

# The Marshall Fire



*Andrew Whelton, Ph.D.*

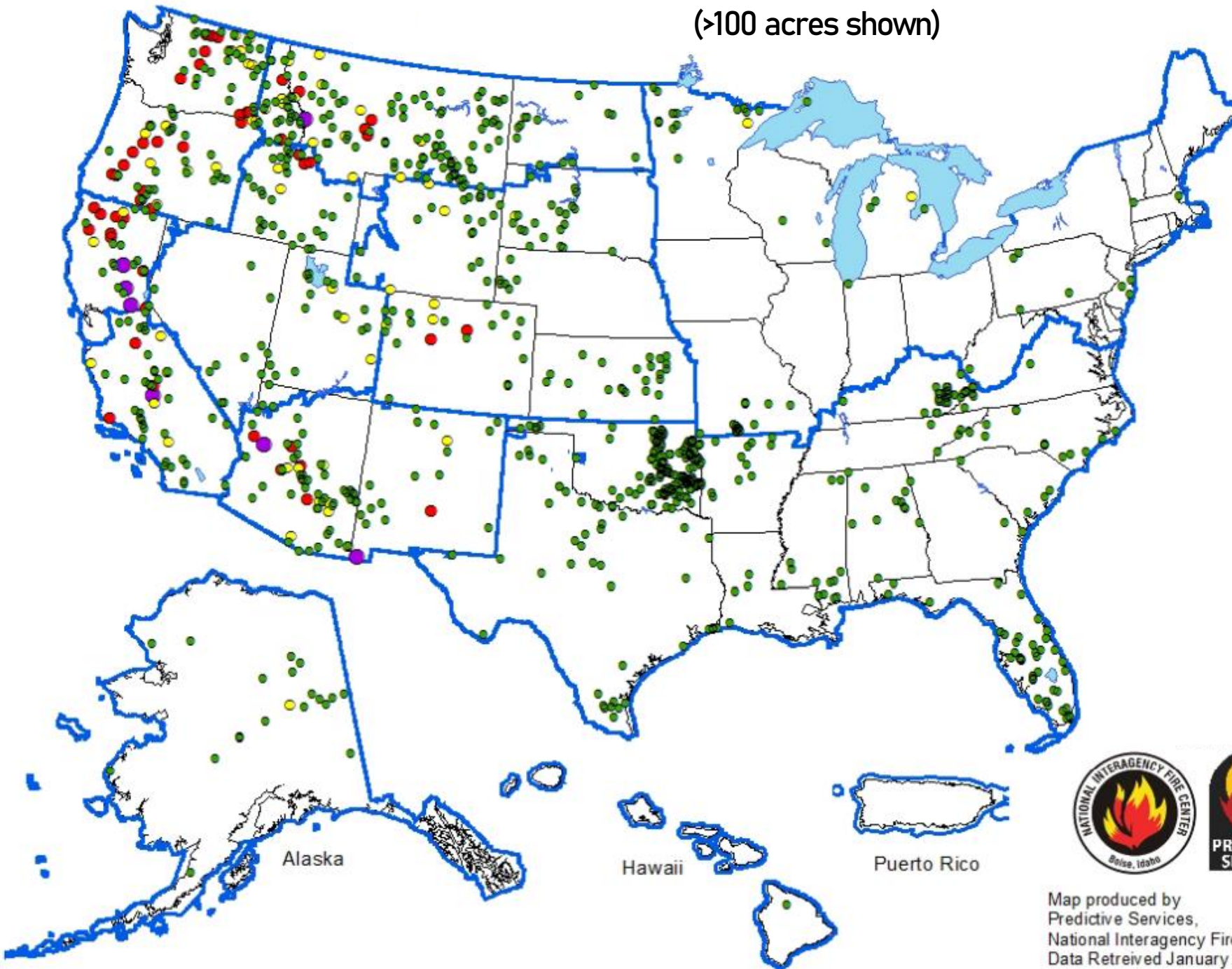
April 12, 2022



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(>100 acres shown)



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

Large fires  
didn't just  
occur out  
West



Map produced by  
Predictive Services,  
National Interagency Fire Center  
Data Retrieved January 20, 2022

# Public water systems and private drinking water wells are vulnerable to fire.



USGS 2009

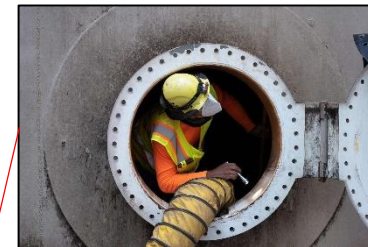
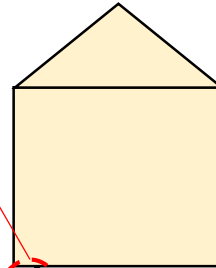
Drinking  
Water  
Source



CA Utility 2021



CA Utility 2021



San Francisco Chronicle  
9/3/20, Sara Gobets

Treatment  
Facility



Storage  
Tank

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

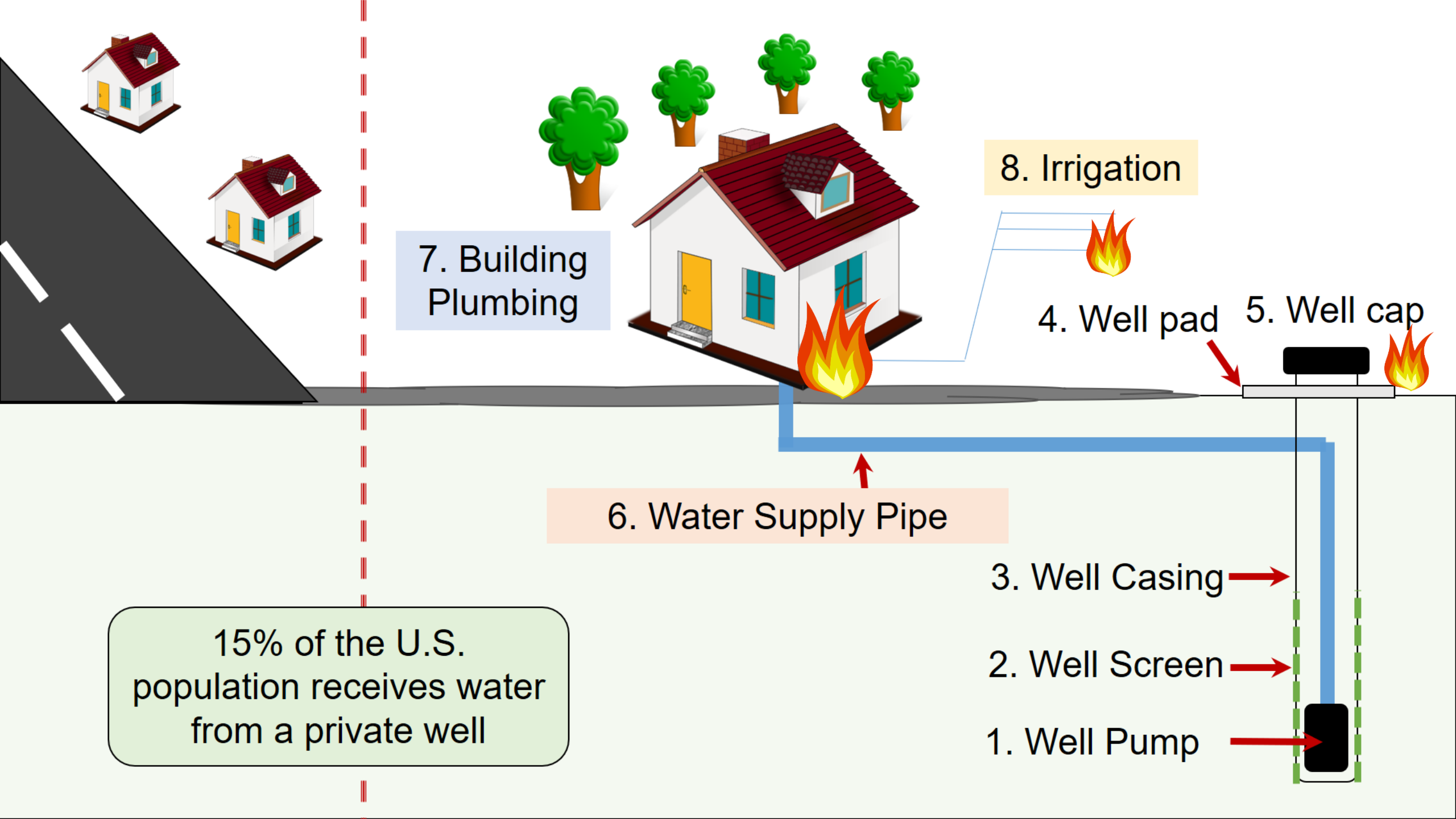
## Confirmed Secondary Sources

Partitioning/Adsorption/Absorption:  
Water ↔ Material

See video at  
[www.PlumbingSafety.org](http://www.PlumbingSafety.org)







7. Building Plumbing

8. Irrigation

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





# Welcome to Boulder County



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

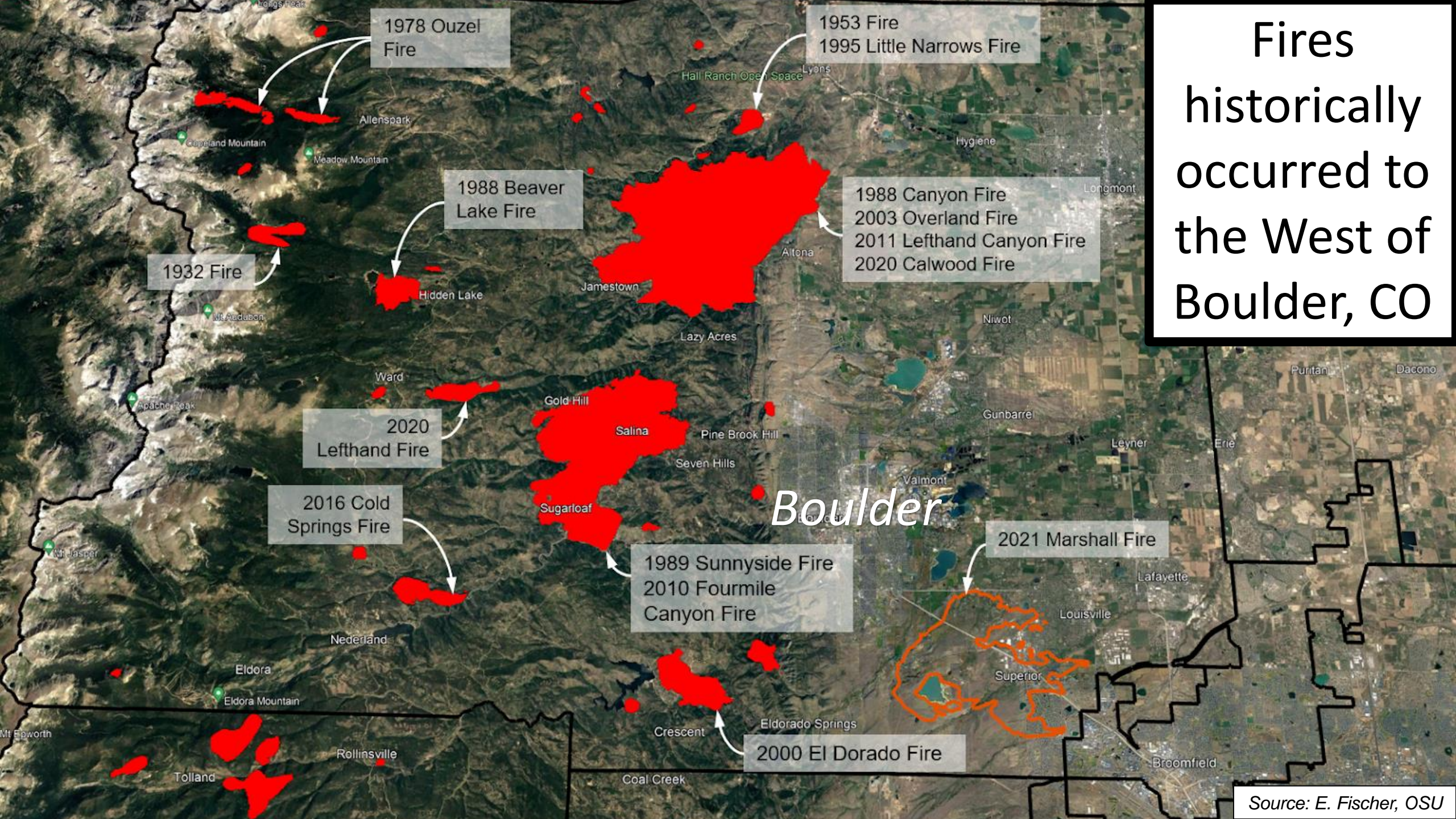
\$51,566

\$49,000

26.0%



Fires  
historically  
occurred to  
the West of  
Boulder, CO





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

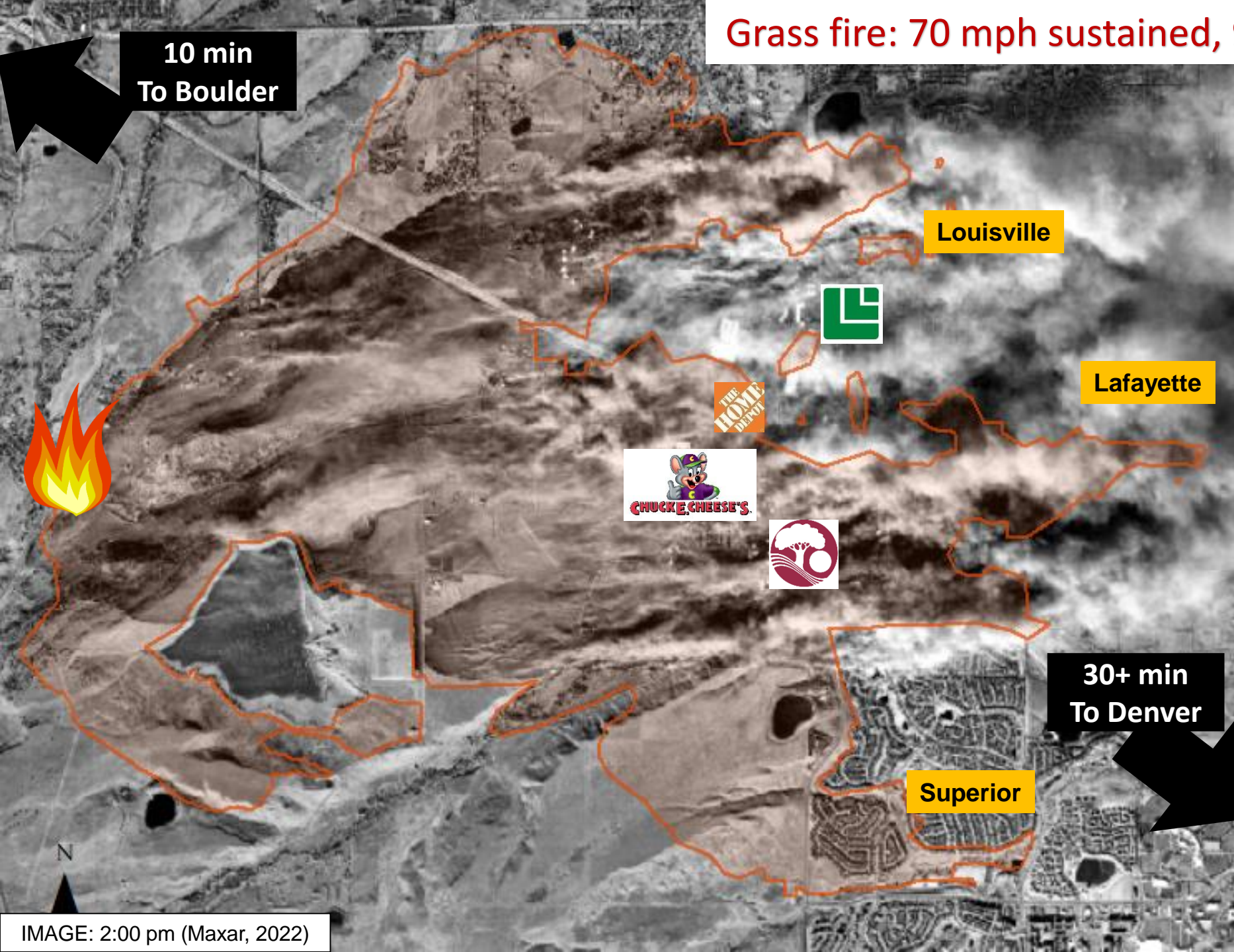
*The 3 largest communities*

Lafayette: 30,411

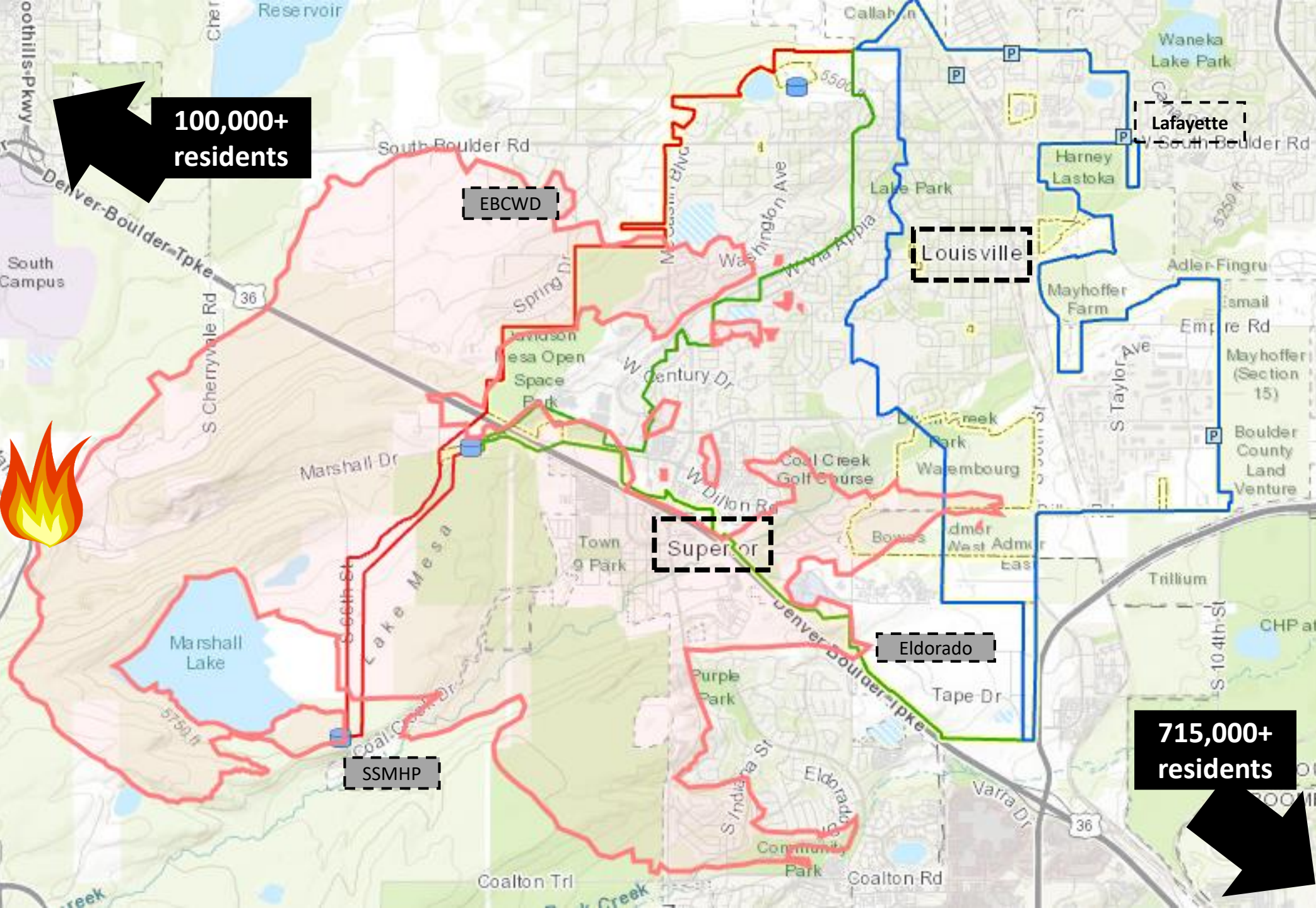
Louisville: 21,266

Superior: 13,094

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







100,000+  
residents

EBCWD

Louisville

Lafayette

6 public water  
systems were  
in the burn  
area

Superior

Eldorado

SSMHP

715,000+  
residents



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

<b>Public Water System (population)</b>	<b>Damaged/ Destroyed Properties</b>	<b>Water Mains, miles</b>	<b>Hydrants</b>	<b>Finished Water Storage, MG</b>	<b>Raw Water</b>
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













1783

ELDORADO.



NATURAL SPRING WATER







**The first 24 hours**



Fire reported, 11:06 am

Emergency declared, 3 pm

BWAs issued by State, 6 pm

LV

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

611 of 7,339

SUP

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

453 of 3,650

LAF

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

18 of 9,700















***After 24 hours***

Snowfall  
helped  
extinguish  
the fire and  
hotspots



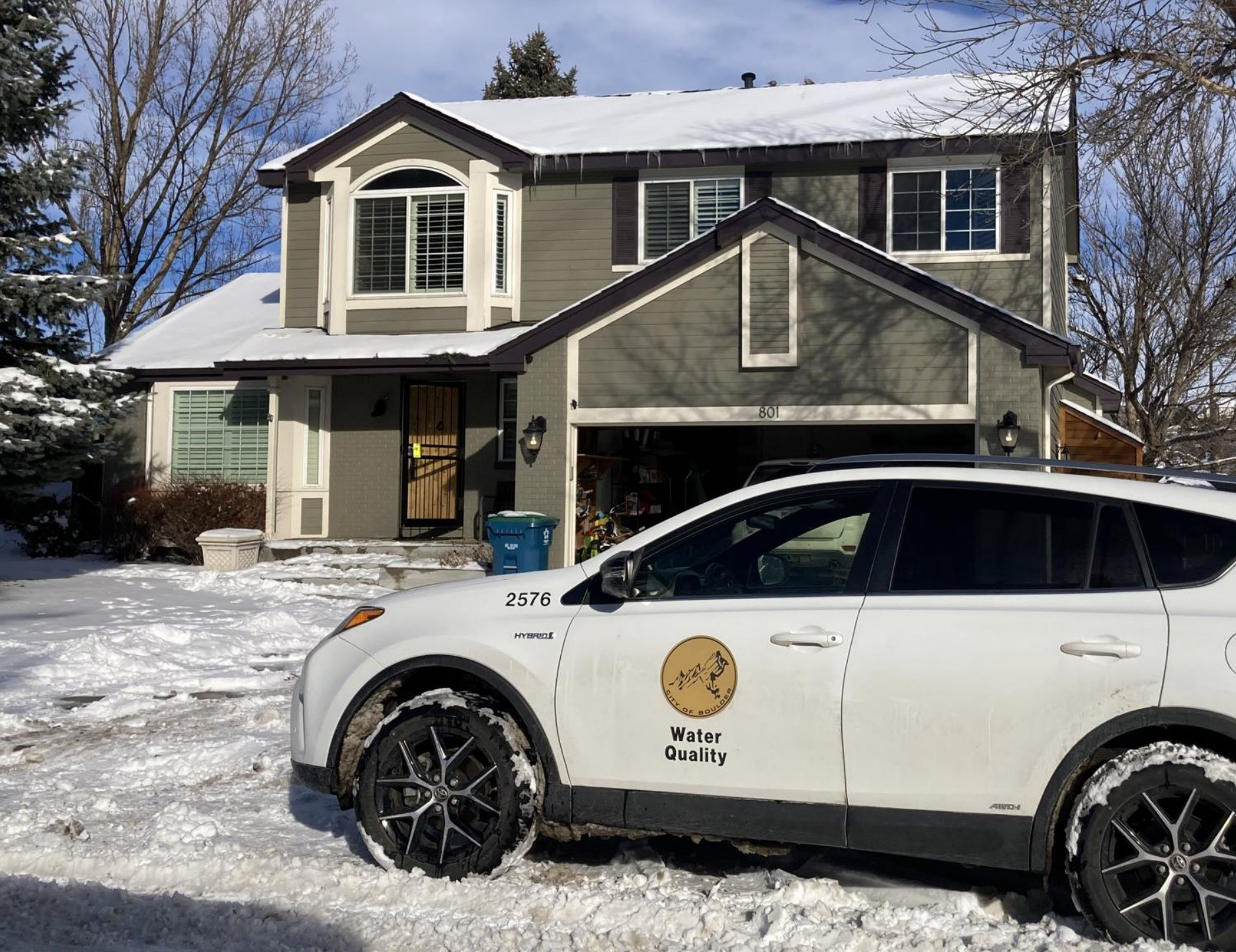








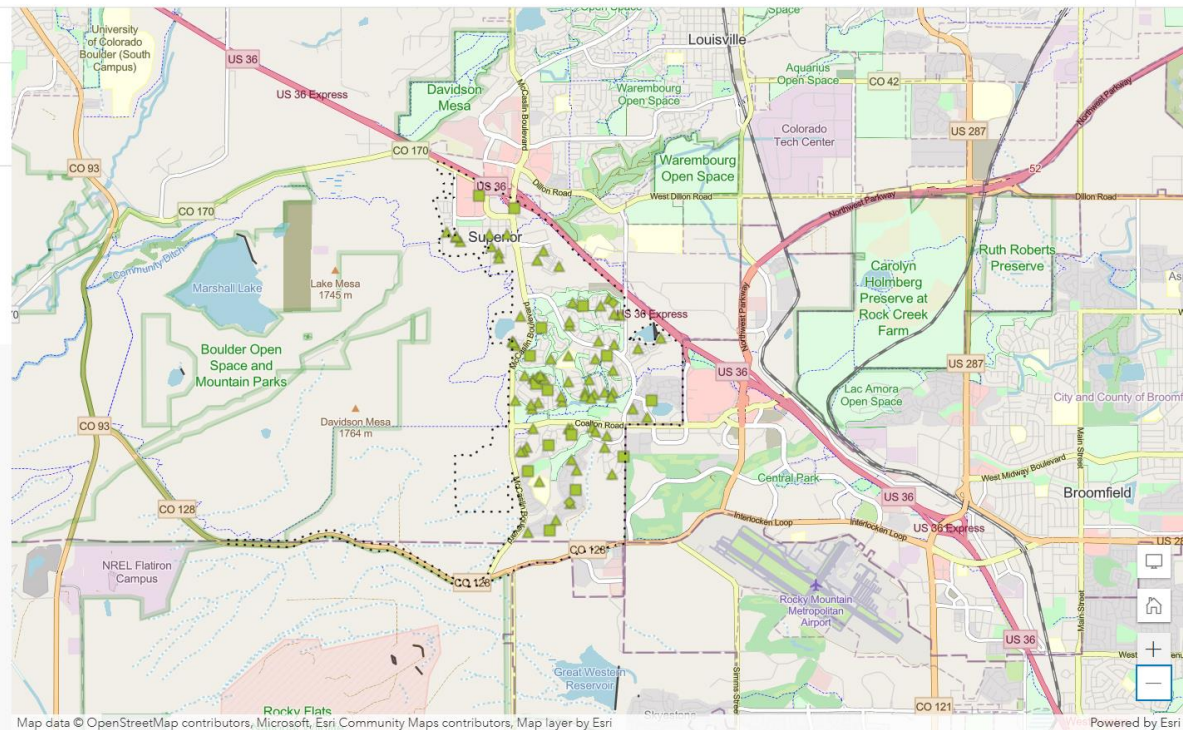




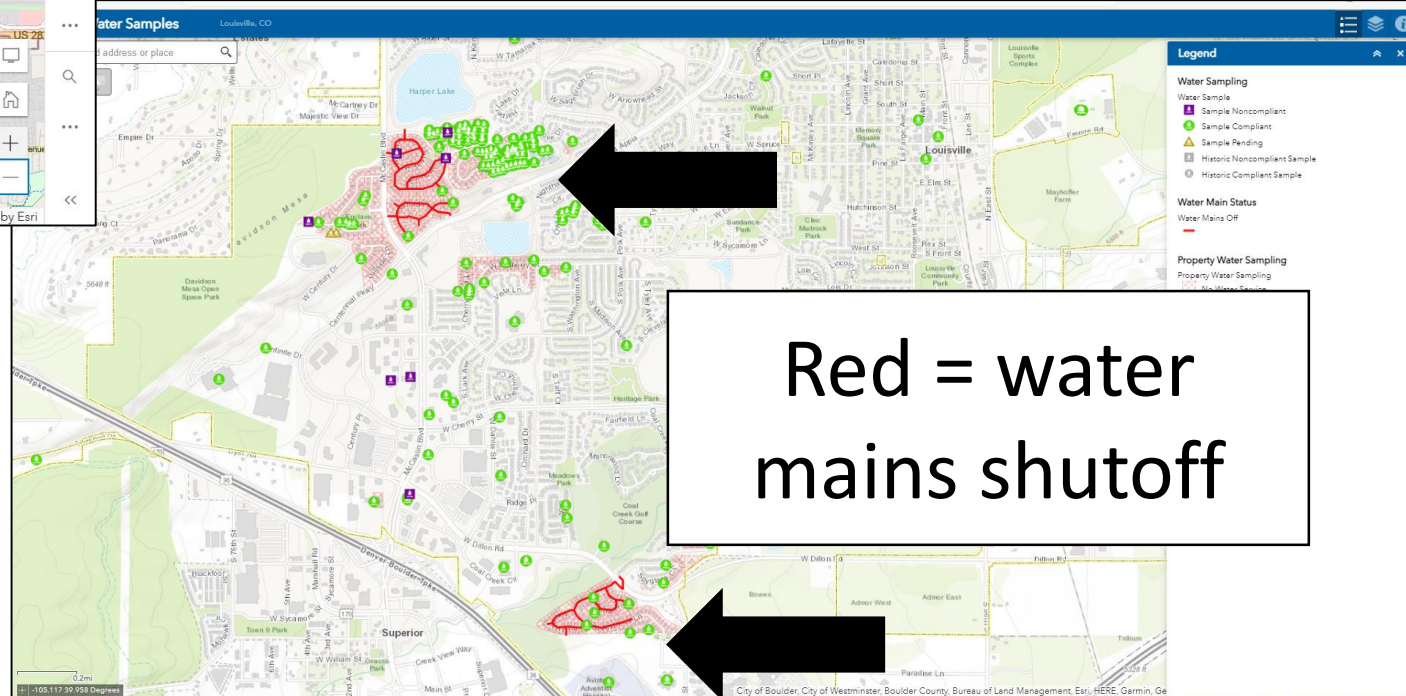
Internal leadership,  
exceptional staff, and  
requests for aide  
helped utilities  
stabilize

Helpful neighbors:  
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.*



Each utility moved at a different pace with different challenges

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



# 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?
<b>Benzene</b>	<b>221</b>	<b>Y</b>	
Toluene	511		<b>Y</b>
Ethylbenzene	160		<b>Y</b>
Xylenes	5		
<b>Styrene</b>	<b>1,900</b>	<b>Y</b>	<b>Y</b>
Naphthalene	11		<b>Y</b>
Acrolein	24		<b>Y</b>

*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

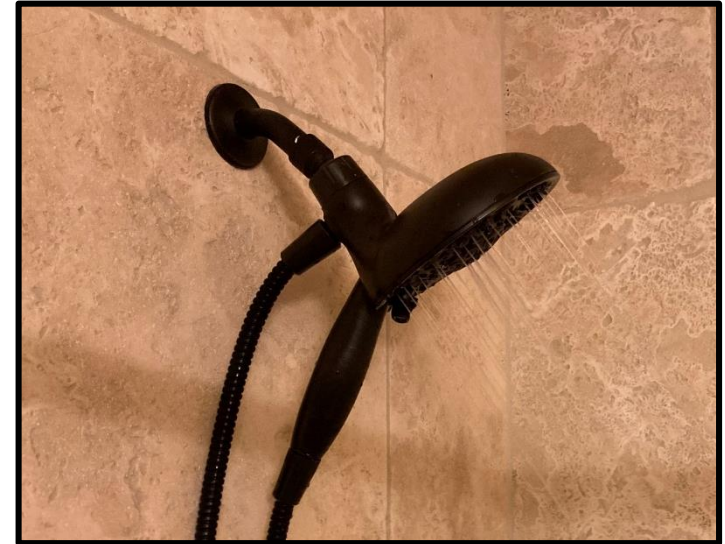


# Smoky, Ash Tray, Camp Fire Flavored Water

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

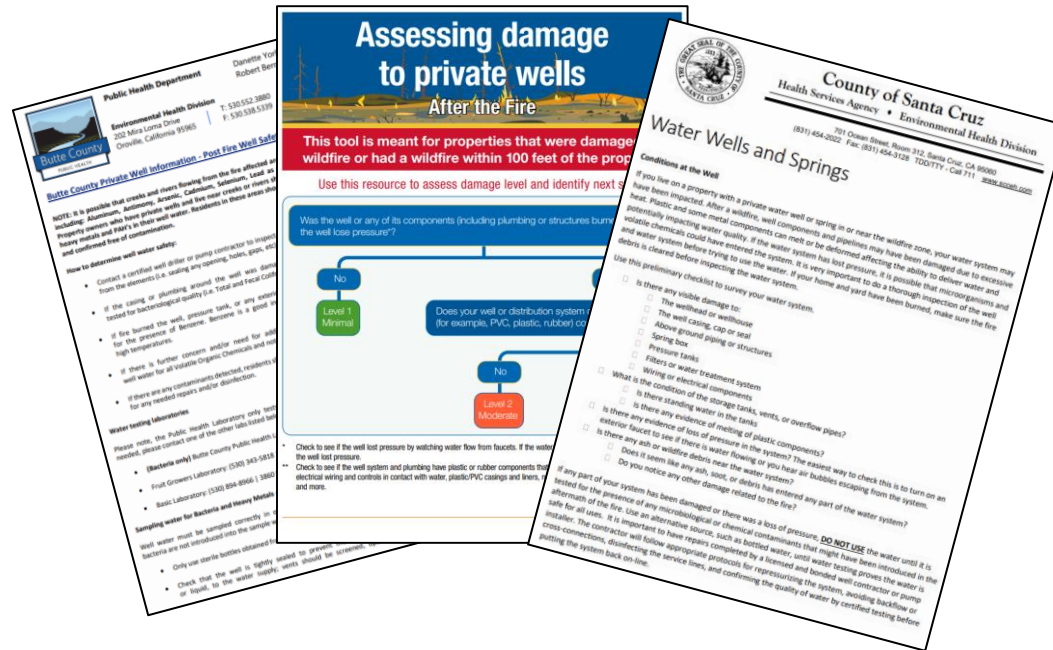
CU Boulder Dr. Thurman, Dr. Ferrer, and Corona identified and attributed a tricarboxylic benzoic acid and a dicarboxylic benzoic acid as the “smoky flavor” agents at ppb (Ferrer et al. 2021)

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,  $\text{NO}_3^-$ ; BTEX; local contaminants

**WaDOH:** Coliform bacteria

**SCCHD:** Coliform bacteria, turbidity, pH, conductivity, color,  $\text{NO}_3^-$ ; VOCs, SVOCs

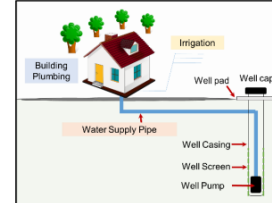
**OHA:** Coliform bacteria, As, Pb,  $\text{NO}_3^-$ ; BTEX



# We reached out to help those served by private wells.



## After a Wildfire: Water Safety Considerations for Private Wells

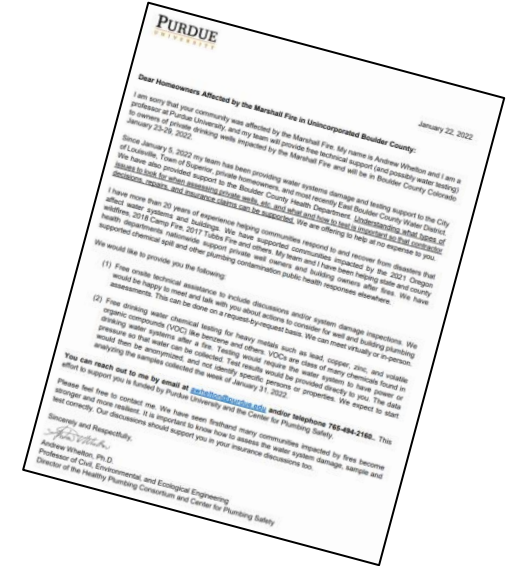


### Damage and Contamination Caused by Wildfires

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 water 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 to 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.



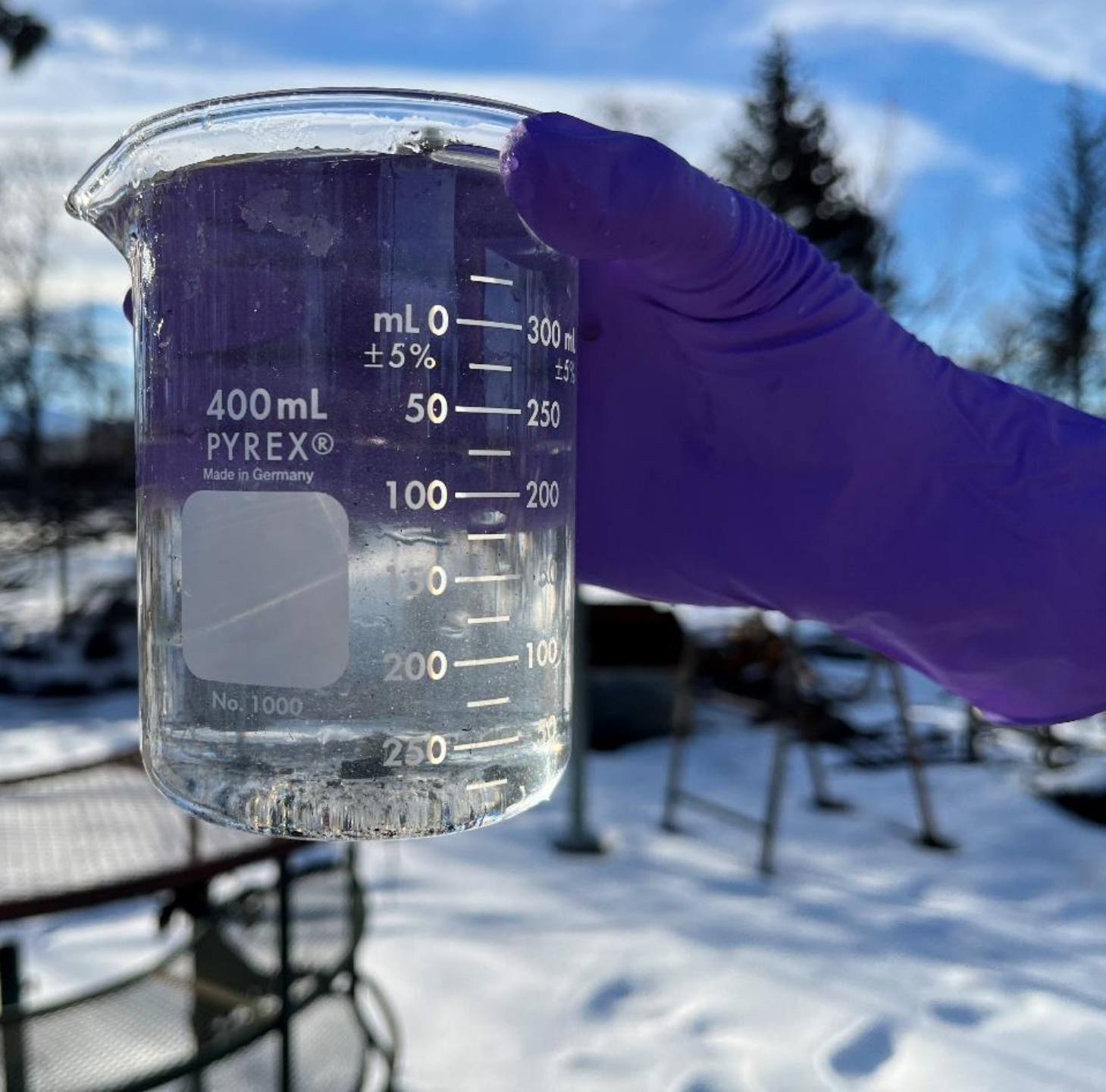
















Other wells had  
structures that  
were destroyed,  
debris was blown  
into them for  
more than 12 hr









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- <i>n</i> -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 $\pm$ Stdev
Wells & Cisterns – Marshall Fire (14)	12.4	105	42 $\pm$ 26
Faucet – Marshall Fire (8)	4.2	89.3	34.8 $\pm$ 25.1
PWS UCMR3 – Colorado (108)	0.9	1,700	20.3 $\pm$ 54.1
PWS UCMR3 – Marshall Fire area (108)	1.6	131	25.8 $\pm$ 23.7

USEPA Health Based Screening Level: 10 ppb

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

USEPA Health Based Regional Screening Level: 86 ppb



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WELLS & WASTEWATER AFTER A FIRE

/ Safety & Law / Fire / Wells & Wastewater After a Fire

## Wells & Wastewater After a Fire

En Español

Your well or septic system could be adversely affected by the fire, power outages, equipment failure from fire damage, or contamination of water supplies. Be prepared, and have plenty of bottled water available for drinking and cooking when you return home.

Have your water tested before using for drinking, brushing teeth, or cooking purposes and for washing dishes or other cooking utensils. Bacteria and volatile and semi-volatile organic compounds could have contaminated drinking water from pressure loss due to power outages or heat and fire damage to the well, plumbing or structures connected to the well.

### Wells

- Visually inspect your well and other components of your water system for damage including melted wiring for pumps and the well head.
- If the well head has been damaged, temporarily cap or cover the well with a 5 gallon bucket to prevent contaminants from entering. If you find damage to your well or water system, contact an appropriate contractor to repair the damage and test the water.
- Thoroughly flush your water lines and be sure to change any water filters in your house and appliances.
- Have your water tested for bacteria, volatile organic compounds (VOC's) and Semi-volatile Organic Compounds (SVOC's).
  - Allow the water to sit undisturbed (stagnate) for 72 hours prior to testing.
  - For more information on [Water Testing](#).

### Water Use While Awaiting Test Results

While awaiting results of water testing, plan to use bottled water for cooking, drinking and brushing your teeth. You can use the water for flushing toilets.

### Related Links

- [Fire & Food Safety](#)
- [Fire Recovery](#)
- [Potential Hazards in a Wildfire Area](#)
- [Safe Cleanup after a Fire](#)
- [Wells & Wastewater after a Fire](#)
- [Wildfire & Mental Health](#)
- [Wildfire & Tetanus Risk](#)

- Assessing well damage
- Permit requirements for well repair
- Water testing
- CDPHE Factsheets: Lithium and vanadium
- Testing laboratories for VOCs, SVOC, and heavy metals
- Home water filtration systems
- Resources for well owners
- Resources for onsite wastewater treatment system owners

### Lithium in drinking water

Lithium is one of Earth's naturally occurring metals. It is found throughout the environment.

Lithium occurs naturally in some ground and surface water used for drinking. Lithium in our diet comes mostly from the foods we eat such as grains and vegetables. Manufacturers use lithium in batteries, renewable energy systems, medicine, and more.

### Vanadium

Vanadium is one of Earth's naturally occurring metals. It is found in rocks and is naturally released into water and soil through erosion. It also can be in the air we breathe.

Vanadium is present in food and drinking water. Manufacturers use vanadium metal to strengthen steel. Other forms of vanadium are used in ceramics, magnets, and dietary supplements.

### ASSESSING THE DAMAGE TO PRIVATE WELLS AFTER A FIRE

USE THIS RESOURCE TO ASSESS DAMAGE LEVELS AND IDENTIFY RECOMMENDED ACTIONS

Is your property in the burn area of the fire?

NO → LEVEL 1: MINIMAL

YES → Was your home destroyed or structurally damaged?

NO → Was your well damaged by fire or heat?

YES → LEVEL 3: SEVERE

NO → Did your home experience smoke damage?

YES → LEVEL 3: SEVERE

NO → Did your home lose water pressure?

YES → LEVEL 2: MODERATE

NO → LEVEL 1: MINIMAL

YES → LEVEL 2: MODERATE

### RECOMMENDED ACTIONS

Some work needs to be done by a licensed contractor, a licensed well construction or an electrician. Make sure you know what work you are authorized to do and what is required to be done by a licensed professional.

**LEVEL 1 MINIMAL: FIRE IMPACTED AREAS**

- Flush your water lines as soon as possible.
- Booster annual testing, including nitrate, nitrite, lead, and coliform bacteria.
- If the well has not had previous baseline water quality sampling, conduct additional sampling to evaluate drinking water quality. As a minimum, test for nitrate, bacteria, coliform bacteria, copper, fluoride, iron, lead, nitrate/nitrite, and uranium.

**HOW TO FLUSH WATER LINES**

Follow these steps to flush all pipes and in-building components:

- Close water after each water tap (sinks, showers, outside hose, etc.) to run for about five minutes. Multiple taps can be run at the same time but maintain vigorous flow.
- Hot water tanks can catch hot water tap until the water turns cold. If you use a tankless water heater, run the hot water for two minutes.
- Refrigerators and other water dispensers (under sink filtration systems) can use the water for several minutes, and then replace the filter if present.
- See meters. Follow the manufacturer's instructions for changing ice maker water lines, dispose of any existing ice, and dispose the ice from three wells.

**LEVEL 2 MODERATE: SMOKE DAMAGE / PRESSURE LOSS**

- Take extra caution.
- Do not drink or boil water until the following steps are completed and test results show no contamination:
- If well is intact but house is damaged, disconnect your home from the well.
- If well head is damaged, cover the well to prevent groundwater contamination.
- Contact well owner/provider for guidance on well repair and water treatment.
- Loss of pressure can lead to bacterial contamination of your well. Test for VOCs, nitrate, nitrite, pH, hardness, coliform bacteria.
- For support with test results, contact Colorado Department of Public Health and Environment's Toll-Free hotline 800-455-3866 or email [cdphe@cdphe.co.us](mailto:cdphe@cdphe.co.us)

**LEVEL 3 SEVERE: BURN DAMAGE**

- See a doctor.
- Do not drink or boil water until the following steps are completed and test results show no contamination:
- If well is intact but house is damaged, disconnect your home from the well.
- If well head is damaged, cover the well to prevent groundwater contamination.
- Contact well owner/provider for guidance on well repair and water treatment.
- Loss of pressure can lead to bacterial contamination of your well. Test for VOCs, nitrate, nitrite, pH, hardness, coliform bacteria.
- For support with test results, contact Colorado Department of Public Health and Environment's Toll-Free hotline 800-455-3866 or email [cdphe@cdphe.co.us](mailto:cdphe@cdphe.co.us)





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**









# National Lessons

A photograph of a vast field of purple flowers, likely wildflowers, in the foreground. The flowers are densely packed and have a vibrant purple hue. In the background, there is a line of trees, some of which appear to be charred or dead, suggesting a forest fire. The sky is clear and blue. The overall scene is a natural landscape.

*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

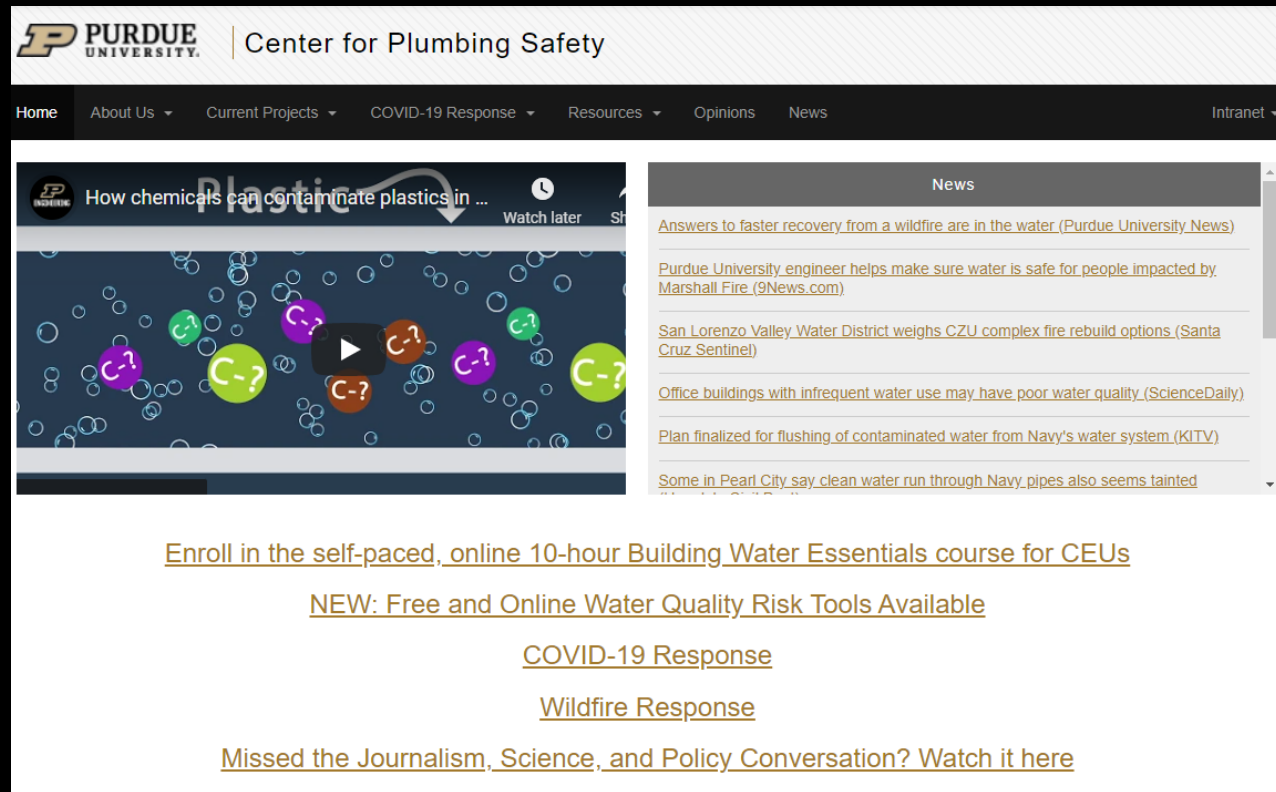


Chad Seidel and more



# Thank you. More results coming...

Andrew Whelton, Ph.D. [awhelton@purdue.edu](mailto:awhelton@purdue.edu)



## Funded by:



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



THE  
Water  
Research  
FOUNDATION



City of  
Louisville

Learn more at:

[www.CIPPSafety.org](http://www.CIPPSafety.org)

[www.PlumbingSafety.org](http://www.PlumbingSafety.org)



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