The Role of Science and Policy:

Drinking Water Safety After Fires

Andrew J. Whelton, Ph.D.
Civil, Environmental, and Ecological Engineering

awhelton@purdue.edu

www.PlumbingSafety.org

Our Focus

Water Safety and Disasters

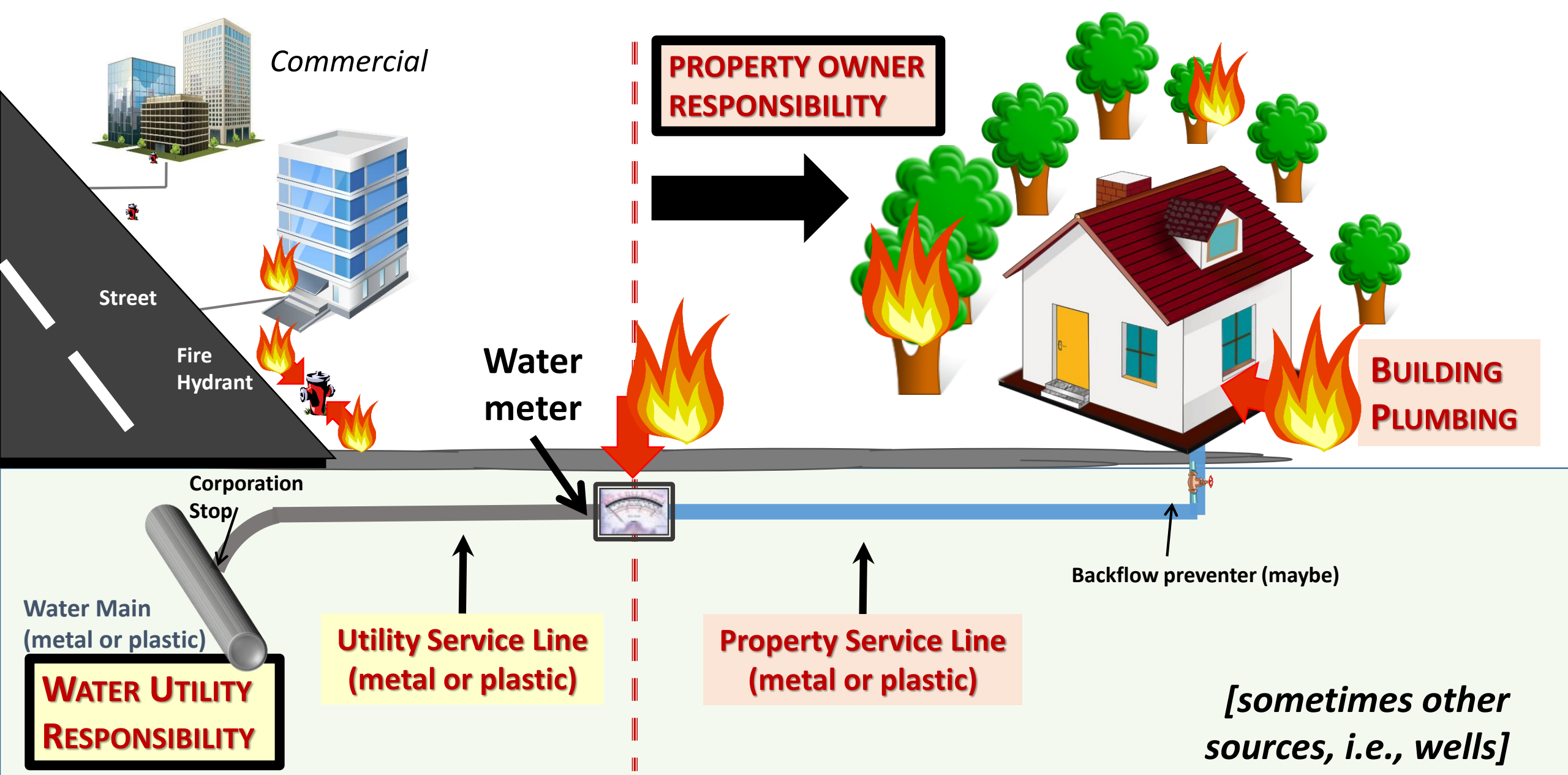
Infrastructure Construction and Repair Technologies

Waste Materials and Management Solutions









Commercial
PROPERTY OWNER RESPONSIBILITY
Street
Fire Hydrant
Water meter
BUILDING PLUMBING
Corporation Stop
Backflow preventer (maybe)
Water Main (metal or plastic)
WATER UTILITY RESPONSIBILITY
Utility Service Line (metal or plastic)
Property Service Line (metal or plastic)
[sometimes other sources, i.e., wells]

In 2021, U.S. wildfires burned 6.5 million+ acres thus far

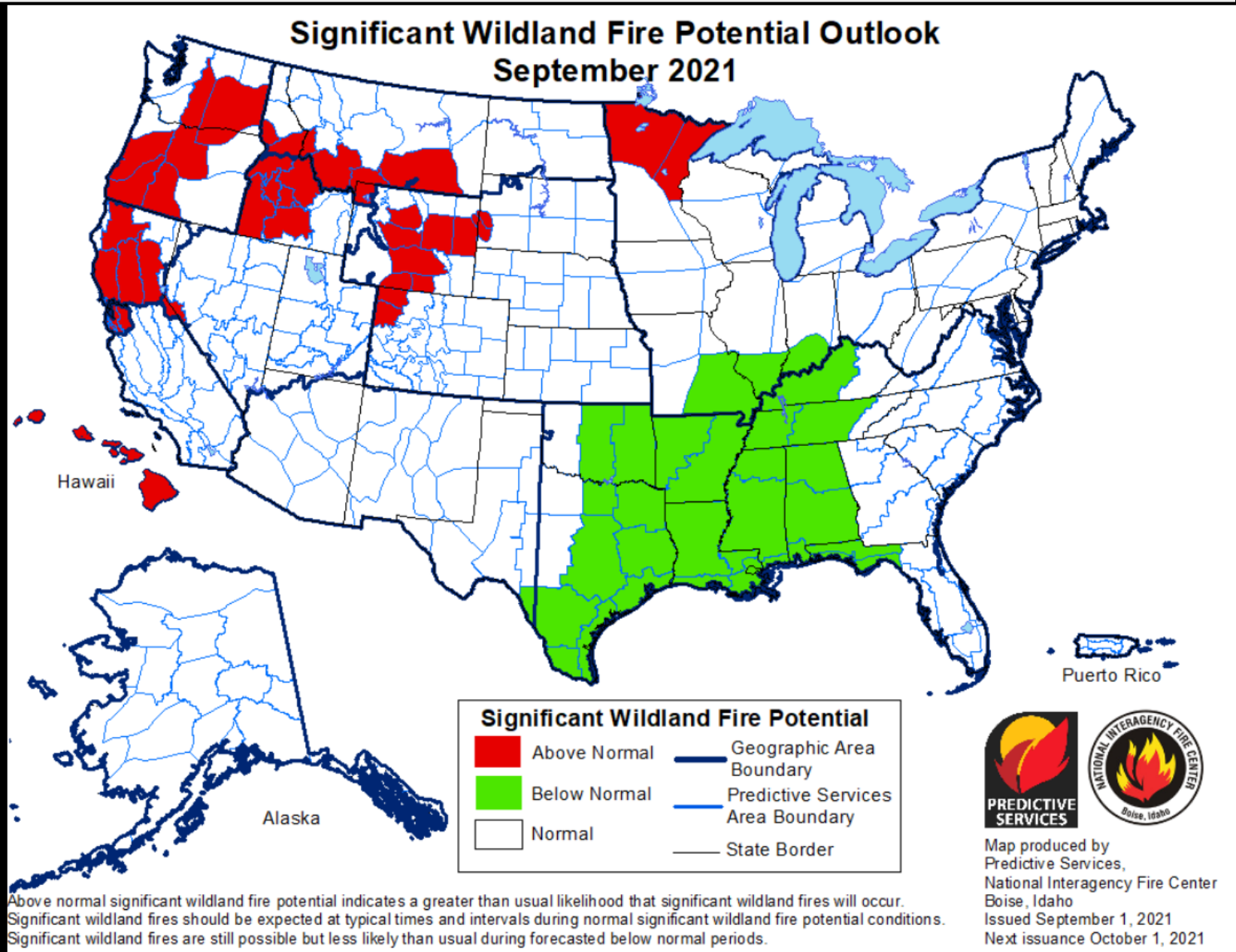
U.S. fire season hoping to end
2 months from now

A few communities impacted and in the news (globally)

- Greenville, CA
- Canyondam, CA
- Lytton, BC CAN
- Outside Athens, GRC
- Inside TUR

Many communities *not* mentioned in the news

https://www.nifc.gov/fire-information/statistics



Policy, *noun*

pol·i·cy | \ ˈpä-lə-sē

a definite course or method of action selected from among alternatives and in light of given conditions to guide and determine present and future decisions

a high-level overall plan embracing the general goals and acceptable procedures especially of a governmental body

U.S. wildfires burned 10 million+ acres (40,406 km^2) in 2020

4 out of the 5 largest wildfires in California on record occurred in 2020

But, the deadliest, most destructive wildfires did not occur in 2020

1. October 2017 **Tubbs Fire**
   - Sonoma and Napa Counties
   - 22 fatalities
2. November 2018 **Camp Fire**
   - Butte County
   - 85 fatalities

In California alone, 2.7+ million people live in very high fire hazard severity zones. WUI – Wildland Urban Interface

Lessons Learned from the 2017 Tubbs Fire and 2018 Camp Fire

AWWA WATER SCIENCE

Wildfire caused widespread drinking water distribution network contamination

Download FREE here:
https://doi.org/10.1002/aws2.1183

VOCs and SVOCs present, levels can exceed hazardous waste limits (40,000 ppb benzene, etc.)

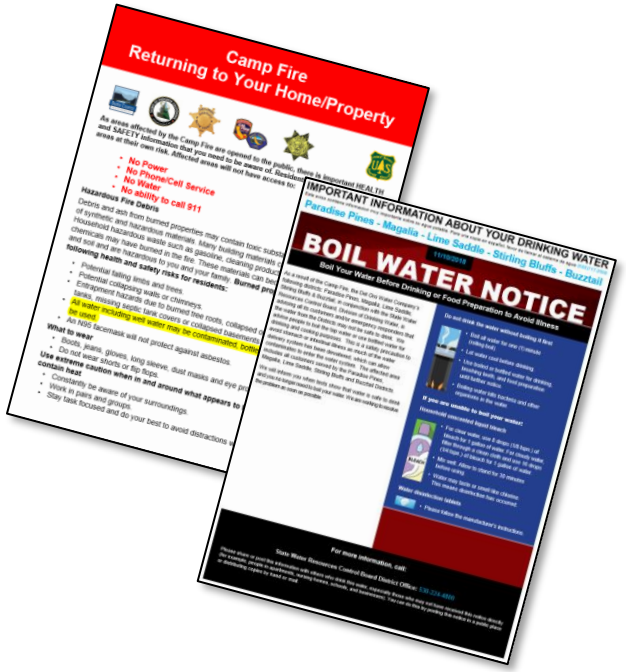
Do Not Use water order should be issued

Protect homeowners and their plumbing

November 8, 2018 Camp Fire

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 day visit and briefing, called us 3 months post-fire





PURDUE UNIVERSITY

MANHATTAN COLLEGE

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

< 50 samples had been collected by PID & DOWC

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

Our onsite recommendations:

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

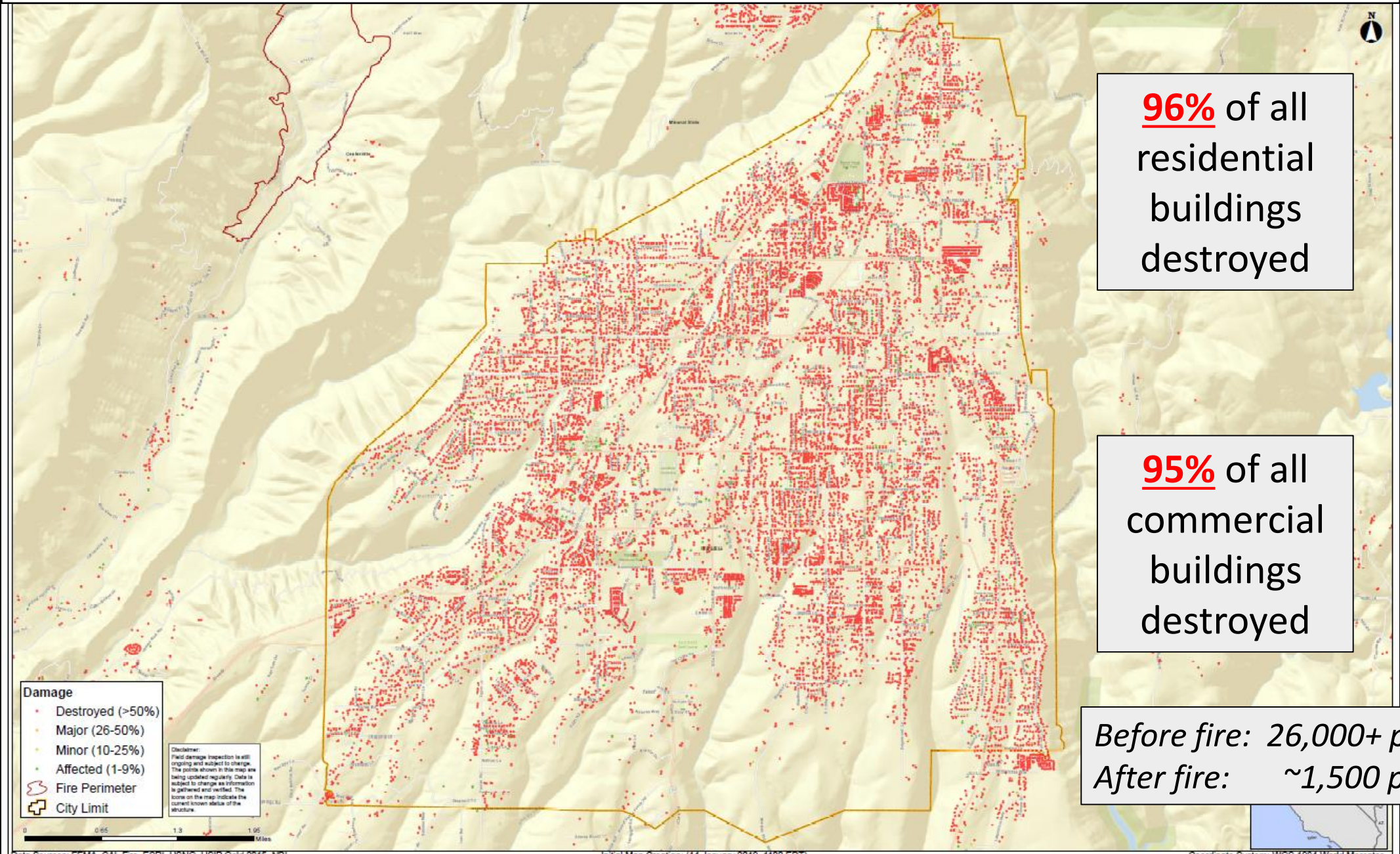
Onsite Visit Response and Recovery Observations Presented to PID February 13, 2019

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.

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

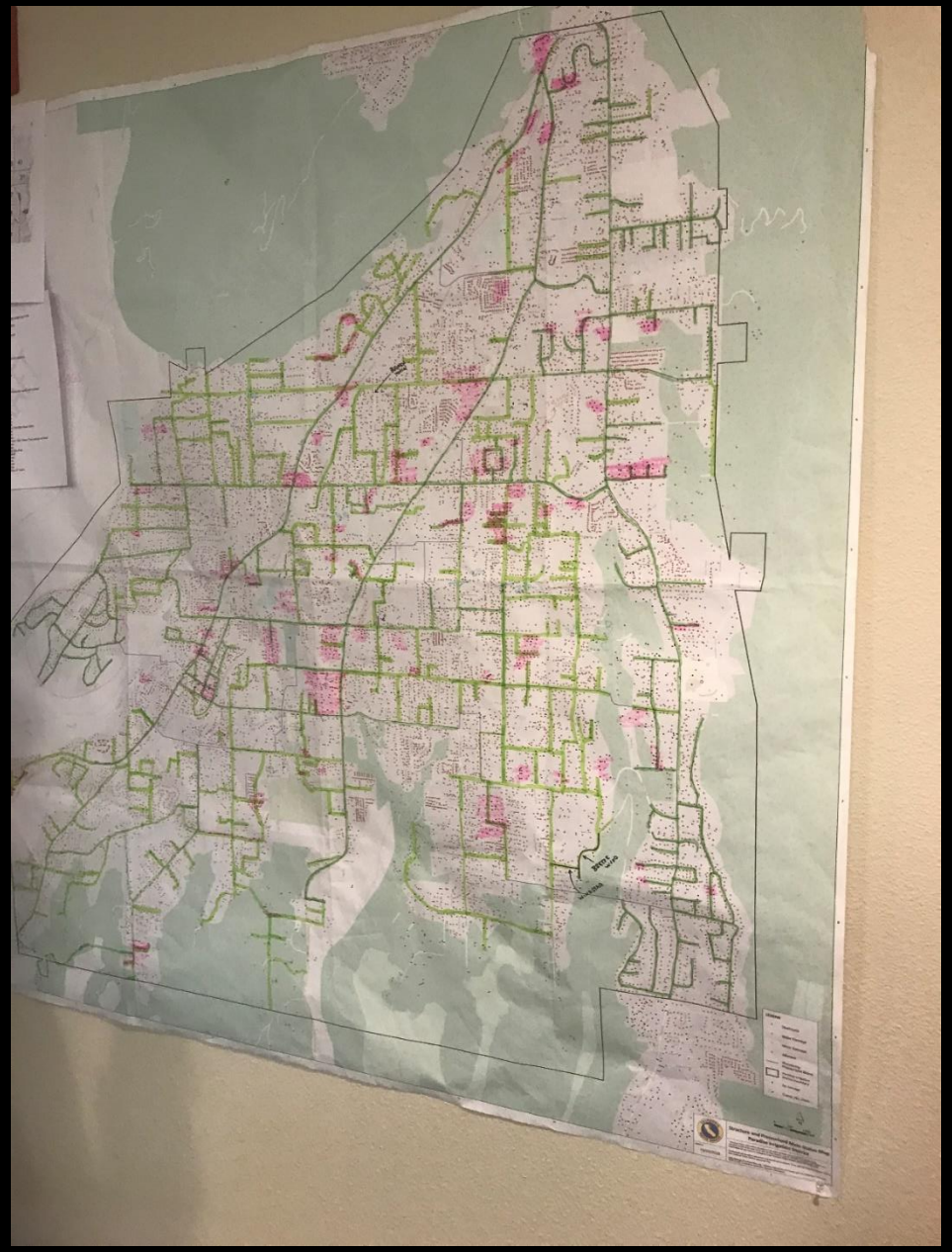
Damage

90%+ of their 172 mile water distribution system was depressurized for hours to weeks

100s+ of leaks

90%+ of their 172 mile water distribution system depressurized for hours to weeks

100s+ of leaks



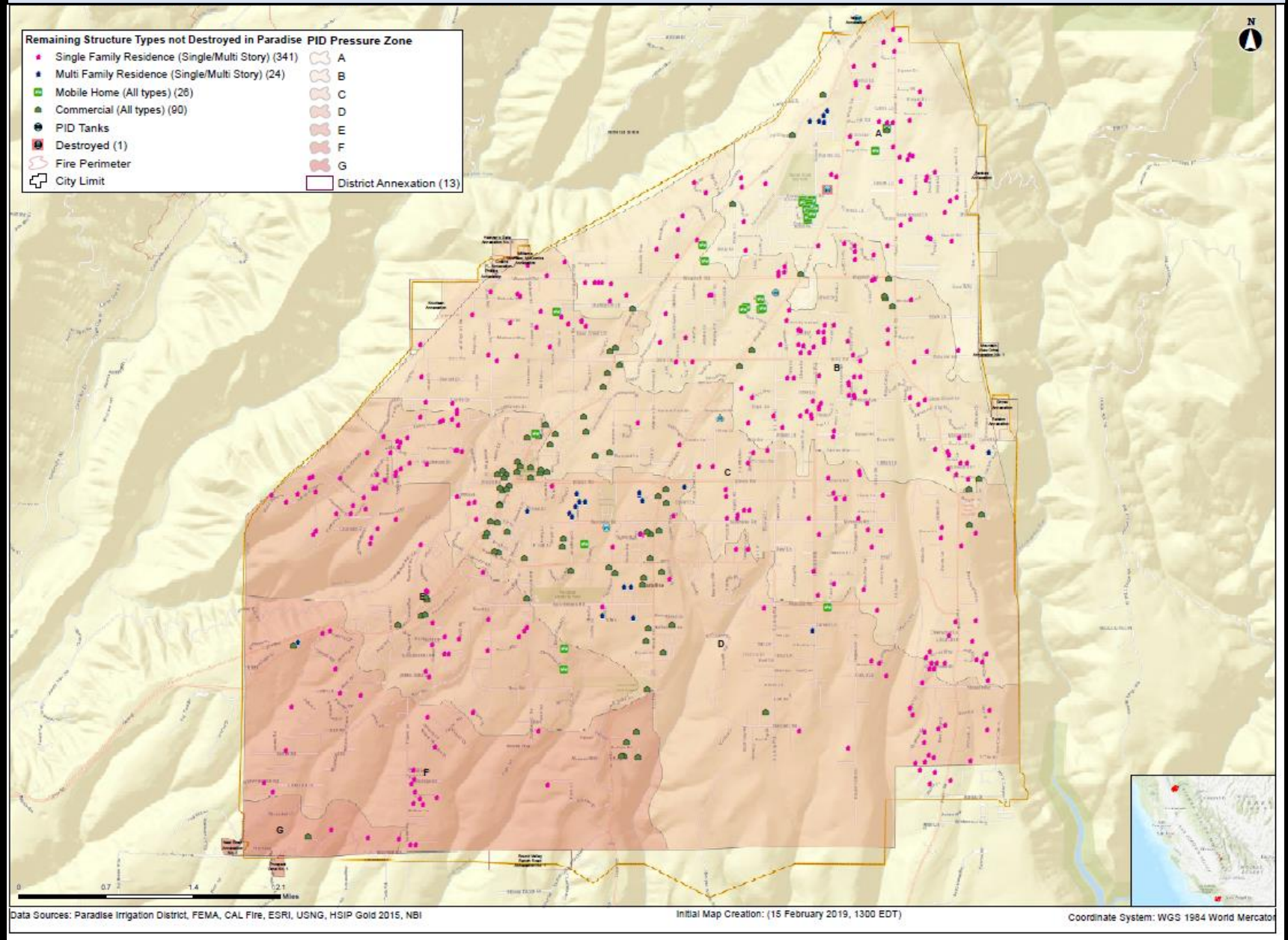
Standing homes were scattered throughout the contaminated water systems: PID Example

2 sources
1 treatment plant

7 pressure zones
172 miles of buried pipe
- PVC (35%)
- Steel (33%)
- CML (19%)
- AC (10%)
- Irons (6%)

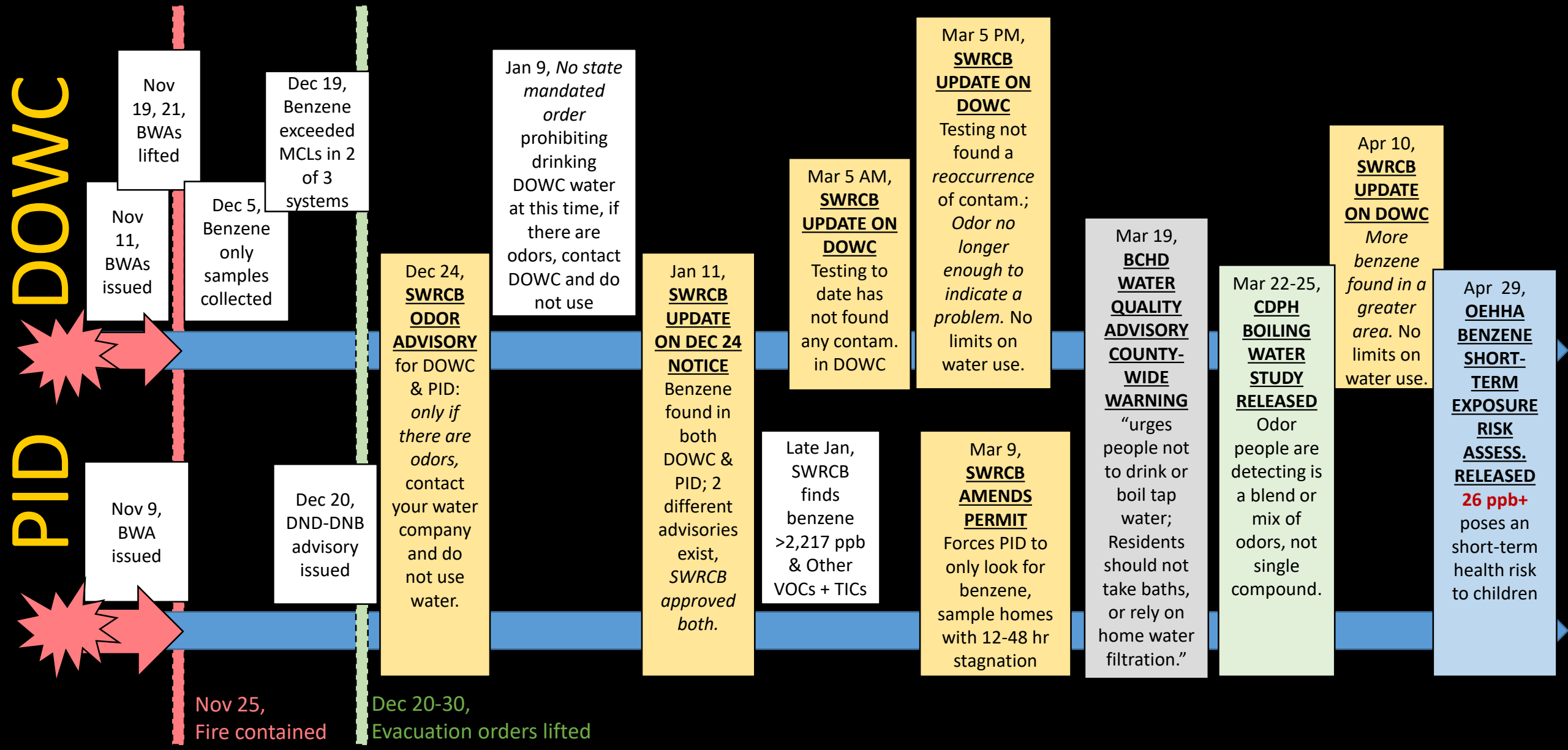
1,400 fire hydrants
10,600 service lines and meters
- Cu, Brass, GIP, GSP, HDPE, PB

PID Pressure Zones vs. Standing Structures




11,000+ homes

Same State, Same Fire, Different Policy for Each Population



TOWN OF PARADISE
BUTTE COUNTY

March 19, 2019 Countywide warning

Butte County Health Officer Issues Water Quality Advisory for Residents in Burn Affected Areas

BUTTE COUNTY, CA. – The Butte County Health Offi
and urges people not to drink or boil tap water.

**Information from water authorities indicates th
residents should not rely on home water filtrati
contamination, residents should not use tap wa**

In addition, it is highly recommended that resident

- Limit use of hot water
- Limit shower time (use lukewarm water and ventilate area)
- Use a dishwasher to wash dishes and use air dry setting
- Wash clothing in cold water
- Do not take baths
- Do not use hot tubs or swimming pools

Residents who use water from private wells or temporary water storage tanks may v
that result from structural damage caused by the Camp Fire.

The Health Department does not have oversight over water authorities. If residents
authority directly.

"…contamination may be present in home plumbing systems, and therefore, residents should not rely on home water filtrations systems as they may not be adequate to provide protection."

"…residents should not use tap water for drinking, cooking, food preparation, brushing teeth, or similar activities."

Drinking Water Distribution System Impacts

500 ppb benzene – U.S. Federal RCRA hazardous waste limit

Chemical that Exceeded a Drinking Water Limit	2018 Camp Fire (8 months after the fire)				2017 Tubbs Fire (11 months after the fire)		
	PID	DOWC	Exceedance		Santa Rosa		
	Max, ppb	Max, ppb	Exceeded Long-Term Limit?	Exceeded ***Short-Term*** Limit?	Max, ppb	Exceeded Long-Term Limit?	Exceeded ***Short-Term*** Limit?
Benzene	>2,217	530	**Yes**	**Yes**	40,000	**Yes**	**Yes**
Methylene chloride	45	NA	**Yes**	No	41	**Yes**	No
Naphthalene	693	NA	**Yes**	**Yes**	6,800	**Yes**	**Yes**
Styrene	378	NA	**Yes**	No	460	**Yes**	No
Tert-butyl alcohol	13	NA	**Yes**	-	29	**Yes**	-
Toluene	676	NA	**Yes**	No	1,130	**Yes**	No
Vinyl chloride	1	NA	**Yes**	No	16	**Yes**	No

Long-term limit for an adult for 70 years
Short-term (1 day) limit for a 1 year old child

AWWA Water Science, Proctor et al. 2020
https://doi.org/10.1002/aws2.1183

Possible Primary Sources

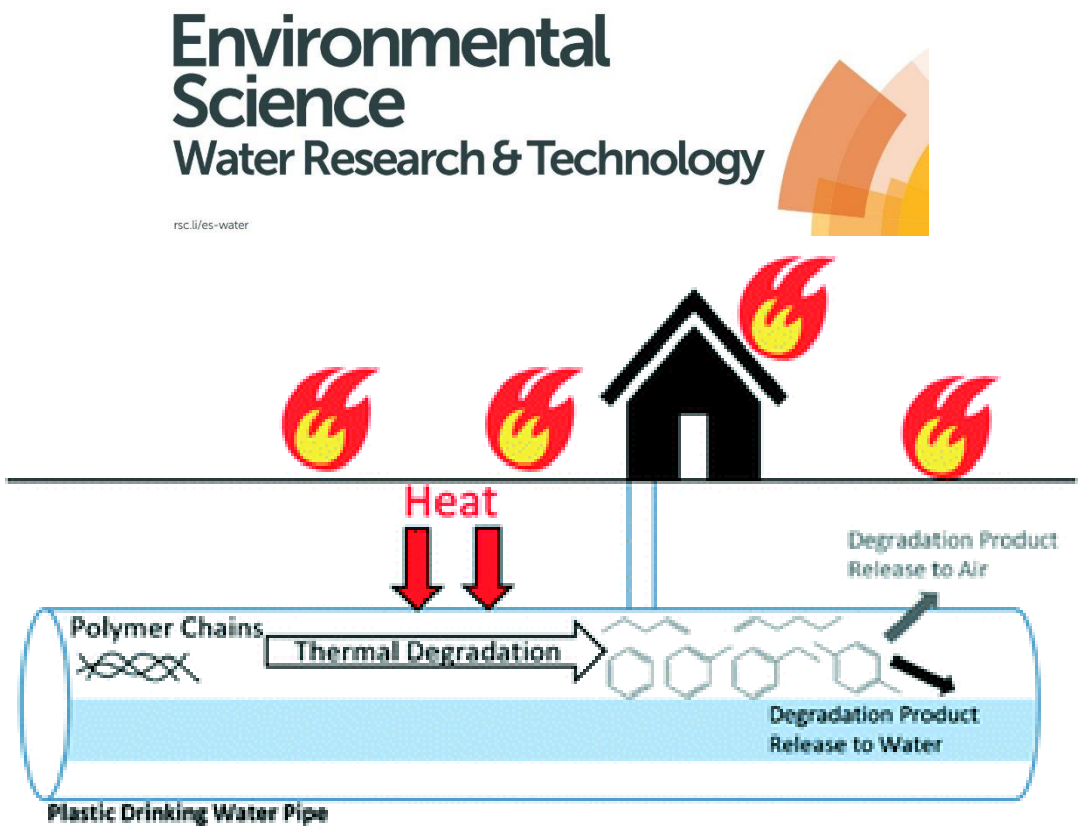
1. *In-situ* plastic thermal decomposition (PVC pipes, HDPE pipes, PB pipes, gaskets, meter components, etc.)
2. Contaminated air/materials drawn into depressurized system
3. Contaminated water from building plumbing drawn into compromised distribution system

Confirmed Secondary Sources

Partitioning/Adsorption/Absorption:
Water ←→ Material

See video at
www.PlumbingSafety.org

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

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 was generated by all pipes except PP

Once plastic cooled, chemicals leached into water

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

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

Chemistry:

Polymer chain scission

Aromatization

The role of additives

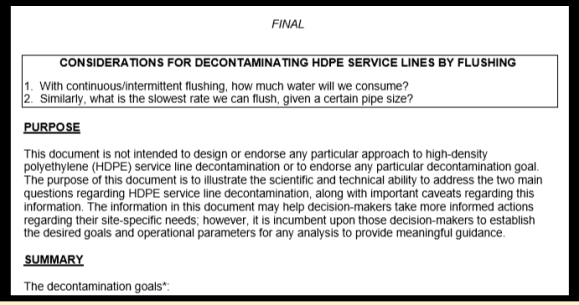
The role of temperature

The role of RH

The role of O_2

Partitioning after generation

Building codes never considered heat damaged plastic plumbing materials becoming a 1˚ or 2˚ source of drinking water contamination. (est. 300,000 structure fires per year - NFPA)



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*:

Water Distribution System Decontamination

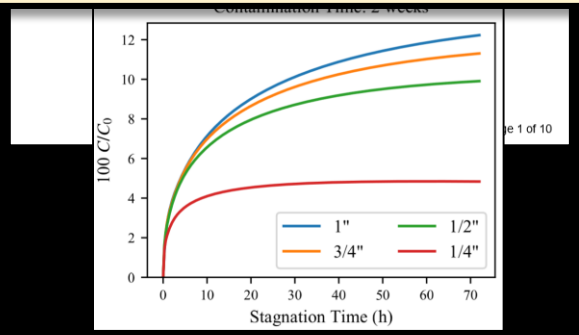
Collaboration between Us & USEPA

Hydraulics

Polymer Science

Environmental Engineering

Science was applied to some water distribution system testing and decontamination decisions, but more work is needed



Numerical modeling:

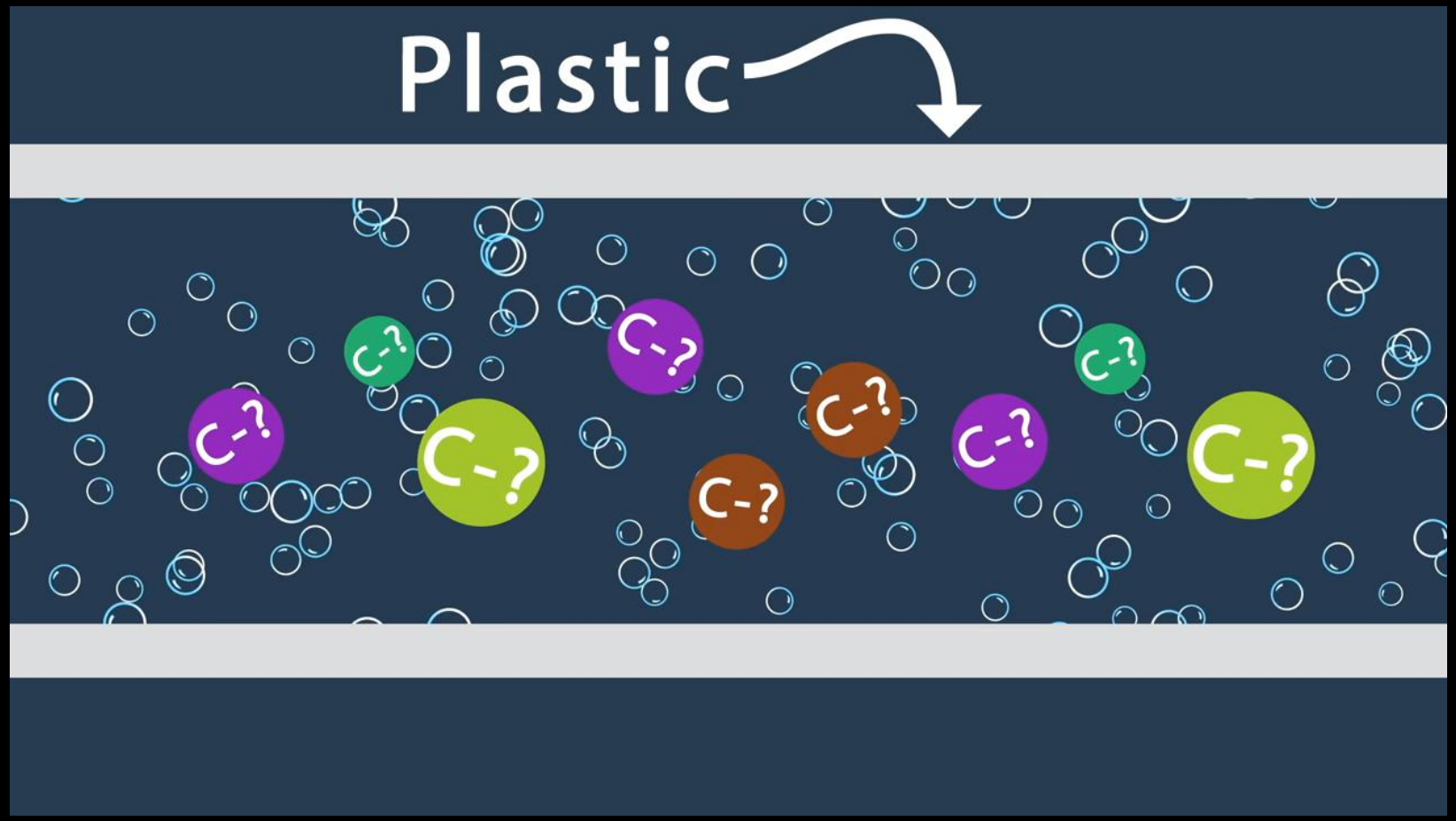
Greater than 286 days vs. less than 64 days of continuous water flushing for 1-inch HDPE service line

(Haupert et al. 2019)

Initial measurement concentration (C_2)	Goal A (never above 0.5 ppb)		Goal B (only exceed 0.5 ppb after 72 hours of stagnation)	
	Continuous	Intermittent (once/72 hrs)	Continuous	Intermittent (once/72 hrs)
100 ppb	286	312	195	240
50 ppb	246	270	156	198
20 ppb	195	213	104	141
10 ppb	155	171	66	99
5 ppb	116	129	33	60
2 ppb	64	74	8	20

https://engineering.purdue.edu/PlumbingSafety/opinions/Final-HDPE-Service-Line-Decontamination-2019-03-18.pdf

Chemicals can sorb into and leach from water system materials including plumbing components



For water samples, ***Stagnation Time*** is needed

Before you collect a water sample you must allow the chemicals to leach out into water.

Watch the video at https://youtu.be/ythX2fP3-S4

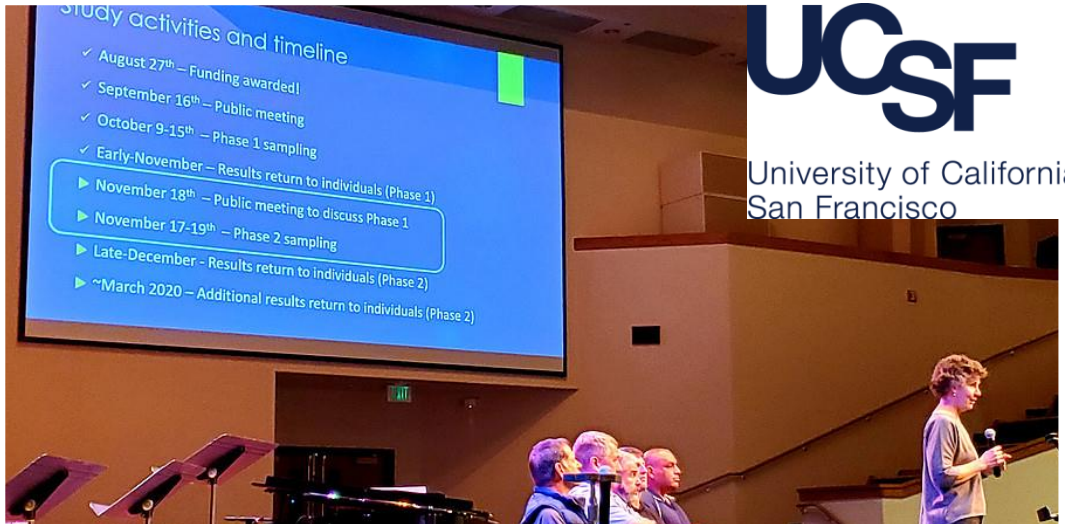
How chemicals contaminate plastic pipes and drinking water

CHICO STATE

PURDUE UNIVERSITY

Butte College
DISTRICT BUTTE - GLENN COMMUNITY COLLEGE

Berkeley
UNIVERSITY OF CALIFORNIA



UCSF
University of California
San Francisco

Fire and Water: Assessing Drinking Water Contamination After a Major Wildfire. ES&T Water. 2021.

In-home testing was conducted 11 months after the fire

125 homes: PID (101), Del Oro (24)

First draw, kitchen sink cold water only, 12+ hr stagnation.

Looked for more than benzene

2 homes: benzene found, and less than 1 ppb CA MCL (11 months later)

4 homes: methylene chloride exceeded USEPA 5 ppb MCL (max. 9.2 ppb)

THF found above other state limits (no CA or federal limit)

H_A: Galvanized iron pipes influenced methylene chloride levels

Not statistically representative, homeowner service lines not tested

Hot water systems are separate, where inhalation exposure occurs, but were not tested

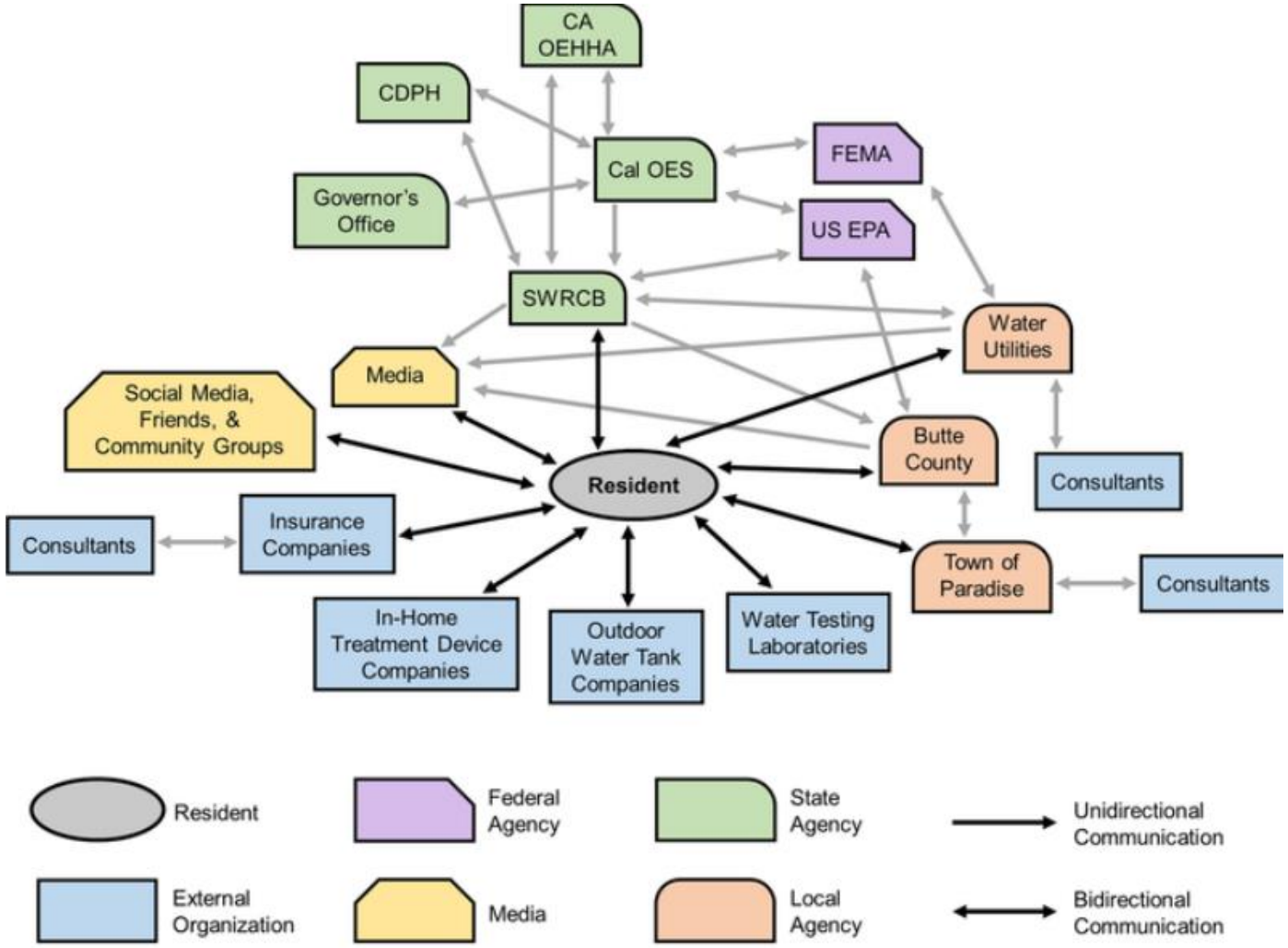
Testing needs to occur as soon as possible. We said this to CalOES 8 months earlier.

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.



Q: Should in-home POU water filtration devices be used to treat wildfire contaminated drinking water?

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

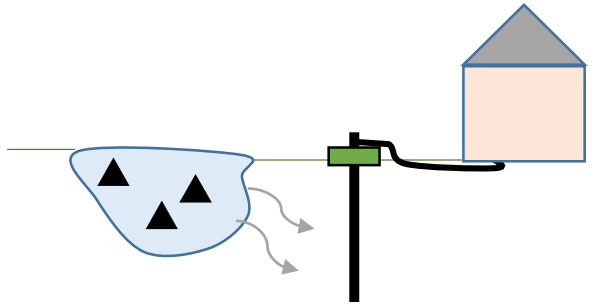
The devices are NOT designed for this. The range of contamination must be known + testing.

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

Camp Fire: ‘Standing Home’ Public Health Issues

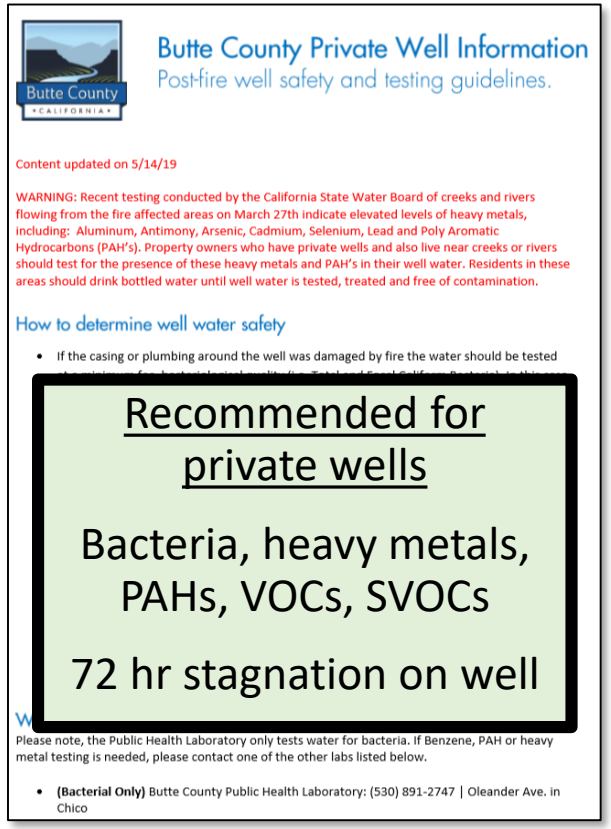
Citizens must be warned and protected from contaminated water

- State officials told people to SMELL (not test) water to determine if its safe
- 2 systems contaminated --- no water restrictions (max. 530 ppb benzene)
- Some Paradise customers did not follow water use restrictions
- Home testing guidance by agencies defied hydraulics and chemistry
- Labs told people to flush taps for 10-15 min BEFORE taking water sample



Contaminated water entered home plumbing for 6+ months

- Benzene found in homes by residents, State said they had no knowledge (because they didn’t credibly sample)
- Utilities were still trying to identify their contaminated assets
- Checkerboard recovery: 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, SVOCs

72 hr stagnation on well

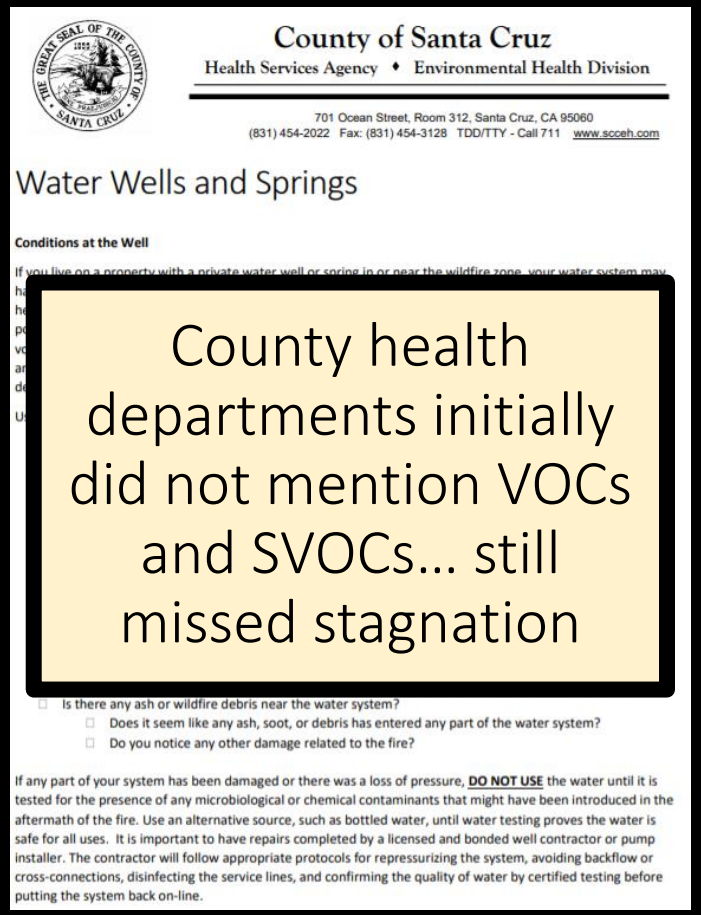
Please note, the Public Health Laboratory only tests water for bacteria. If Benzene, PAH or heavy metal testing is needed, please contact one of the other labs listed below.

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

Plumbing received 6+ months of contaminated water

Cold and hot water systems became nonpotable
Trunk-and-branch vs. homerun designs
In-home treatment devices (est. $7 million)
Paying for water testing, results not representative
External water tank maintenance and microbiological growth
Some had no economic capacity to purchase bottled water, devices

Insurance companies made decisions (not USEPA, State or health department) about in-home treatment



County of Santa Cruz
Health Services Agency • Environmental Health Division

701 Ocean Street, Room 312, Santa Cruz, CA 95060
(831) 454-2022 Fax: (831) 454-3128 TDD/TTY - Call 711 www.sceeh.com

Water Wells and Springs

Conditions at the Well

If you live on a property with a private water well or spring in or near the wildfire zone, your water system may

County health departments initially did not mention VOCs and SVOCs… still missed stagnation

- 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?

If any part of your system has been damaged or there was a loss of pressure, **DO NOT USE** the water until it is tested for the presence of any microbiological or chemical contaminants that might have been introduced in the aftermath of the fire. Use an alternative source, such as bottled water, until water testing proves the water is safe for all uses. It is important to have repairs completed by a licensed and bonded well contractor or pump installer. The contractor will 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 on-line.

2020 CZU Lightning Complex Fire

SLVWD 42 ppb benzene + more

(Yes bathe, no wait don't bathe)

BBWC 1.8 ppb benzene + more

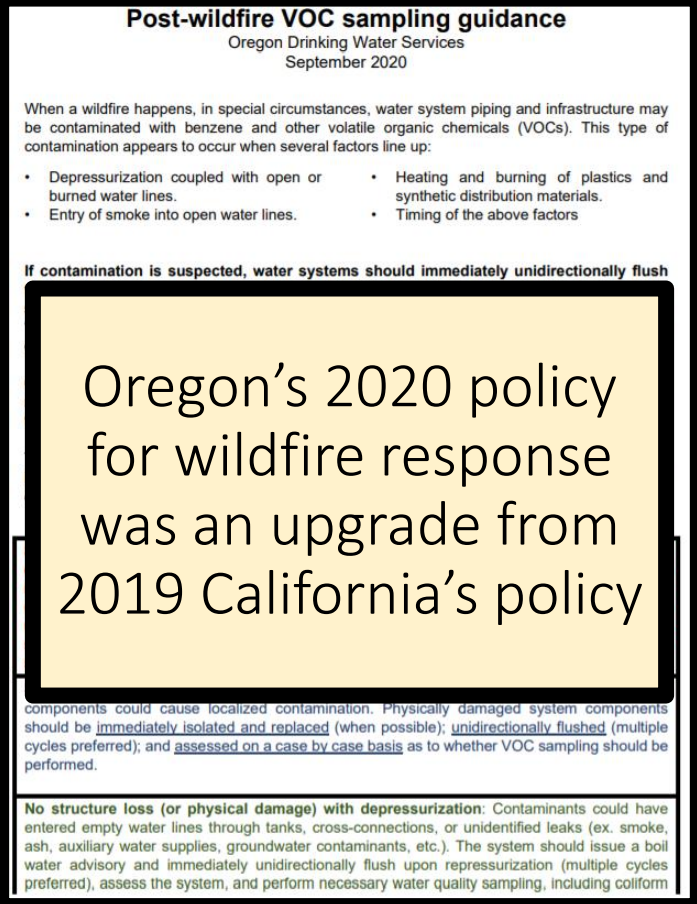
2020 LNU Lightning Complex Fire

Napa 31 chems, other systems…

No SVOC testing

Private well testing data not found

BWAs issued, then lifted, then tested, then found VOC contamination



Post-wildfire VOC sampling guidance
Oregon Drinking Water Services
September 2020

When a wildfire happens, in special circumstances, water system piping and infrastructure may be contaminated with benzene and other volatile organic chemicals (VOCs). This type of contamination appears to occur when several factors line up:

- Depressurization coupled with open or burned water lines.
- Entry of smoke into open water lines.
- Heating and burning of plastics and synthetic distribution materials.
- Timing of the above factors

If contamination is suspected, water systems should immediately unidirectionally flush

Oregon's 2020 policy for wildfire response was an upgrade from 2019 California's policy

components could cause localized contamination. Physically damaged system components should be immediately isolated and replaced (when possible); unidirectionally flushed (multiple cycles preferred); and assessed on a case by case basis as to whether VOC sampling should be performed.

No structure loss (or physical damage) with depressurization: Contaminants could have entered empty water lines through tanks, cross-connections, or unidentified leaks (ex. smoke, ash, auxiliary water supplies, groundwater contaminants, etc.). The system should issue a boil water advisory and immediately unidirectionally flush upon repressurization (multiple cycles preferred), assess the system, and perform necessary water quality sampling, including coliform

“The Safe Drinking Water Act doesn’t have a clause like, this is what you do in a fire when a community is completely burned to the ground.”

– Governor Newsom’s California Waterboard

CalMatters, October 2020

It's California and USEPA Region 9's Policy…

DOWC found **1 to 530 ppb** benzene in their drinking water system but ***did not*** warn their customers. Families used contaminated water. A homeowner hooked up their RV, then DOWC testing found benzene in their RV.

"The Public Notification Rule ensures that consumers will know if there is a problem with their drinking water and alerts if there is risk to public health" – USEPA website; October 7, 2020

Tier 1 Violation – Immediate Notice, within 24 hours…..
"Other violations or situations determined by the primacy agency."
Must include 10 specific elements

CA SWRCB *and* USEPA Region 9 ***chose not to*** invoke the Public Notification Rule to require DOWC notify customers that there was a problem, a risk to public health, or prescribe water use restrictions.

Oregon 2020 Fires - Regulated Contaminants

At least 7 PWSs contaminated in Oregon as of May 10, 2021

VOCs were the sole focus; EPA method 524.2 for VOCs was applied for all samples

No data was found for SVOC testing. It was likely never conducted.

Vinyl chloride and MTBE exceeded federal MCLs in water samples when there was NO benzene.

Methylene chloride was not reported above the 5 ppb MCL

Volatile Organic Compound	Maximum Concentration of Contaminant (ppb)							Exposure Limits (ppb)		
	Detroit Water System	City of Gates	Whispering Pines Mobile Home Park	City of Phoenix	City of Talent	Hiland WC-Echo Mountain	Panther Creek	Federal MCL	CA MCL	USEPA 1-day Health Advisory (for 10kg child)
Benzene	**44.9**	ND	**5.5**	ND	**76.4**	**11.3**	**1.1**	5	1	200
Vinyl Chloride	**0.6**	**8.2**	ND	ND	ND	ND	ND	2	0.5	3,000
Chlorobenzene	**127**	ND	6.08	ND	ND	4.6	ND	100	70	4,000
Dichloroethane	ND	ND	**1.05**	ND	ND	ND	ND	5	0.5	700
1,4-dichlorobenzene	**9**	ND	**10.8**	ND	ND	ND	ND	75	5	11,000
Methyl-*tert*-butyl ether (MTBE)	**358**	ND	ND	589	ND	3.17	ND	N/A	13	N/A
Service Population	205	490	120	4,630	6,850	362	760	____	____	_____

CA OEHHA concluded that 26 ppb benzene in drinking water would prompt an increased risk of blood effects in children such as a decrease in lymphocytes and white blood cells

Oregon 2020 Fires: Non-Regulated Contaminants

Volatile Organic Compound	Maximum Concentration of Contaminant (ppb)					Exposure Limits
	Blue River	Whispering Pines Mobile Home Park	City of Talent	Hiland WC-Echo Mountain	Medford Water Commission	USEPA 1-day Health Advisory (for 10kg child)
Acetone	10,600	206,000	ND	1,290	ND	N/A
Acrolein	ND	ND	8.9	ND	ND	N/A
Methyl ethyl ketone (MEK)	3,890	138,000	638	2,440	900	75,000
Tetrahydrofuran (THF)	26	14,300	ND	200	ND	N/A

Potential sources: Organic solvents and chemicals associated in plastic manufacture?

MEK exceeded the US EPA 1-day health advisory level

(138,000 ppb found in the absence of benzene)

No OR or CA advisory levels for these chemicals, but exceeded some for other states

All compounds found in samples with and without benzene

Wildfires have profound impacts on health, safety, and economic prosperity

Maximum Benzene Level	Event/Location	Population Affected	System Name	Year
6	Echo Mountain Fire/Oregon	120	Whispering Pines Mobile Home Park	2020
11	Echo Mountain Fire/Oregon	362	Hiland WC - Echo Mountain	2020
1	Echo Mountain Fire/Oregon	760	Panther Creek Water District	2020
76	Almeda Fire/Oregon	6,850	City of Talent	2020
45	Lionshead Fire/Oregon	205	Detroit Water System	2020
2	CZU Lightning Complex Fire/California	1,650	Big Basin Water Company	2020
42	CZU Lightning Complex Fire/California	21,145	San Lorenzo Water District	2020
2,217	Camp Fire/California	26,032	Paradise Irrigation District	2018
38	Camp Fire/California	924	Del Oro Water Co.-Magalia	2018
8	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

Hazardous waste levels of benzene in drinking water. More VOCs, SVOCs above safe limits.

Sources: Smoke and plastics thermal degradation

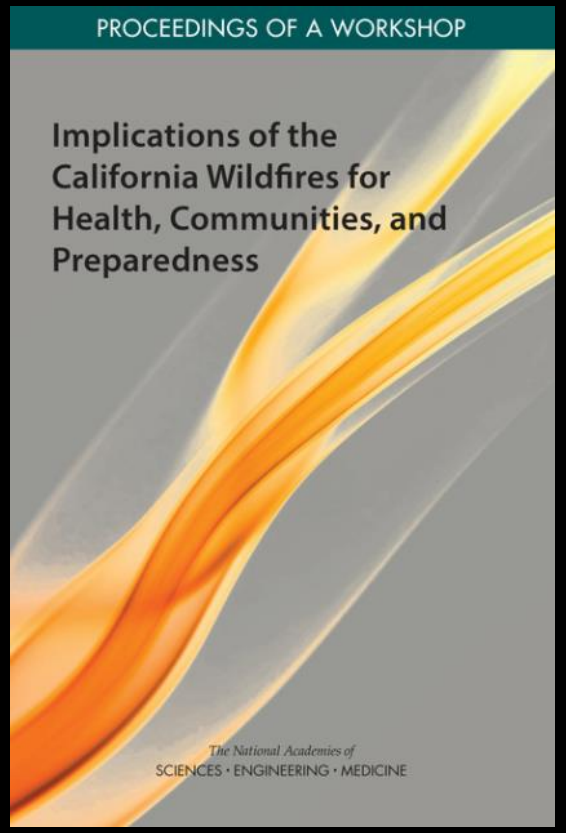
Some plumbing plastics uptake chemicals and leach them back out making clean water unsafe

PURDUE UNIVERSITY

Exhumed PVC drinking water pipe, 2021 Fire Season, California

Research and Policy Needs Identified in 2019: Opportunities for the improved protection of public health

The National Academies of SCIENCES ENGINEERING MEDICINE



https://www.nap.edu/read/25622/

Forum on Medical and Public Health Preparedness for Disasters and Emergencies, Roundtable on Population Heath Improvement, Roundtable on the Promotion of Health Equity, Roundtable on Environmental Health Services, Research, and Medicine, Board on Health Sciences Policy, Board on Population Health and Public Health Practice, Health and Medicine Division

Federal Insurance and Mitigation

Job Aid for Disaster Recovery Reform Act, Section 1205 Additional Activities for Wildfire and Wind Implementation under Hazard Mitigation Assistance Programs

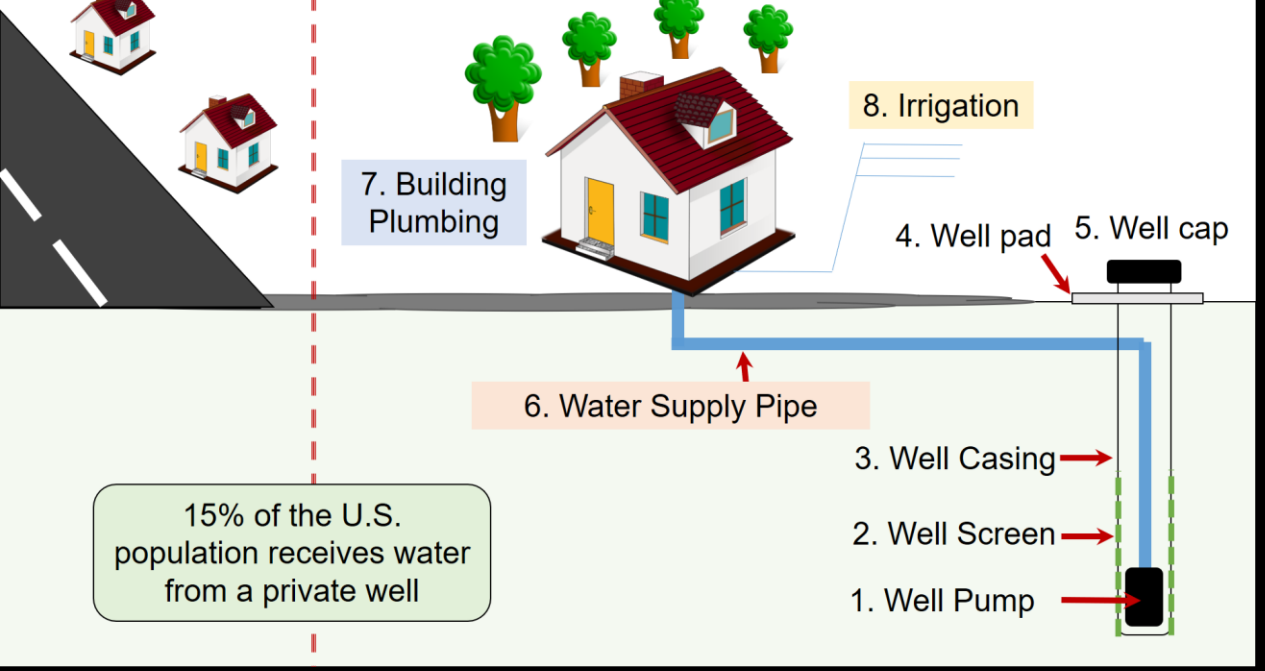
December 3, 2019

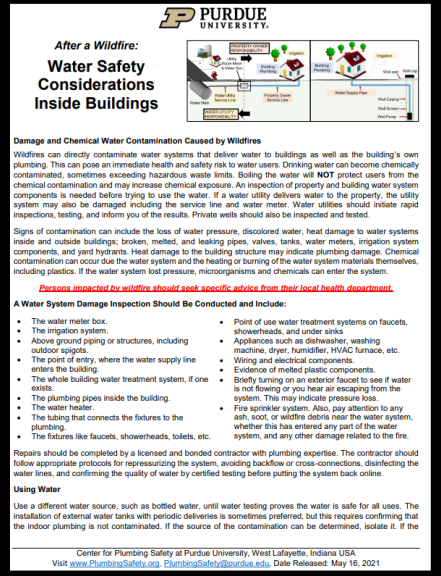
Replacing water systems that have been burned and have caused contamination

Wildfires generate intense heat that can adversely impact water system components both on the surface and underground. If intense heat modifies the chemical properties of water system components, chemicals might leach into the water, causing contamination. Infrastructure retrofits that reduce future risk to existing utility systems, including water systems, are eligible for HMA funding. The mitigation measures that are applied to the utility system can be multi-hazard to address more than just the hazard that caused the damage. Because HMA grants can be used to address undamaged portions of a utility system, they can be used to mitigate system components that have not been damaged but have properties like other systems that have sustained damage as well as undamaged portions of systems that have been partially damaged.

FEMA

[Federal Policy]





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:

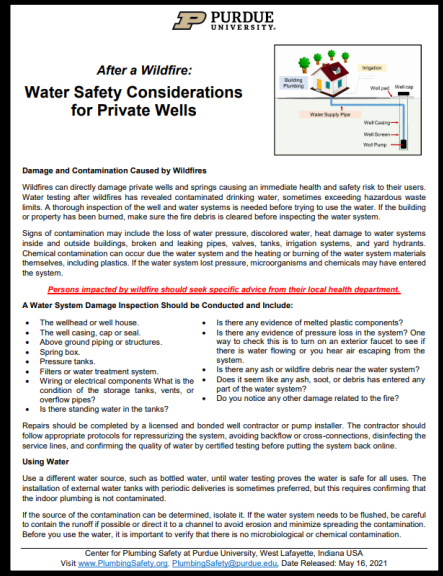
- The water meter box.
- The irrigation system.
- Above ground piping or structures, including outdoor spigots.
- The point of entry, where the water supply line enters the building.
- The whole building water treatment system, if one exists.
- The plumbing pipes inside the building.
- The water heater.
- 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

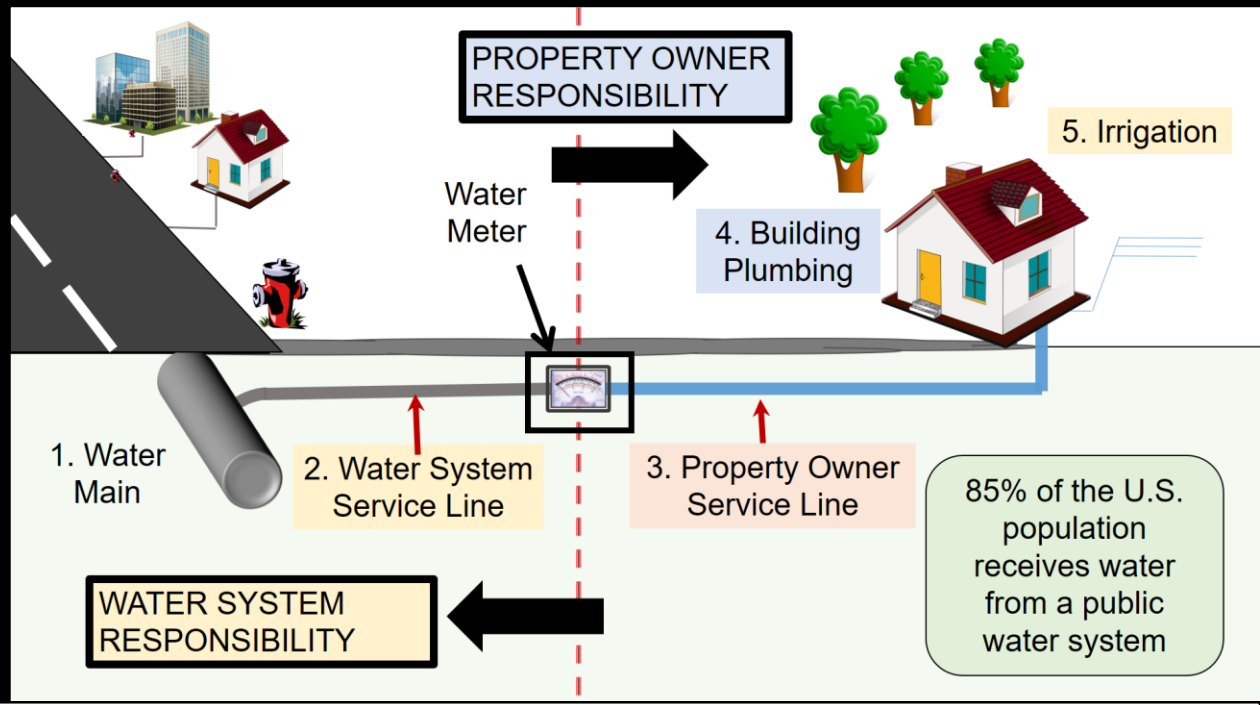
Use a different water source, such as bottled water, until water testing proves the water is safe for all uses. The installation of external water tanks with periodic deliveries is sometimes preferred, but this requires confirming that the indoor plumbing is not contaminated.

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]

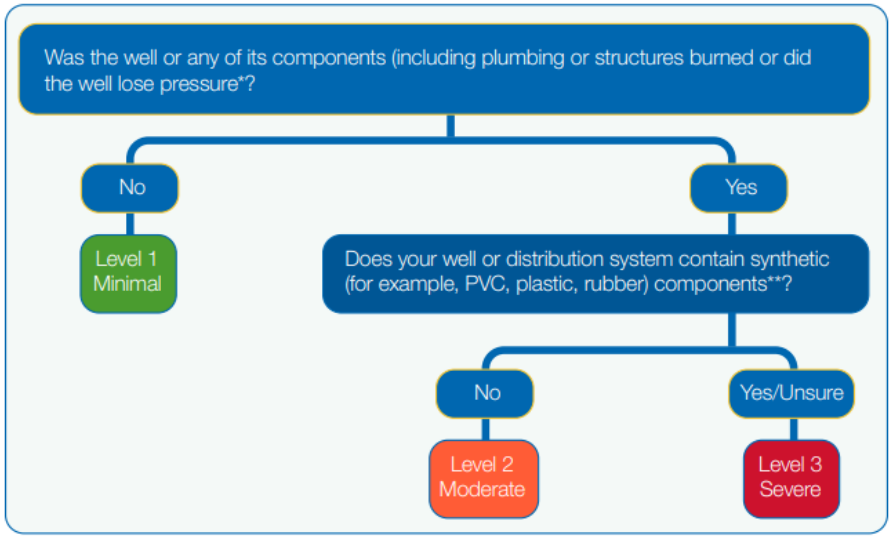


Assessing damage to private wells

After the Fire

This tool is meant for properties that were damaged by wildfire or had a wildfire within 100 feet of the property.

Use this resource to assess damage level and identify next steps



* Check to see if the well lost pressure by watching water flow from faucets. If the water flow is interrupted by air escaping, the well lost pressure.

** Check to see if the well system and plumbing have plastic or rubber components that contact drinking water. This may include electrical wiring and controls in contact with water, plastic/PVC casings and liners, rubber gaskets, treatment equipment, and more.

Released January 2021

Oregon Health Authority
PUBLIC HEALTH DIVISION

Addressing Contamination of Drinking Water Distribution Systems from Volatile Organic Compounds (VOCs) After Wildfires

After the 2017 Tubbs Fire and the 2018 Camp Fire in California, volatile organic compounds (VOCs) were found in the drinking water of the impacted towns. Tests of the water revealed elevated levels of several VOCs, such as benzene, in water mains, service connections, and building fixtures. If unaddressed, VOC contamination can pose a potential health risk for consumers and result in a loss of consumer confidence.

Addressing VOC contamination can be a potentially long-term problem. Flushing is the primary method for removing VOC contamination; however, flushing may not always be effective or feasible. Infrastructure replacement is another option, but depending on the scale, can take time and be cost-prohibitive. Delays in addressing contamination can impact the return of residents to their homes and the restart of commercial businesses, significantly slowing community recovery. This factsheet examines VOC drinking water contamination from the Tubbs and Camp Fires and recommends practices to assist drinking water utilities in identifying and addressing contamination. While this information is intended for public water systems, it also may benefit private water systems and well owners.

The causes and remediation of VOC contamination in distribution systems is an emerging field of study. The cited research reflects the current understanding of wildfire impacts on drinking water distribution systems as well as the informational gaps. This document is meant to provide a resource for water utilities, communities, and state primacy agencies dealing with wildfire damage and public health concerns. Utilities should contact their state primacy agency or EPA Regional Office for additional technical assistance.

Wildfire VOC Contamination

VOC contamination may occur when water distribution infrastructure (e.g., pipes, valves, meters, etc.) is impacted by a wildfire. VOC contamination has been observed primarily in areas that were damaged during the wildfire and experienced pressure loss in the water system. Research into the exact cause of the VOC contamination is ongoing, but two possible explanations have been proposed that may account for such contamination either alone or in combination.

1. Contamination may be released into the water from infrastructure containing polyvinyl chloride (PVC), high density polyethylene (HDPE), or other plastic materials that degrade when exposed to heat.[1]

Released September 2021

For more information, please visit **www.epa.gov/waterutilityresponse** 1

Plastic use is growing

Water pipes, gaskets, water meters, valves, faucet connectors, appliance lines, fixture components, shower hose, pipe and tank linings, well casings, water softeners (resin), water heater (dip tubes), membranes, and more…

Not considered in building codes or public health decisions

1. Heat damaged plastics becoming generators of water contamination
2. Heat damaged plastics being 2˚ sources of contamination

PurdueX: Massive Open Online Course (MOOC)

Plastics in Infrastructure and the Environment

Summer 2021, Summer 2022
Online 8 week course
est. 6-8 hours/week
FREE

Learning Objectives

- Explain the properties of polymer materials.
- Recognize the performance differences between polymeric materials.
- Describe the advantages and disadvantages of polymers for engineering applications.

More info and enroll: https://www.edx.org/course/plastics-in-infrastructure-and-the-environment

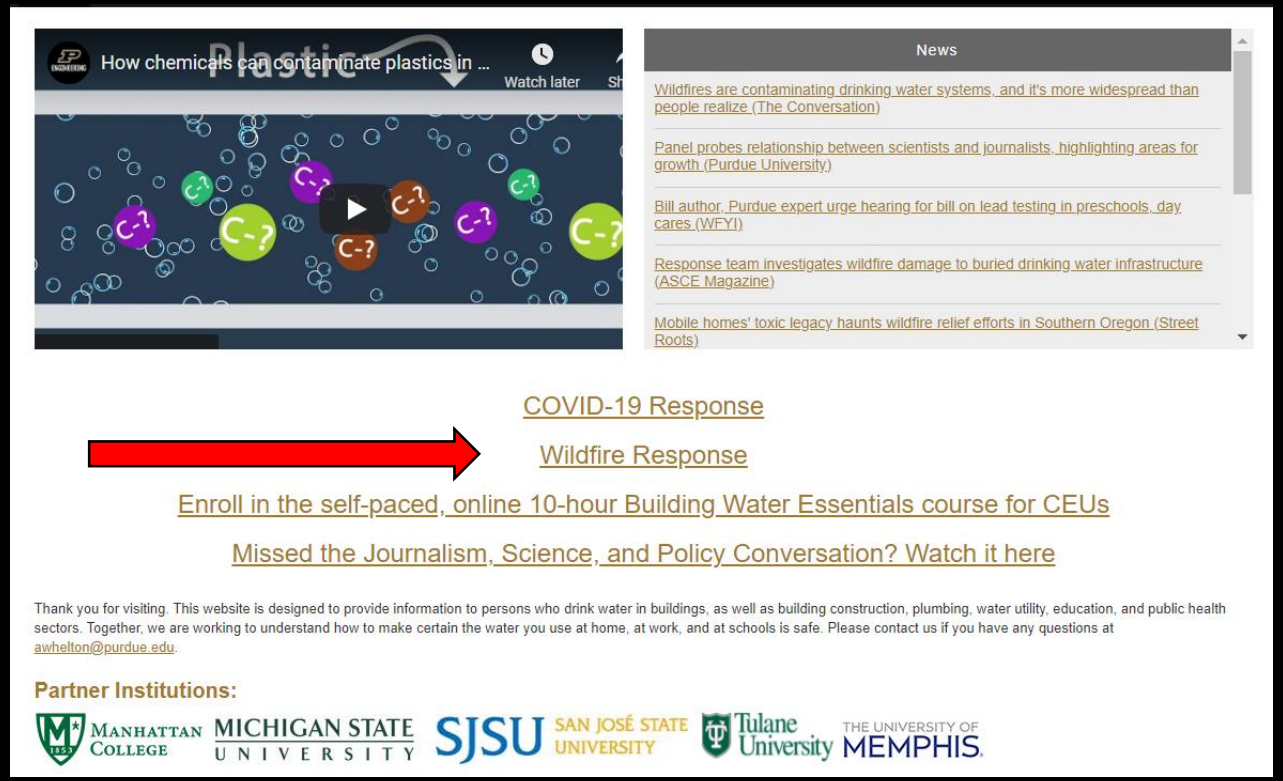
A few impact needs

1. What are the conditions that prompt drinking water system plastics to generate and leach VOC and SVOC contamination due to single brief and continued thermal exposure?
2. What are the rapid and most effective decontamination methods for returning contaminated infrastructure to safe use?
3. What is the evidence based decision making process for excessively contaminated water use and recovery?
4. Which post-contamination POU interventions can help reduce health risks and return plumbing to safe use?
5. How do we better train engineers and scientists so they don’t make bad decisions?

Many people have made this possible.

Thank you.

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



- ✓ Online short-course
- ✓ Plumbing education videos
- ✓ Flushing plans
- ✓ Plumbing explainers
- ✓ List of projects
- ✓ Scientific opinions
- ✓ Resources ➔ presentations
- ✓ Scientific reports
- ✓ External plumbing docs
- ✓ YouTube Channel

10 hr, 1 CEU, Self-paced, Online Building Water Essentials Short-Course:
https://engineering.purdue.edu/online/certifications/building-water-essentials

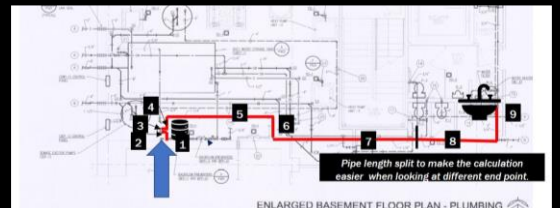
www.PlumbingSafety.org

Additional Information

NEW: Building Water Essentials – Public Health
10 Hour, Online Short-Course







Input from practicing engineers, scientists, utilities and public health officials.

A training tool, an encyclopedia, and an extensive FAQ, designed to be immediately applicable in the field.

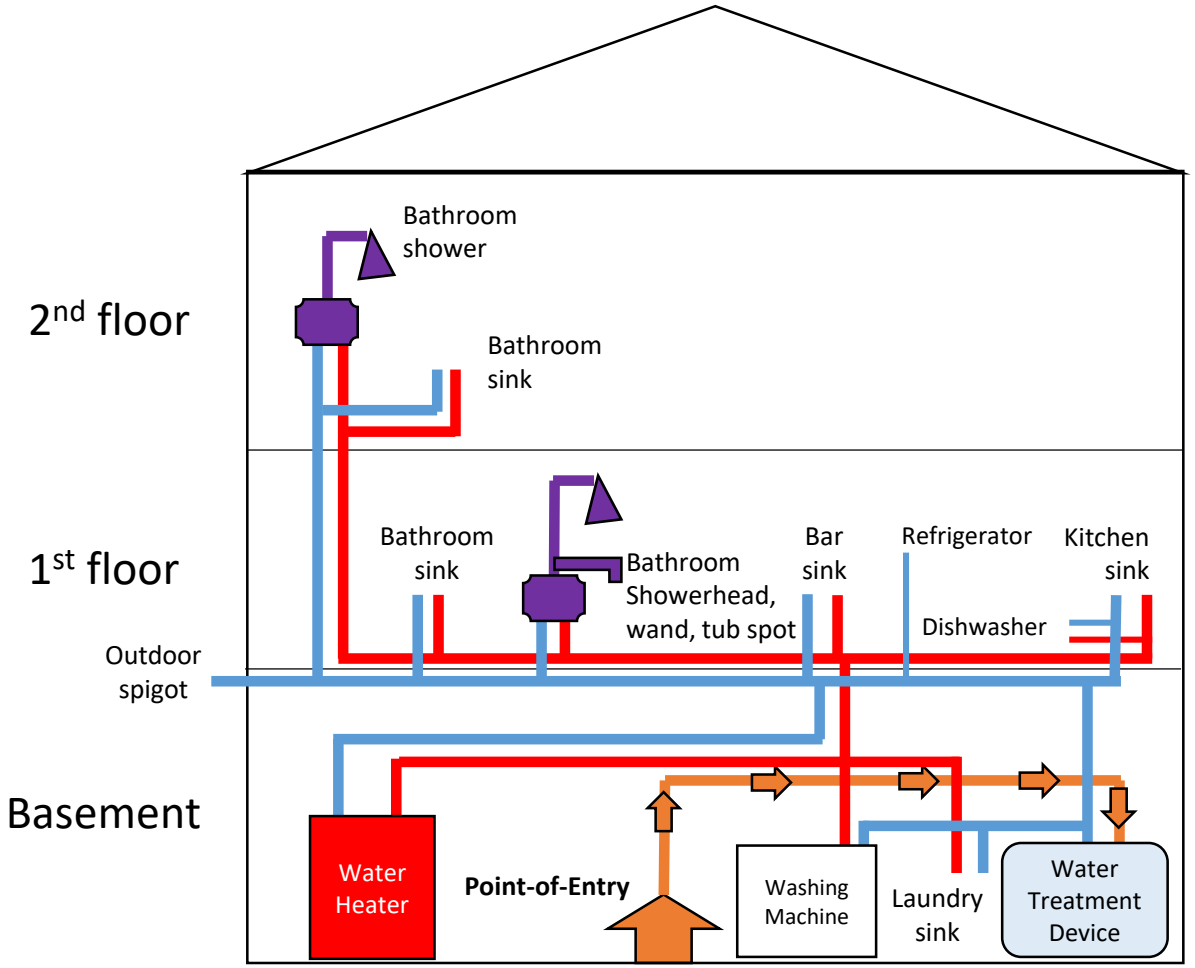
Modules do not have to be taken in sequence.




If interested e-mail awhelton@purdue.edu

Info and registration: https://cutt.ly/Sg4RXJv

Example single family home / trunk and branch design with a centralized water heater

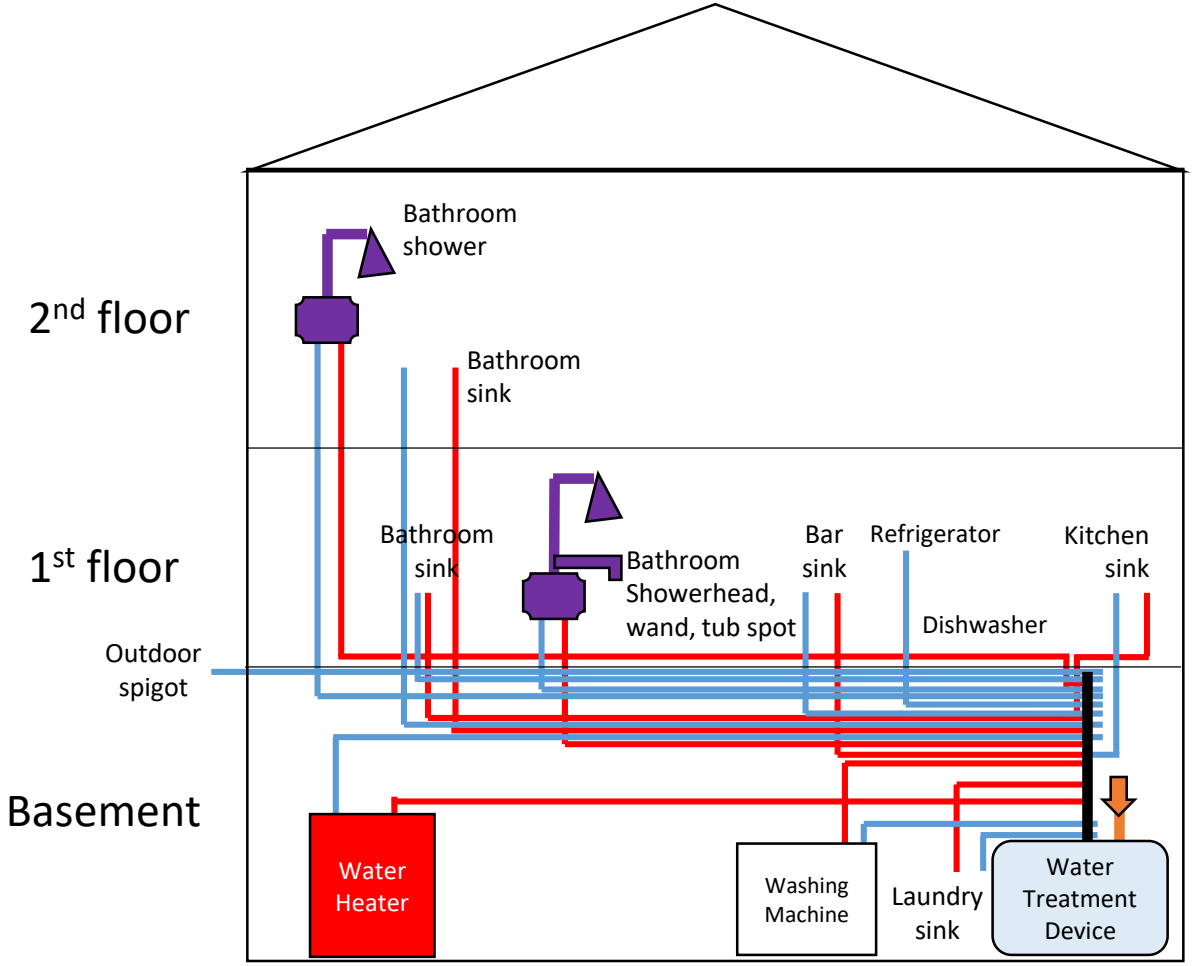


Cold and hot water flow through separate pipes

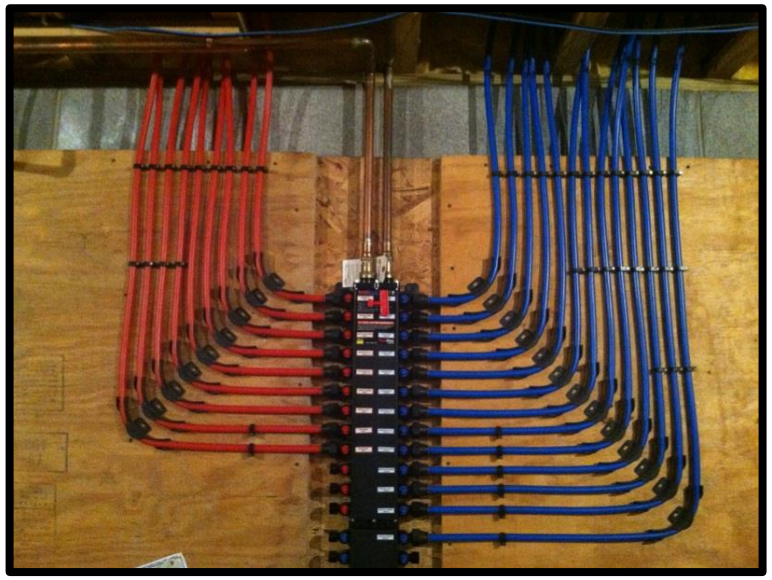
Some locations are downstream from others, but branch off into separate pipes

A whole house water treatment device may or may not be present

Example single family home / PEX manifold plumbing design and centralized water heater



Cold and hot water flow through separate pipes
Each fixture has it's own isolated pipe
No two pipes convey the same water
Co-located shutoff location for all each fixture
Smaller diameter pipes compared to T/B design



Household emergency water sources

- **Bottled water** donated; purchased at stores (cost to household)
- **Trucked in water** and fill cans at centralized locations
- **In-home water treatment** (capital cost $3k to $12k)
  - ***No, unless*** you know the type and range of concentrations entering buildings
  - NSF International certified devices are NOT designed for chemical disasters
  - Monthly validation testing recommended (reoccurring costs)
- **Water storage tank** connects to plumbing (cost $4k to $5k)
  - Deliver periodically (1x/2 weeks?); cost $200 to $500 twice per month
  - Are water haulers delivering confirmed safe water?
  - Who's monitoring water quality deterioration as water sits in tanks (sun)?

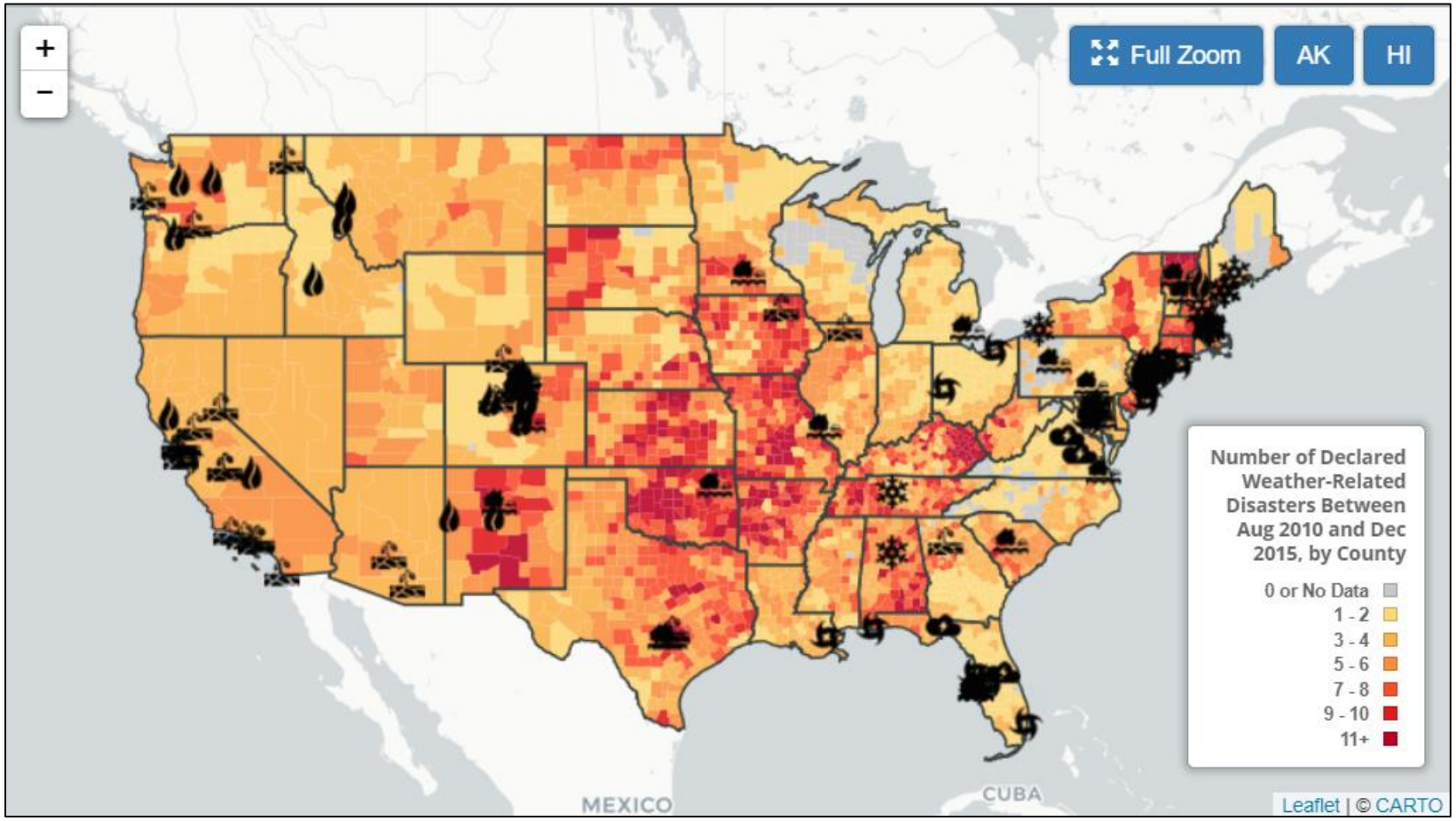
➢Don't forget pets, plants, livestock, and landscaping demands.

Plumbing component	Type of material
Service lines	Polyvinyl chloride (PVC), high-density polyethylene (HDPE), cross-linked …VC), copper, lead, multilayer pipes …arrier layers could be aluminum or
Piping and tubing	…temperature, copper, ductile iron, … steel, black steel, malleable iron, …stic layer–barrier layer–plastic layer; …ene vinyl alcohol)
Pipe and tank coatings	
Fixture fittings, valves, fittings	…ess steel
Gaskets	…and peroxide cross-linked], natural …eoprene
Water-heater specific	…nterior linings, magnesium, or
Domestic storage and cistern	…, HDPE
In-building treatment	…ers), plastic housing for sorbent or …ge resin, stainless steel
Small-diameter tubing for faucet conn… humidifiers, dishwasher supply, was… machine supply, in-building water treatment systems	…er, PVC, HDPE

Residential Systems

Service line (single vs. shared)
POE/POU devices
Central vs. on-demand water heaters
Recirculation loops
Irrigation
Mixing valves
Fixture types and internals
Faucet gaskets and aerators

Julien et al. 2020. https://doi.org/10.1002/aws2.1177



Wildfires
Droughts
Floods
Tornadoes
Snow & Ice
Tropical Storms
Severe Storms
Hurricanes

Natural disasters affect 1,000s of communities each year prompting microbial and chemical risks

EnvironmentAmerica.org

After the 2014 Freedom Industries Chemical Spill, we took a hard look at 'flushing' as a plumbing decontamination approach for water infrastructure decontamination

Decontaminating chemically contaminated residential premise plumbing systems by flushing

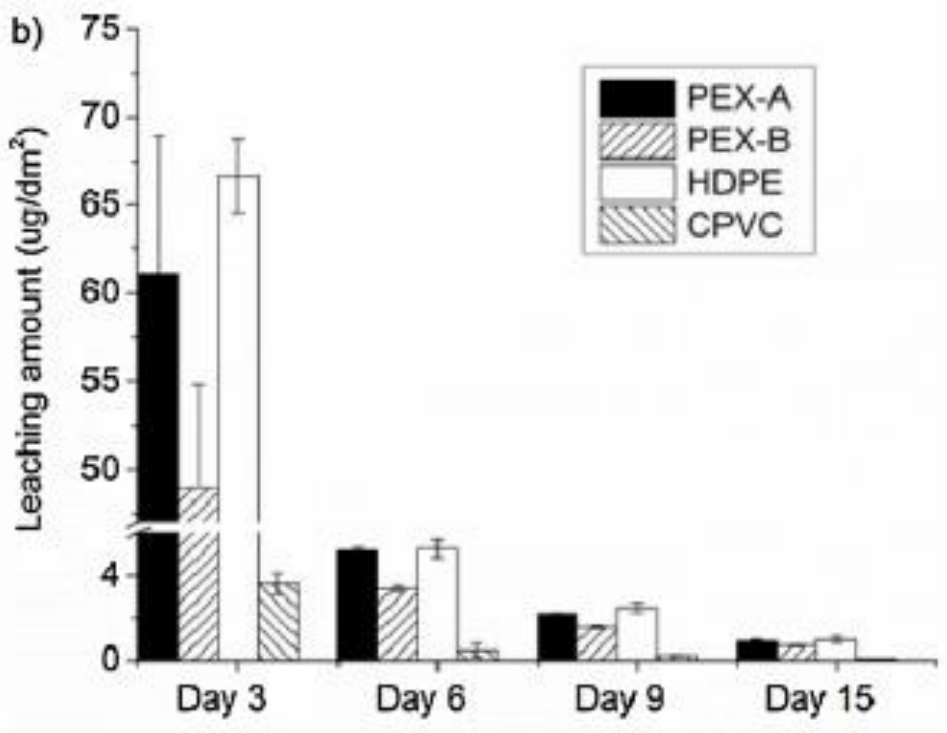
Download FREE here:

https://doi.org/10.1039/C5EW00118H

Minimal data available on flushing protocol design and effectiveness. Plumbing design, operational conditions, contaminants present and their properties, as well as building inhabitant safety have not been fully considered in flushing protocol design.

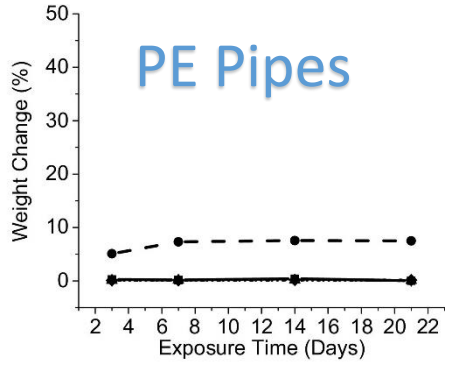
When you look back at U.S. incidents, flushing guidance for single family homes varied drastically, would likely not work, nor was it followed up with confirmatory sampling

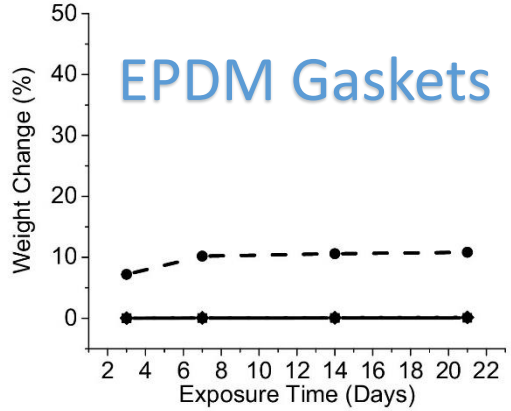
Also Not Considered: VOCs Diffuse In & Out of Plastic Plumbing Slowly

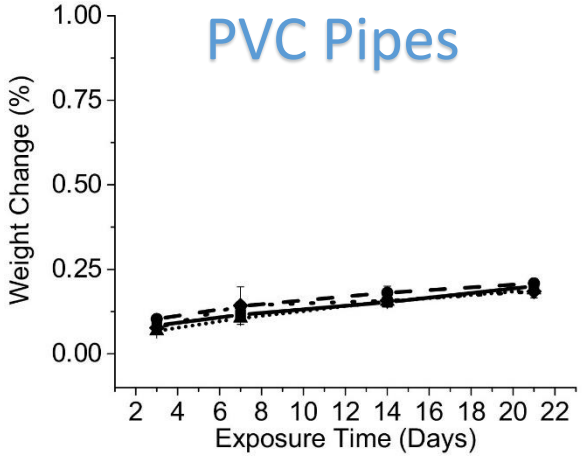


Huang et al. 2016. Crude oil contamination of plastic and copper drinking water pipes. https://doi.org/10.1016/j.jhazmat.2017.06.015

Also Not Considered: Surfactant-Plastic Interactions are Not Trivial





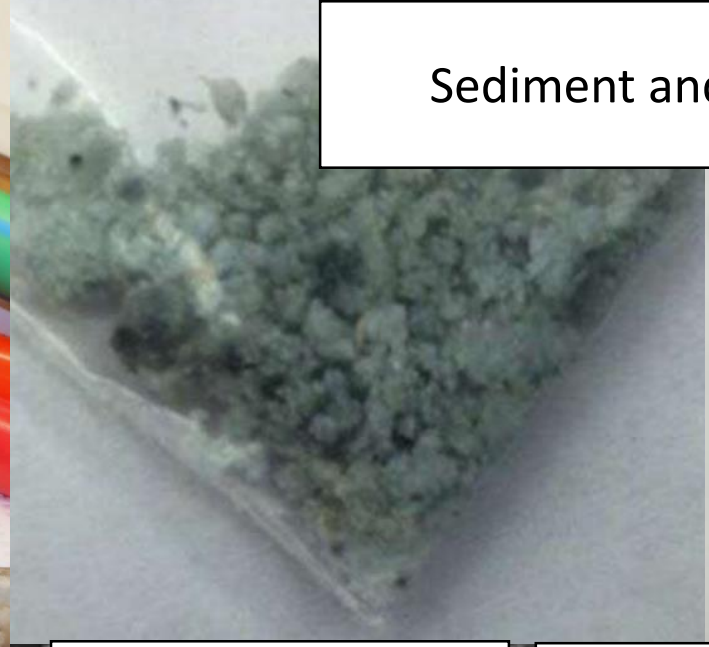


Surfactant Liquids

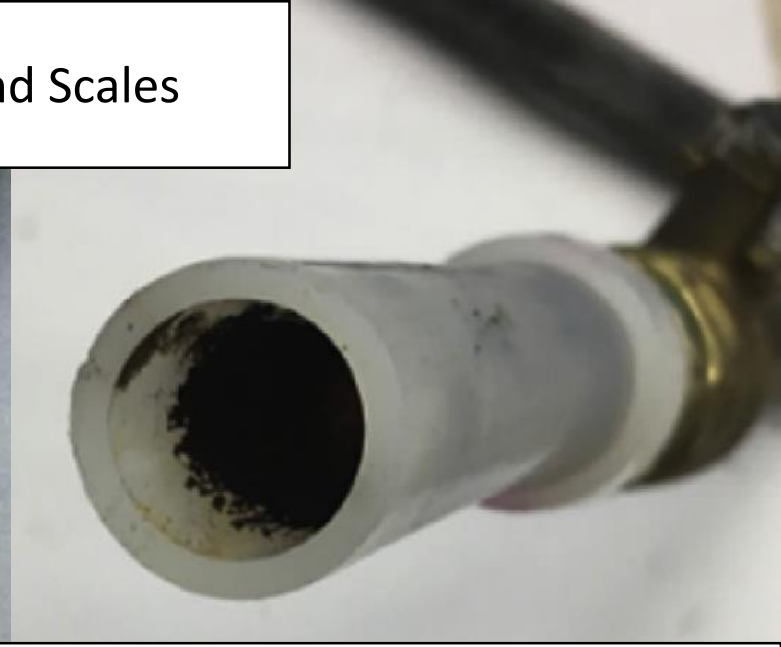
Alconox (●)
MAG (*)
Dawn (▲)
Tap (■)

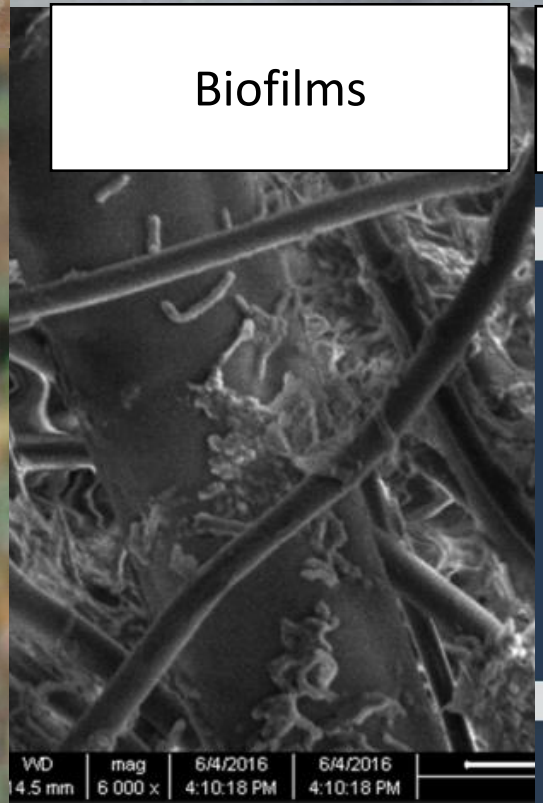
Casteloes et al. 2017. The interaction of surfactants with plastic and copper plumbing materials during decontamination. https://doi.org/10.1016/j.jhazmat.2016.11.067

Piping and Tubing Types, and Coatings



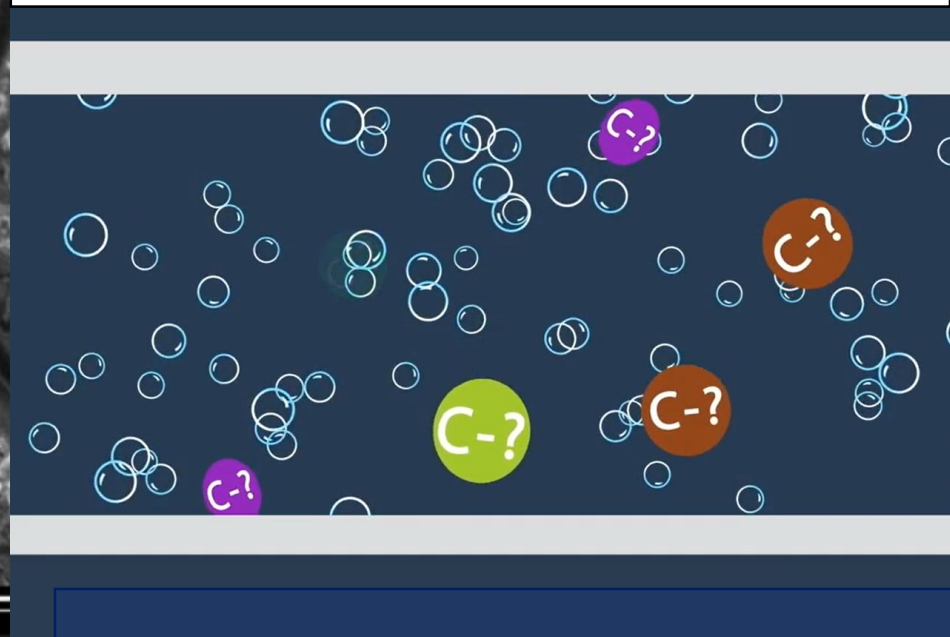
Sediment and Scales



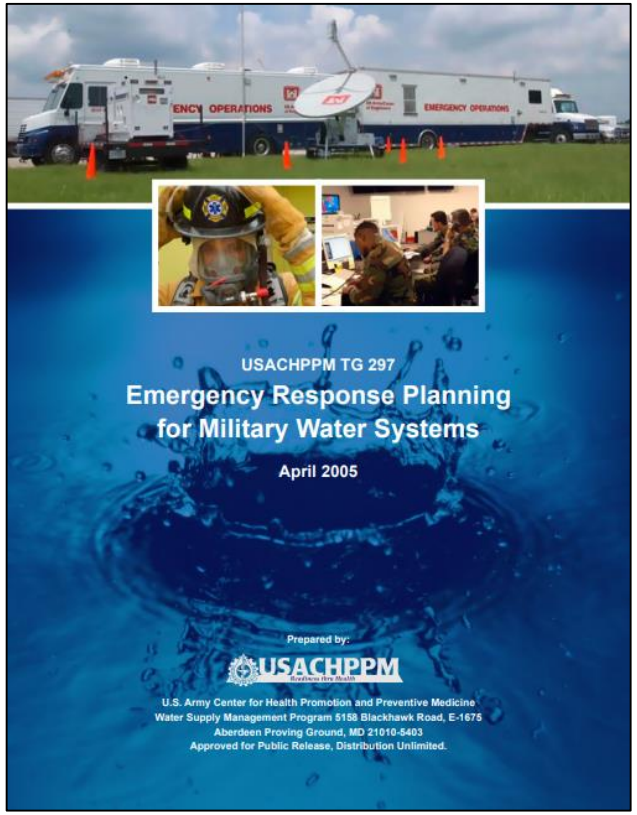


Biofilms

Plastics can Uptake Organic Chemicals



Looking back:



LESSONS LEARNED
from drinking water disaster and terrorism exercises

JournalAWWA

Whelton et al. 2006.
98 (8), 63-73.

16+ years ago with the US Army I was working on contamination/decontamination issues associated with water infrastructure systems

This project will to improve the understanding of how thermally damaged plastics contribute to the observed VOC and SVOC drinking water contamination post-fire, and propose response and recovery actions (CONOPS plans) that impacted utilities can implement.

EBMUD

LA DWP Los Angeles Department of Water & Power

CONTRA COSTA WATER DISTRICT

San Jose Water Company

WaterRF Project 5106: Post-Wildfire Distribution System Water Quality Impacts and Potential Responses (2021-Ongoing)