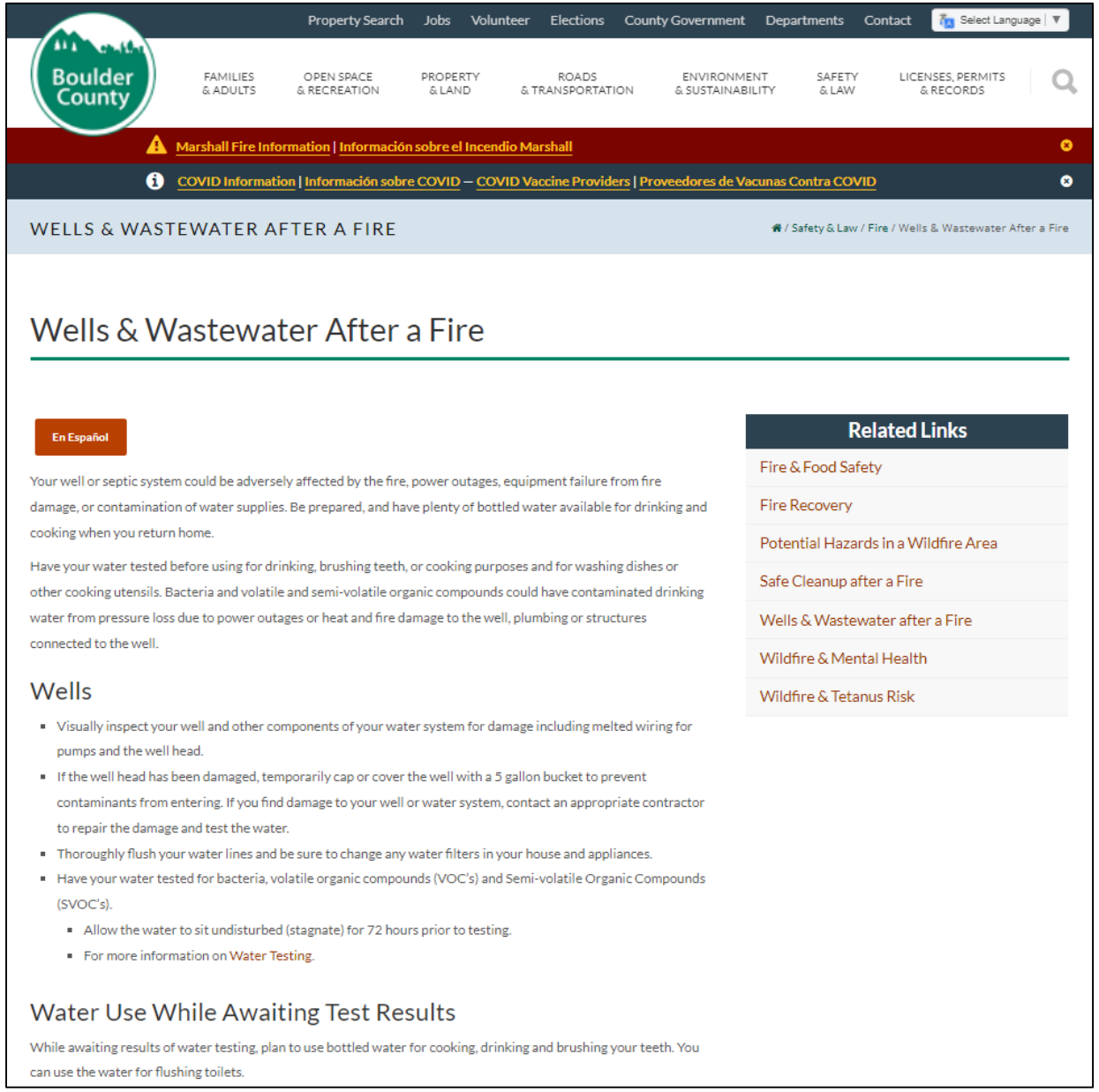
W7 was a hand-dug well with debris

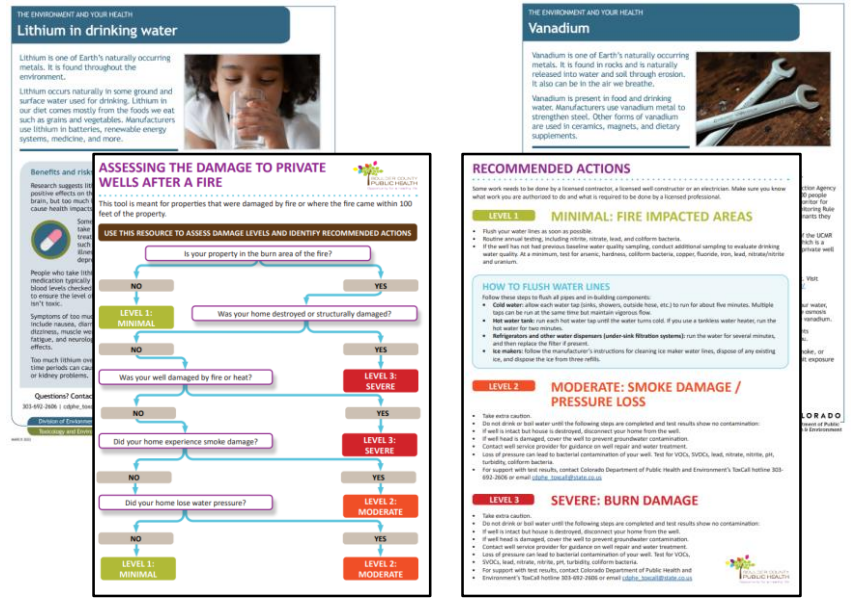
Lithium Source Data Description	Min	Max	Mean ± Stdev
Wells & Cisterns – Marshall Fire (14)	12.4	105	42 ± 26
Faucet – Marshall Fire (8)	4.2	89.3	34.8 ± 25.1
PWS UCMR3 – Colorado (108)	0.9	1,700	20.3 ± 54.1
PWS UCMR3 – Marshall Fire area (108)	1.6	131	25.8 ± 23.7

USEPA Health Based Screening Level: 10 ppb

Vanadium Source Data Description	Min	Max	Mean ± Stdev
Wells & Cisterns – Marshall Fire (14)	9.3	243	69.4 ± 73
Faucet – Marshall Fire (8)	15.5	86.5	59.3 ± 30.4
PWS UCMR5 – ongoing	tbd	tbd	tbd

USEPA Health Based Regional Screening Level: 86 ppb





1. Assessing well damage
2. Permit requirements for well repair
3. Water testing
4. CDPHE Factsheets: Lithium and vanadium
5. Testing laboratories for VOCs, SVOC, and heavy metals
6. Home water filtration systems
7. Resources for well owners
8. Resources for onsite wastewater treatment system owners

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

11 days after the fire… before debris removal began


FOR SALE
11BENCHMARK.COM


FOR SALE
RESIDENTREALTY
GreatFamilyLiving LLC
(303)325-5461
shiquansu@hotmail.com

National Lessons

Source: Ellen Harris, Boulder Co Open Space

1. For initial response, success can be achieved with trained staff, practice, nearby friends, interconnections, maintaining power, water storage, pressure, and knowing where and how to monitor and operate facilities without technology.

2. Decision making processes for water contamination response and recovery continue to be made on-the-fly. Qualified expert input can expedite and hone decision making. A guiding CONOPS plan is needed…and is being developed by Purdue with partners.

3. Boulder County-CDPHE-USEPA demonstrated admirable community support.

4. Very small systems and well owners need explicit help post-fire. Remains unclear what specific contaminants are most likely after fire.

5. After fires, are we focused on the right contaminants?

   VOC and SVOC drinking water contamination after fires is real. Bacteria contamination of public water systems not found yet for any wildfire I've been involved in. Are health officials focused on the right contaminants?

Angela Raff, Melissa Westendorf, Carmen Turner, Caroline Jankowski, Kris Isaacson, Myles Cook, Madeline Larsen, Deepika Solamuthu, Alan Holtman, Brad Caffery

Christian Ley, Brad Wham, Amy Javernick-Will, Karl Linden

Kurt Kowar, Justin Ferron, Cory Peterson, Greg Vinette, Jill Fischer, and more

Alex Arinello, David Lewis, Jim Widener, Wayne Ramey, and more

Scott Pavlik, Callie Hayden

Tyson Engles, Chelsea Cotton, Kelsey Barton, Shannon Barbare, Kristy Richardson

Erin Dodge, Celeste Gleason, Nickie Mercke, and more

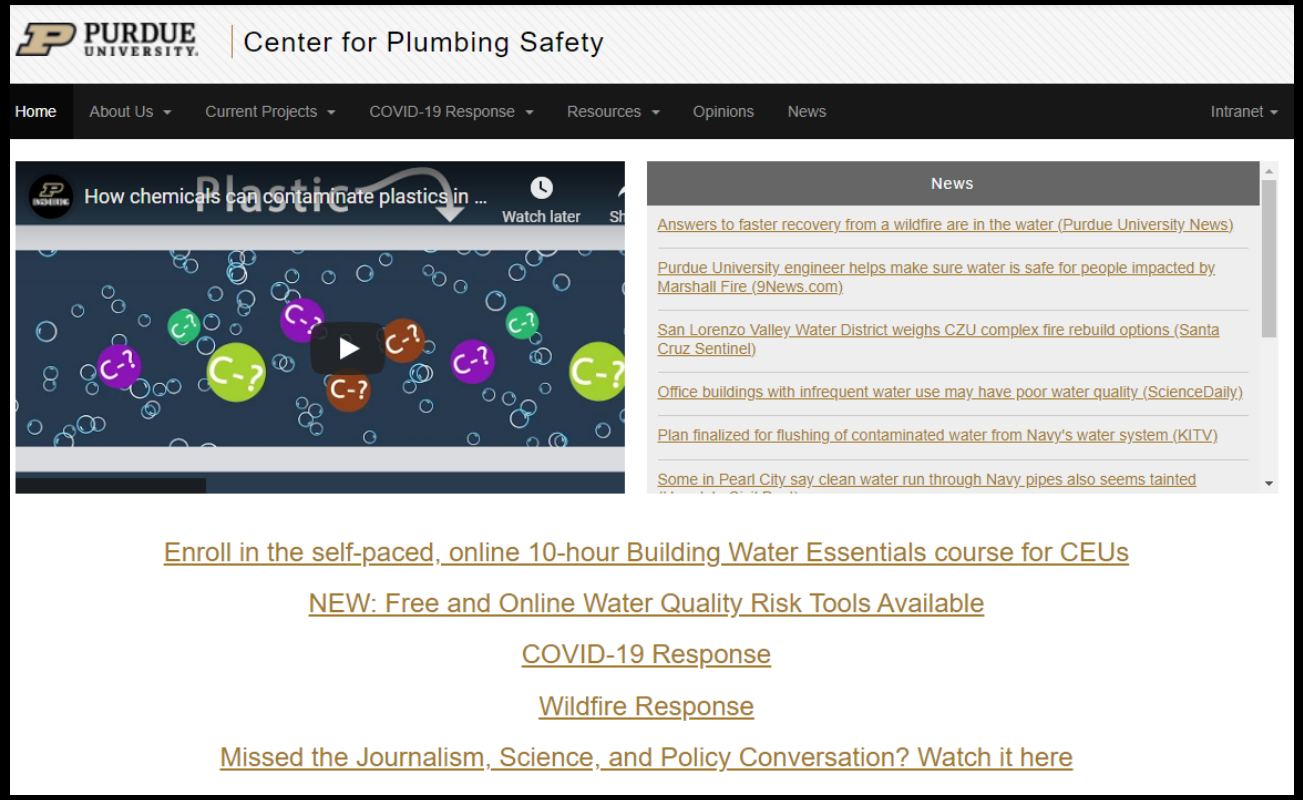
Mark Johns, Marsh Lavenue

Erica Fischer

Chad Seidel and more

Thank you. More results coming…

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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