Plumbing: Disaster Response and Safe Water for Schools and Homes

Andrew J. Whelton, Ph.D.

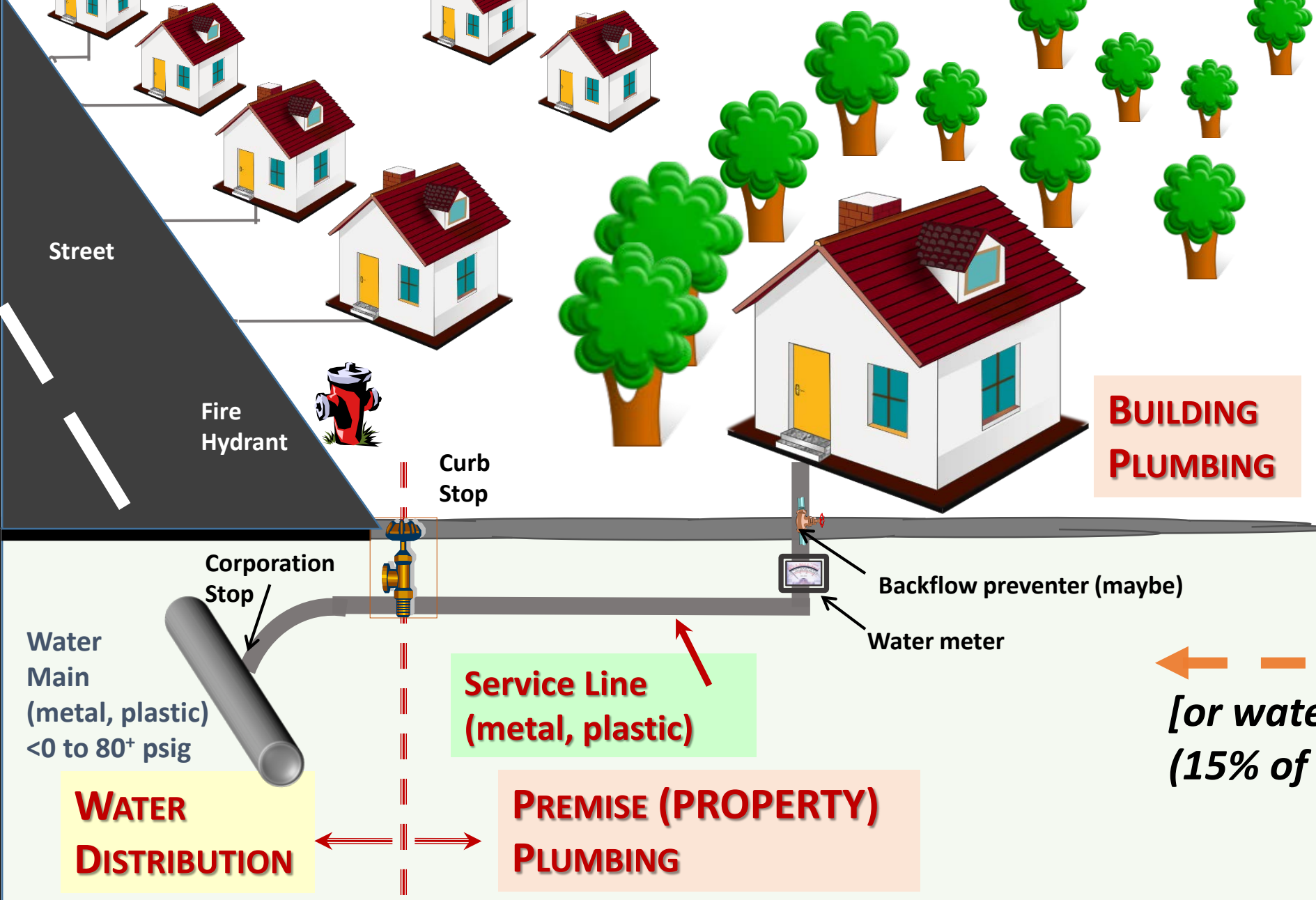
Purdue University

An Update of the National Priority Plumbing Study & Importance of Plumbing After a Disaster

More information here… www.PlumbingSafety.org

A Resource for All

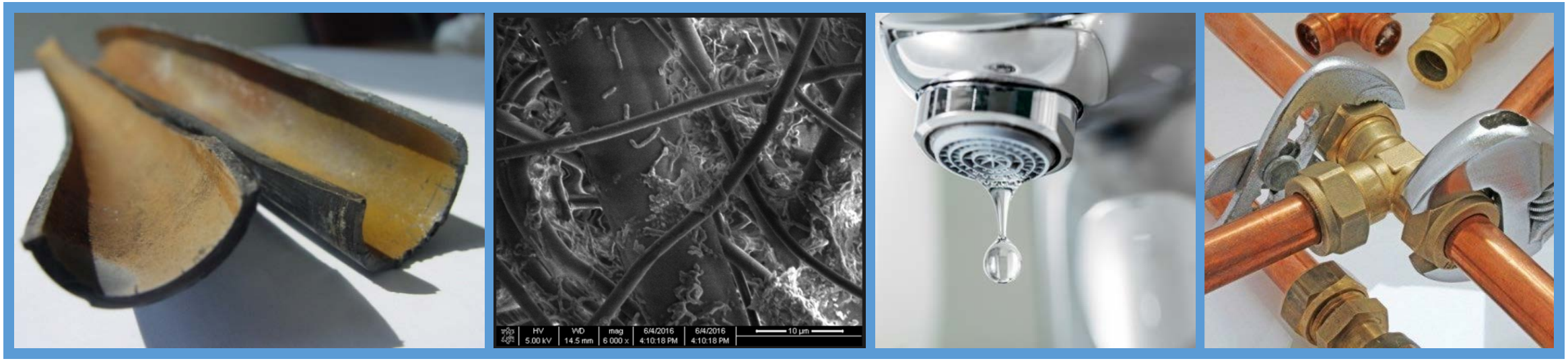
- ✓ Plumbing news
- ✓ Plumbing education videos
- ✓ Plumbing explainers
- ✓ List of projects
- ✓ Scientific opinions
- ✓ Scientific presentations
- ✓ Scientific reports
- ✓ External plumbing docs



Drinking water is critical for community health, safety, and economic security

[or water from a private well, (15% of US population)]

Right Sizing Tomorrow's Water Systems for Efficiency, Sustainability, and Public Health



Andrew Whelton, Jade Mitchell, Joan Rose, Juneseok Lee, Pouyan Nejadhashemi, Erin Dreelin, Tiong Gim Aw, Amisha Shah, Matt Syal, Maryam Salehi

PURDUE UNIVERSITY
MICHIGAN STATE UNIVERSITY
SJSU SAN JOSÉ STATE UNIVERSITY
MANHATTAN COLLEGE
Tulane University
THE UNIVERSITY OF MEMPHIS

Our USEPA Backed Study Goal and Objectives *Year 3 of 4*

To better understand and predict water quality and health risks posed by declining water usage and low flows

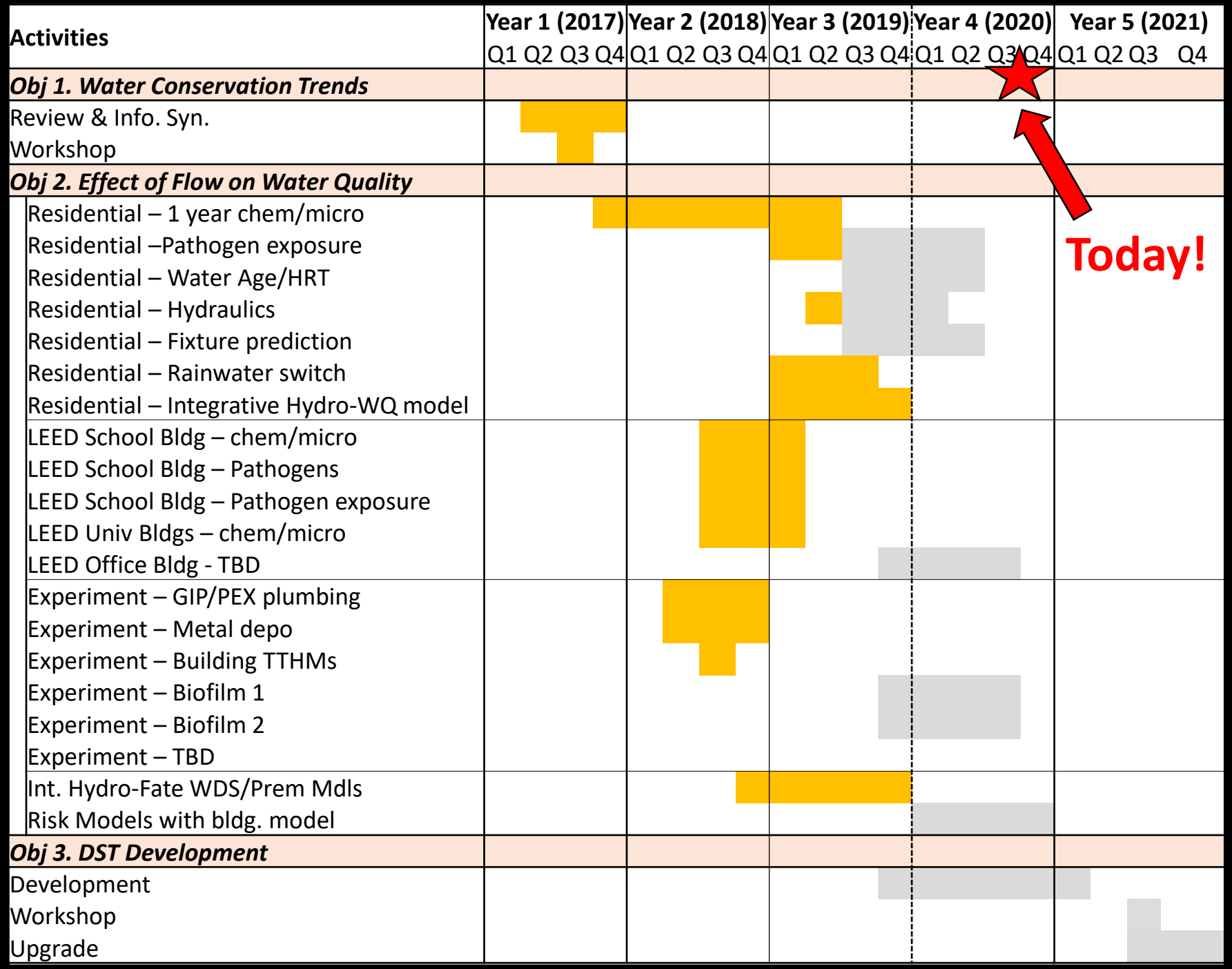
1. **Improve the public's understanding of decreased flow** and establish a range of theoretical premise plumbing flow demands from the scientific literature and expert elicitation with our strategic partners ***[done, continuing]***

2. **Elucidate the factors and their interactions that affect drinking water quality** through fate and transport simulation models for residential and commercial buildings ***[in progress]***

3. **Create a risk-based decision support tool** to help guide decision makers through the identification of premise plumbing characteristics, operations and maintenance practices that minimize health risks to building inhabitants ***[in progress]***

We've expanded the value of data being collected

15+ ongoing studies



Published, peer-reviewed scientific reports = 3

Corrosion of upstream metal plumbing components impact downstream PEX pipe surface deposits and degradation. *Chemosphere*. 2019. https://doi.org/10.1016/j.chemosphere.2019.07.060

Metal Accumulation in Representative Plastic Drinking Water Plumbing Systems. *Journal of the American Waterworks Association*. https://doi.org/10.5942/jawwa.2017.109.0117

Case Study: Fixture water use and drinking water quality in a new residential green building. *Chemosphere*. 2017. Available https://doi.org/10.1016/j.chemosphere.2017.11.070

Submitted, undergoing peer-review scientific reports = 8

Formal scientific opinions issued on emerging issues = 5 [2018 Camp Fire]

Delivered meeting presentations = 80+ [AWWA, NEHA, ASPE, USGBC, IAPMO, ACS, SRA, USEPA, and more]

Delivered public plumbing education training event = 1 [Camp Fire, 4000+ people reached]

Industry plumbing innovation event = 1

www.PlumbingSafety.org website visitors

2017: 1,790 visitors
2018: 3,325 visitors
2019 (so far): 7,853 visitors

Status Update

1. Spatial and temporal drinking water chemical quality variation in green residential plumbing, *Andrew Whelton,* ***Maryam Salehi*** *et al.*

National average: 83 m^3/season
CA study building: -50% national average
IN study building: 19.7-25.5 m^3/season

1 year, > 12 events/season

58 water sampling events

- ❑ Service line
- ❑ Kitchen sink cold/hot
- ❑ Bathroom sink cold/hot
- ❑ Water heater
- ❑ Shower

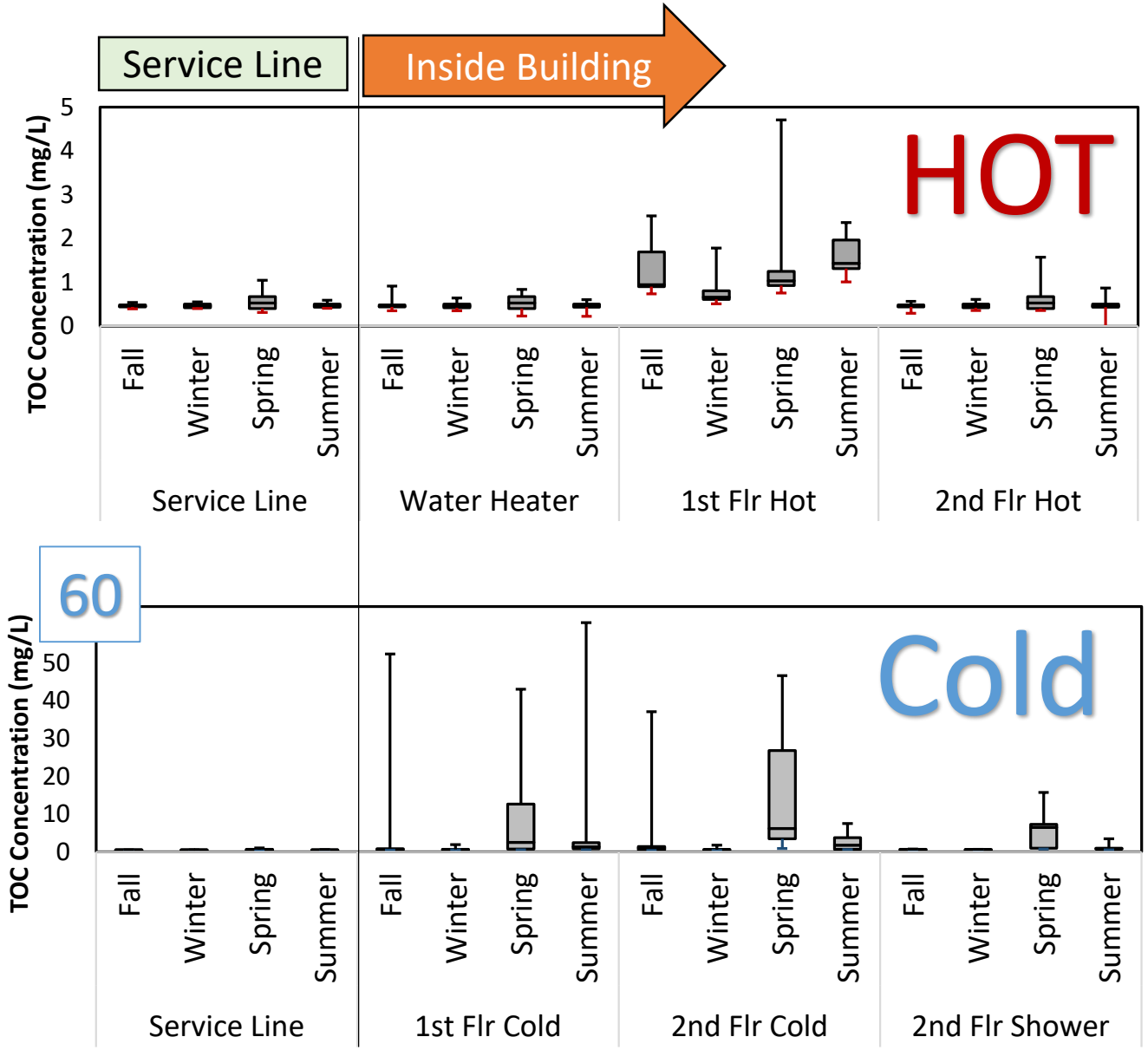
Online monitoring:

- ❑ Service line + every fixture: flow, temp., 1x/s, > 2.4 billion records

Single Family Home: Water at Service Line ≠ Water at the Tap

	Service Line	Cold Water Lines	Hot Water Lines	MCL[1] SDWR[2]
Water pH	7.65 –(7.73)– 7.81	7.43 –(8.17)– 9.24	7.35 –(8.18)– 9.01	6.5-8.5[2]
Total Chlorine (mg/L)	BDL –(0.7)– 1.6	BDL –(0.1)– 0.8	BDL –(0.3)– 1.7	State Dependent
Temperature (C)	11.5 –(18.0)– 23.8	19.1 –(22.1)– 27.4	17.2 –(22.3)– 27.9	N/A
TTHM (µg/L)	0.00 –(1.64)– 9.62	1.91 –(16.79)– 41.88	3.42 –(19.91)– 39.20	80[1]
TOC (mg/L)	0.32 –(0.41)– 1.05	0.40 –(3.92)– 46.7	0.49 –(0.94)– 4.71	N/A
Calcium (mg/L)	36.79 –(84.62)– 100.47	0.13 –(1.68)– 77.29	0.50 –(1.53)– 14.19	N/A
Iron (µg/L)	ND –(11.5)– 40.3	ND –(12.2)– 132	2.0 –(7.1)– 16.3	300[2]

Service line chlorine levels varied significantly during the day and throughout the week.



Typical TOC in water distribution systems
1-6 mg/L

TTHMs = pH, carbon, chlorine, temperature, stagnation time

[80 ug/L = MCL]

1. pH drastically increased, 7.5 to 9.4
2. Carbon came from utility water
3. Carbon leaching from new PEX pipe was pH and temperature dependent.
4. Carbon also present in biofilms
5. TTHMs increased in the building
   - < 4.8 ug/L entering building
   - Max 42 ug/L inside building (+89%)

❑ In-building TTHM levels were not predicted by 3 available models

2. Microbiology in a Water-Efficient Home: Stagnation, Seasonality, and Physiochemical Effects on Opportunistic Pathogen and Total Bacteria Proliferation, *Tiong Gim Aw, **Christian Ley**, et al.*

Service line water quality varied by season

Season	Range		
	Chlorine*, (mg/L)	TOC (mg/L)	HPC** (CFU/100mL)
Fall (13)	0.2 – 0.8	0.40 – 0.54	22 – 23,600
Winter (17)	ND – 1.6	0.40 – 0.56	ND – 11,700
Spring (12)	0.1 – 2.1	0.32 – 1.05	4.3 – 21,666
Summer (16)	ND – 0.8	0.41 – 0.59	18.3 – 11,366

**Chlorine detection limit = 0.1 mg/L*
*** HPC detection limit = 20 CFU/100mL*

Opportunistic pathogen survey of residential water system using qPCR

Location	*Legionella spp.*, % samples positive			*Mycobacterium spp.*, % samples positive		
	Sum.	Fall	Winter	Sum.	Fall	Winter
Service Line	12.5	30.8	14.3	87.5	38.5	37.5
Water Heater	100	100	50	100	92.3	87.5
Kitchen cold	100	61.5	62.5	100	69.2	87.5
Kitchen hot	100	84.6	75	85.7	76.9	75
Bathroom cold	100	69.2	50	100	69.2	75.0
Bathroom hot	100	92.3	87.5	100	69.2	87.5
Shower	100	92.3	100	100	76.9	100

Number of sampling events: Summer n=16; Fall n=13; Winter n=8

3. Prevalence of Opportunistic Pathogens in School Plumbing during Periods of Low Use and a Transition to Normal Use

Tiong Gim Aw, *Kathryn Jordan, Kyungyeon Ra, Christian Ley, Andrew Whelton*

- To better understand microbial water quality changes in a LEED-certified school building during low water use (Summer) and normal water use (Fall)
- The copper plumbed building contains water saving devices, hot water recirculation system, and receives chloraminated drinking water from a public water system.

For all water samples:

68% no disinfectant detected, **83%** contained free ammonia

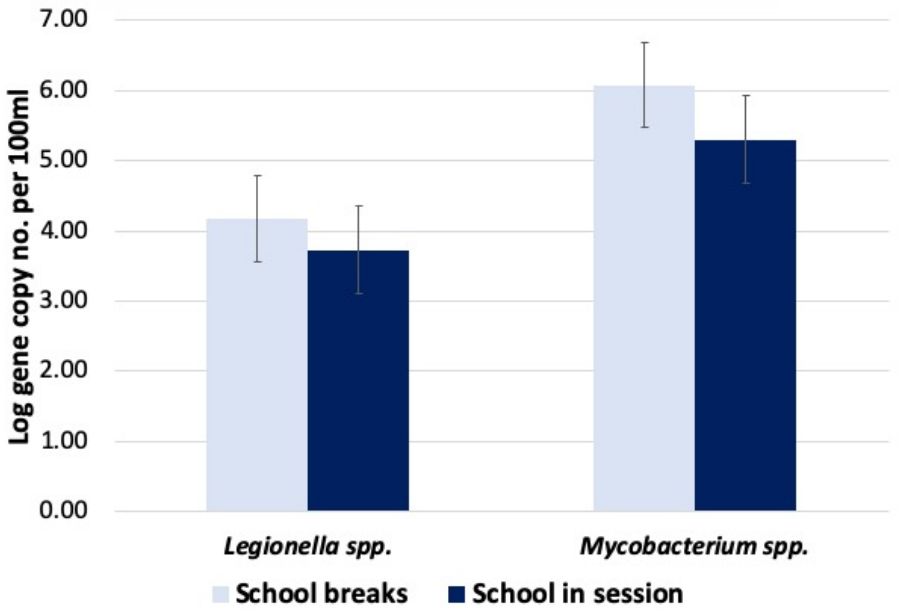
Opportunistic pathogen survey of school water systems using qPCR

Target organism	Occurrence rate (%)		Concentration (gene copy no. per 100ml)	
	Sites (n = 20)	Water samples (n = 120)	Highest	Average for positive samples
Legionella spp.	100	100	1.7×10^5	9.0×10^3
Legionella pneumophila	0	0	N/A	N/A
Mycobacterium spp.	100	100	2.2×10^7	5.0×10^5
Mycobacterium avium	95	75	2.1×10^6	4.9×10^4
Naegleria fowleri	0	0	N/A	N/A
Acanthamoeba spp.	70	17.5	6.0×10^5	6.3×10^2

Conclusions

- The presence of opportunistic pathogens in premise plumbing can be affected by the frequency of water use in a building.
- The rapid rate of disinfectant loss in green buildings due to high water stagnation needs to be better understood and addressed.

Comparison of average concentrations of *Legionella* and *Mycobacterium* in water systems under low vs. normal water use conditions



Significant difference: Conc. of *Mycobacterium* spp. and *Legionella* spp. between school breaks and when in session.

4. Legionella from Source to Exposure in a Complex Water System, ***Joan Rose*** *et al.*

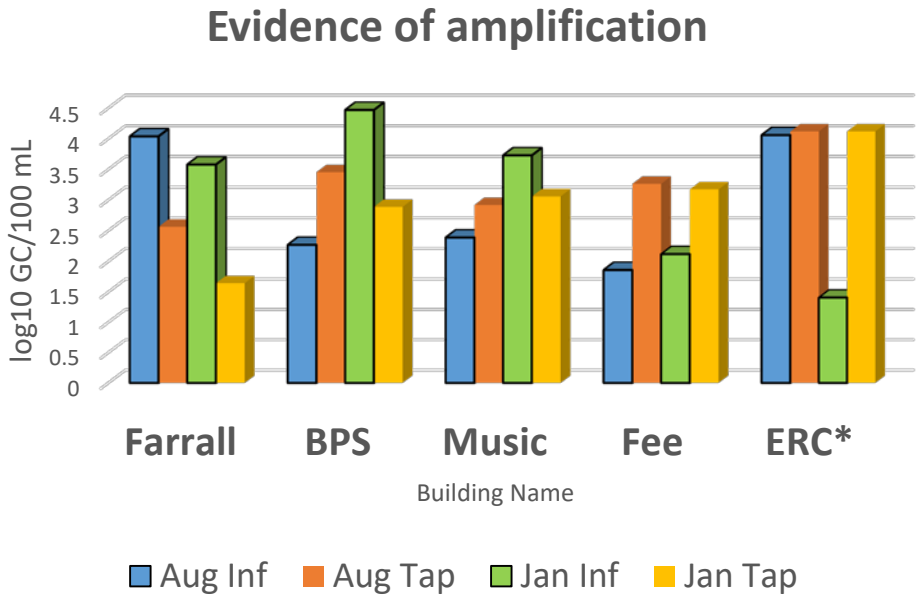
Goal: To evaluate the microbial water quality of academic buildings which have varying water residence times, use and chlorine residual.

Key Findings:

1. Legionella spp. are a consistent part of the water microbiome and growth was seen. Building ERC with furthest distance from reservoir had distinguishable water quality from closest building (Farrall), not related to water use.
2. *Legionella pneumophila* positive twice. Concentrations: 1.46 $\log_{10}$ CFU/mL, 1.99 $\log_{10}$ CFU/mL

Prevalence of Legionella spp. 23s gene in MSU building water samples

n = 14 (100% positive)



5. Exploratory Data Analysis to Evaluate Relationships between Water Quality Parameters and Water Usage, ***Ryan Julien***, *Jade Mitchell*

- Evaluated correlations of 12 WQ parameters and 3 use metrics
- Principal Component Analysis (PCA) used to identify most influential variables
- General Linear Model (GLM) applied to predict *Legionella* concentrations

	pH	Temp	DO	Total.Cl	Free.Cl	TOC	DOC	Alka	TTHM	TCC	HPC	Leg.sp	vol.events	num.events	MTSL
pH	1														
Temp	0.09	1													
DO	-0.30	-0.40	1												
Total.Cl	-0.20	-0.51	0.27	1											
Free.Cl	-0.18	-0.41	0.22	0.79	1										
TOC	0.19	0.49	-0.42	-0.35	-0.25	1									
DOC	0.16	0.53	-0.45	-0.42	-0.27	0.97	1								
Alka	0.07	0.31	-0.14	-0.21	-0.12	0.36	0.35	1							
TTHM	0.24	0.20	-0.34	-0.29	-0.33	0.65	0.62	0.32	1						
TCC	-0.06	0.48	-0.23	-0.28	-0.14	0.53	0.56	0.56	0.26	1					
HPC	0.19	0.46	-0.35	-0.30	-0.16	0.61	0.60	0.50	0.37	0.70	1				
Leg.sp	0.14	0.39	-0.04	-0.47	-0.32	0.59	0.57	0.54	0.38	0.56	0.66	1			
vol.events	-0.11	-0.27	0.34	0.18	0.15	-0.57	-0.57	-0.16	-0.47	-0.16	-0.24	-0.27	1		
num.events	-0.19	-0.29	0.37	0.16	0.04	-0.53	-0.53	-0.12	-0.31	-0.19	-0.40	-0.41	0.75	1	
MTSL	0.18	0.34	-0.39	-0.21	-0.07	0.53	0.54	0.14	0.30	0.23	0.42	0.44	-0.74	-0.99	1

Legionella:

+ HPC, TCC, water age, alkalinity
- Number of usage events, total chlorine

Older water implies:

Lower DO and disinfectant levels
Higher carbon, TTHM, alkalinity, and bacteria

Water age is not directly measureable

Developing a model to estimate water age for residential plumbing more accurately

# of usage events ≠ volume of events ≠ elapsed time between events (MTSL)≠ hydraulic residence time≠ water usage/water age

6. Risk assessment for opportunistic pathogens in non-ingestion exposure scenarios, *Jade Mitchell,* ***Kara Dean***

- Regular way…Forward Method:

  Concentration in the Water → Risk of Infection

- Reverse Method:

  Infection risk level → Conc. in the Water

  Steps:

  1. Select risk of infection of concern → 10^{-4}
  2. Calculate exposure dose based on *dose response models*
  3. Parameterize exposure model based on systematic literature reviews
  4. Create distributions for the parameters with a Monte Carlo sampling method and 10-100,000 iterations
  5. Determine concentration in the water responsible for known risk of infection

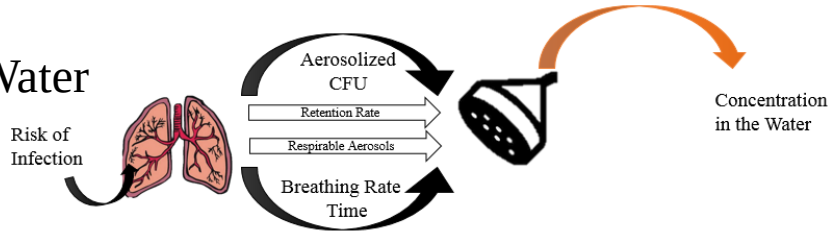


Figure 1: Flowchart of the Reverse QMRA Calculations for a Showering Event

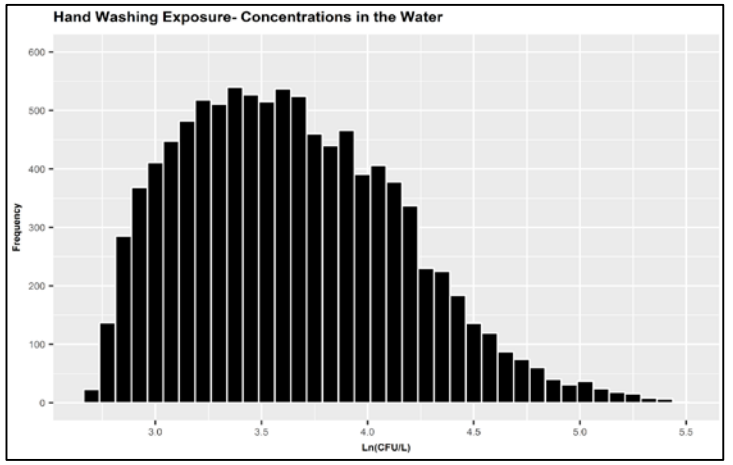


Figure 2: The model generates a distribution of concentrations responsible for a 1:10,000 risk level for a hand washing event (eye-touch event after)

- *Pseudomonas aeruginosa* causes keratitis [eye infection] in healthy individuals and lung infections in immunocompromised individuals
  - The risk assessment evaluated a showering, face washing and hand washing exposure scenario
- *Legionella pneumophila* causes Legionnaire's disease and Pontiac Fever (pneumonia-like infections)
  - The risk assessment will evaluate the distribution of risk in a locker room environment where multiple showers are generating aerosols at onc

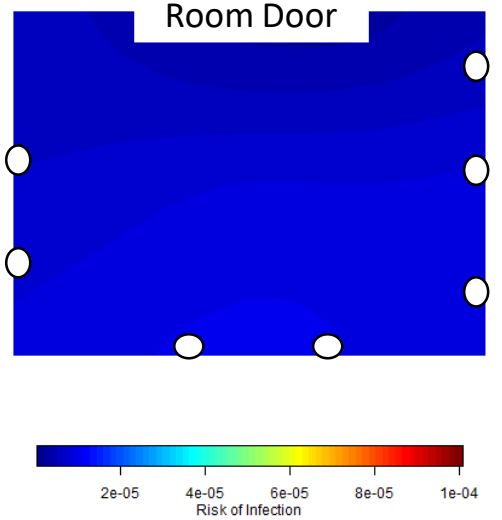


Figure 3: Distribution of risk in a square shower room with seven showers (⬭) as concentrations of *L. pneumophila* increase in the water

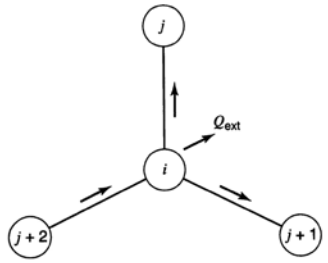
7. Integrative Hydraulic & Water Quality Modeling,

Juneseok Lee et al.

Hydraulics (Steady | Extended Period)

Continuity Equation

$$\sum Q_{in} - \sum Q_{out} = \sum Q_{ext}$$

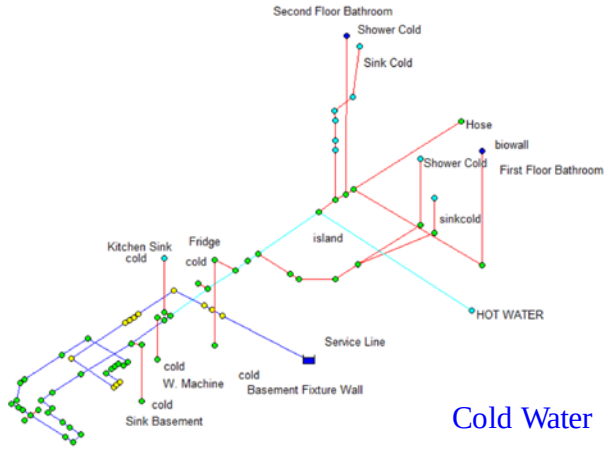


Energy Equation

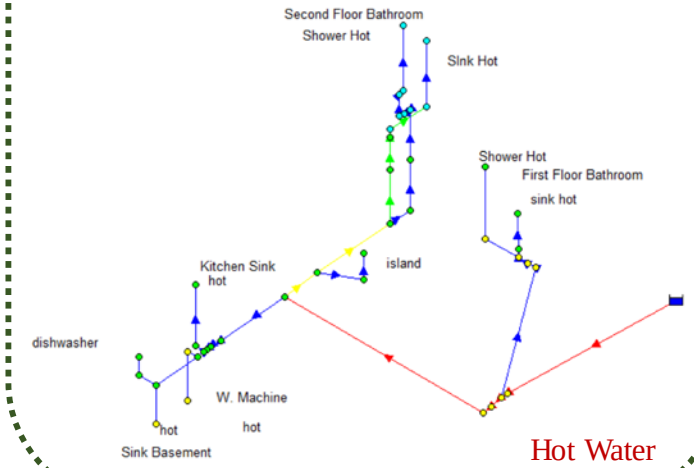
$$\sum_{i,j \in I_p} h_{L_{i,j}} - \sum_{k \in J_p} H_{pump,k} = 0$$

Multi-species modeling

- Free Chlorine (FC) $\frac{d(Free\_Chlrorine)}{dt} = -K_c(Free\_Chlrorine)$
- HPC/DOC $\frac{d(HPC)}{dt} = -K_{h1}(Free\_Chlorine) + K_{h2}(DOC)$
- TTHM $\frac{d(TTHM)}{dt} = -K_{TTHM}(Free\_Chlrorine)$
- Legionella (LEG) $\frac{d(Legionella)}{dt} = K_l(HPC);$



Cold Water



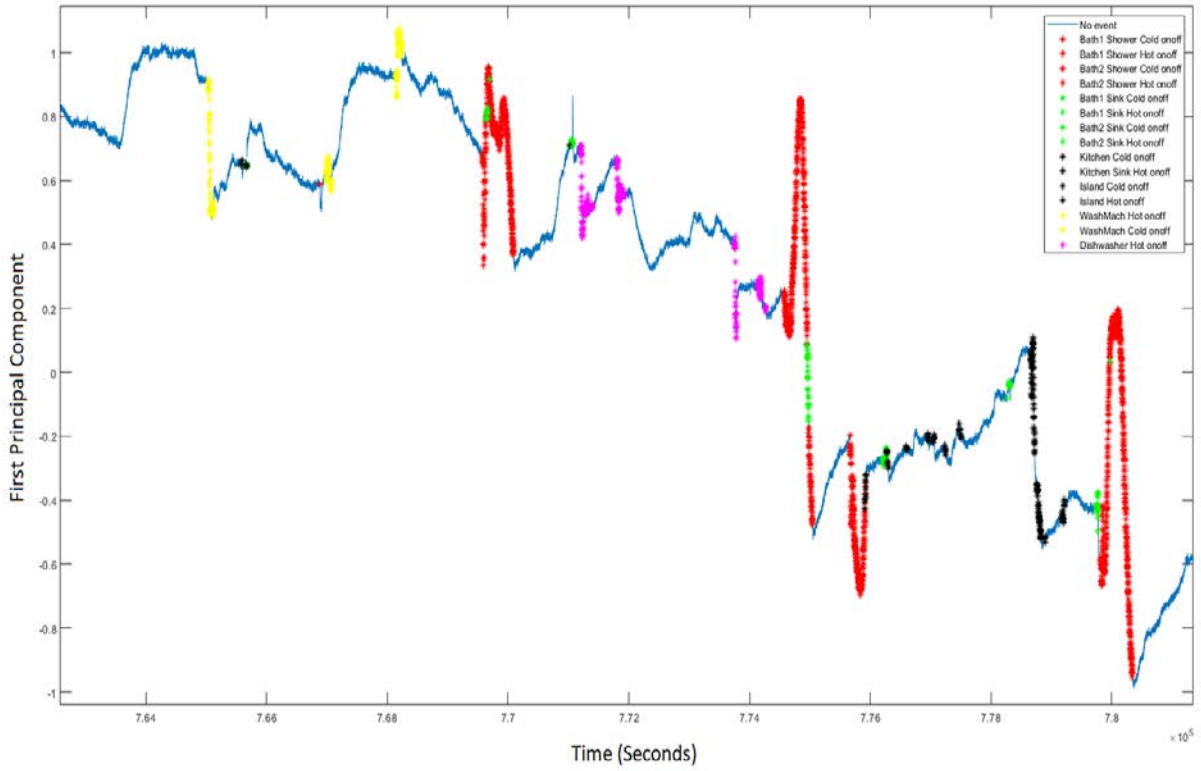
Hot Water

Development of Calibrated Model

Probability Density Functions for HPC, Legionella, TTHM, and Chlorine

8. Predicting Fixture Events Through Upstream Features, *A. Pouyan Nejadhashemi*, ***Ian Kropp***

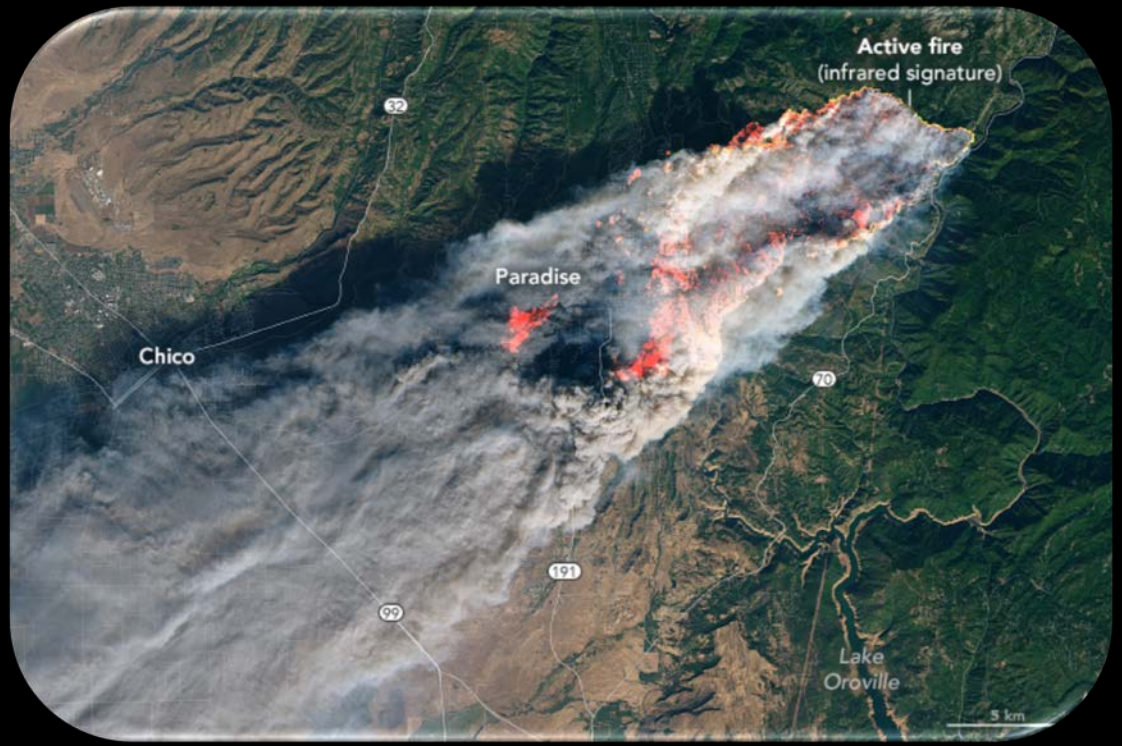
- Compiled the seven separate time series (sensors) into a single time series
- Principal Component Analysis (PCA) used to identify most significant component
- Data is separated by fixture type
- Applied Density-based spatial clustering of applications with noise (DBSCAN) to the time series to discretize the flow events
- Classification with support vector machines (SVM)
- Accuracy 99% using the linear SVM



Artificial intelligence applied to plumbing safety

Implications for Health: Plumbing Contamination After a Disaster

November 8, 2018 (1 year ago)
Camp Fire, Butte County, California



Disasters can Trigger Widespread Drinking Water Contamination

The deadliest most destructive wildfires

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

In California, 2.7+ million people live in very high fire hazard severity zones

Wildfire risk is growing

The 2018 Camp Fire – Deadliest and Most Destructive

Executive Department
State of California

November 8, 2018

Proclamation of a State of Emergency

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

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

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

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

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

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

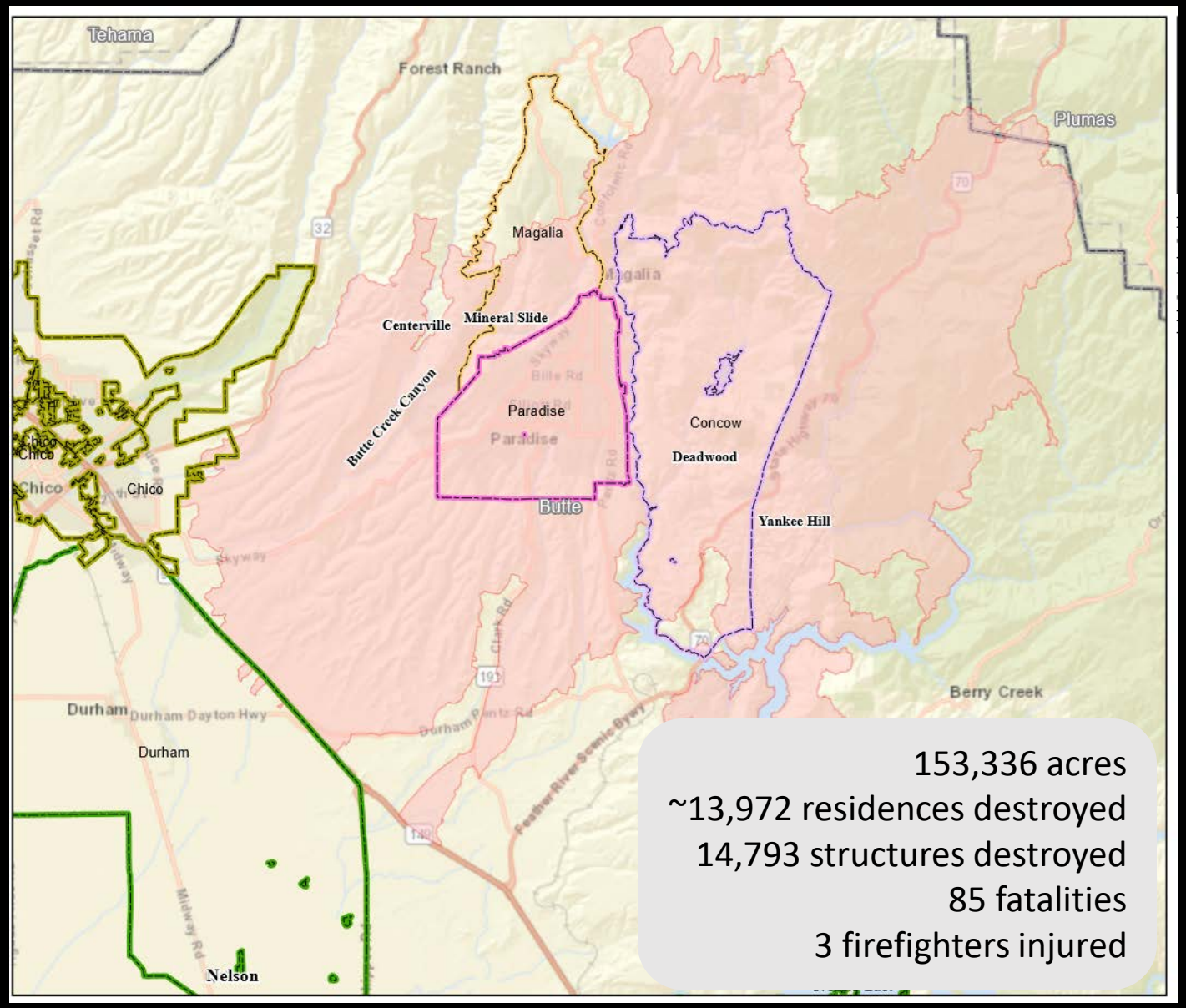
WHEREAS under the provisions of Government Code section 8558(b), I find that conditions of extreme peril to the safety of persons and property exists in Butte County due to this fire; and

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

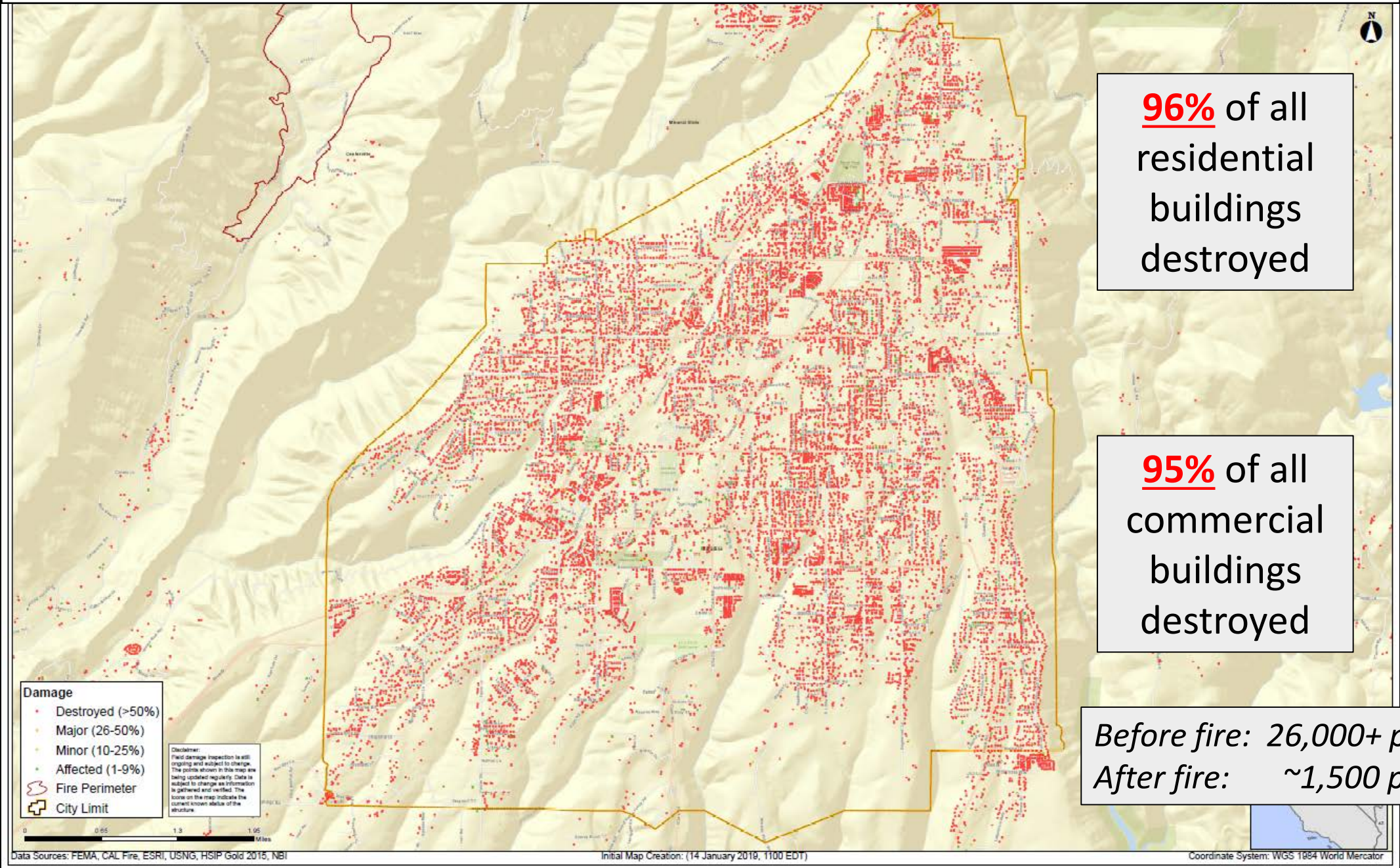
NOW, THEREFORE, I, GAVIN NEWSOM, Acting Governor of the State of California, in accordance with the authority vested in me by the State Constitution and statutes, including the California Emergency Services Act, and in particular, Government Code section 8625, **HEREBY PROCLAIM A STATE OF EMERGENCY**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

IT IS HEREBY ORDERED THAT:

1. All agencies of the state government utilize and employ state personnel, equipment, and facilities for the performance of any and all activities consistent with the direction of the Office of Emergency Services and the State Emergency Plan. Also, all citizens are to heed the advice of emergency officials with regard to this emergency in order to protect their safety.
2. The Office of Emergency Services shall provide local government assistance to Butte County, if appropriate, under the authority of the California Disaster Assistance Act, Government Code section 8680 et seq., and California Code of Regulations, Title 19, section 2900 et seq.



Town of Paradise Limits



96% of all residential buildings destroyed

95% of all commercial buildings destroyed

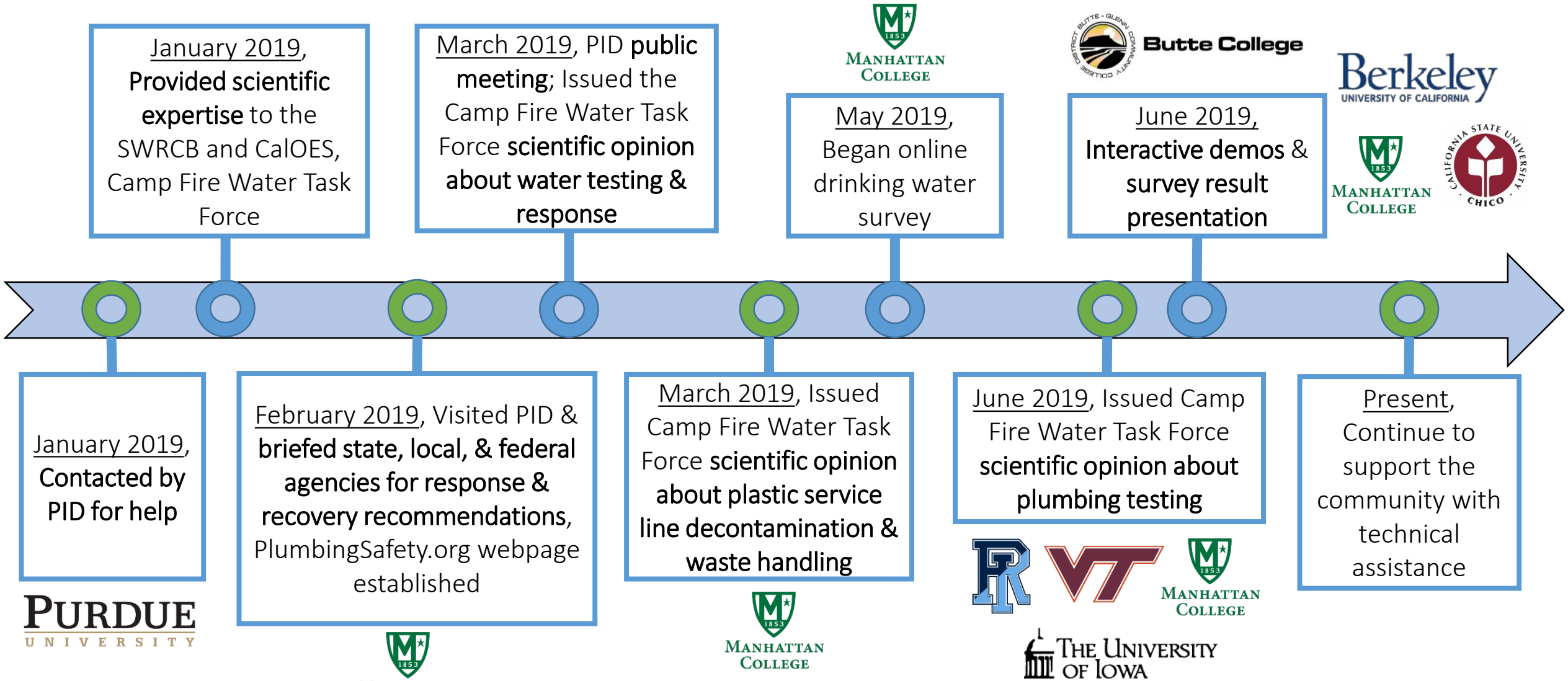
Before fire: 26,000+ people
After fire: ~1,500 people

Some meters did not survive

Fire Speed: 60 football fields per minute

Some HDPE plastic service lines melted, decomposed, and cooled

Our Assistance with Partners



Severity: Water Distribution System Impacts

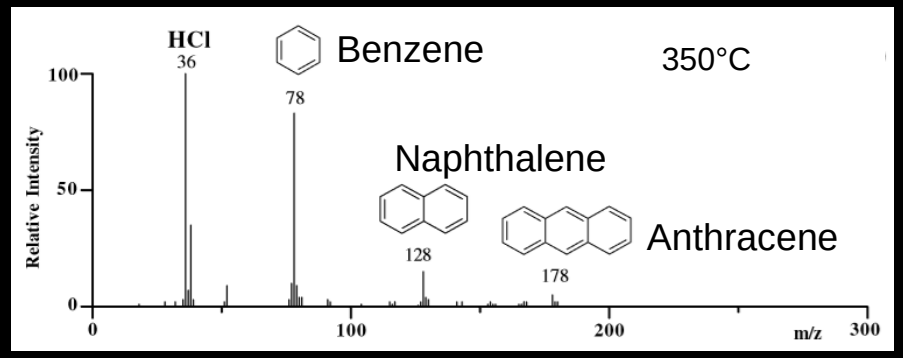
500 ppb benzene - Federal RCRA hazardous waste limit

Chemical that Exceeded a Drinking Water Limit	2018 Camp Fire (6 months after the fire)				Tubbs Fire (11 months after the fire)		
	PID	Del Oro	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

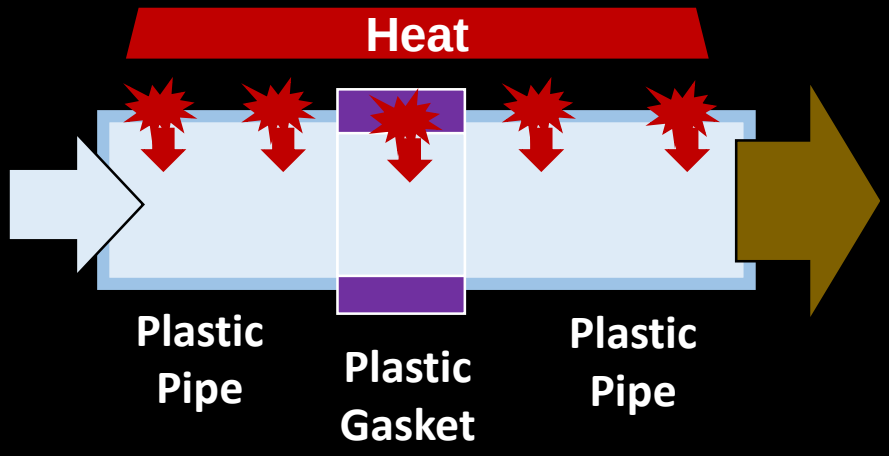
Long-term limit for an adult for 70 years
Short-term (1 day) limit for a 1 year old child

NA = Results were not available

1. Plastic Pyrolysis



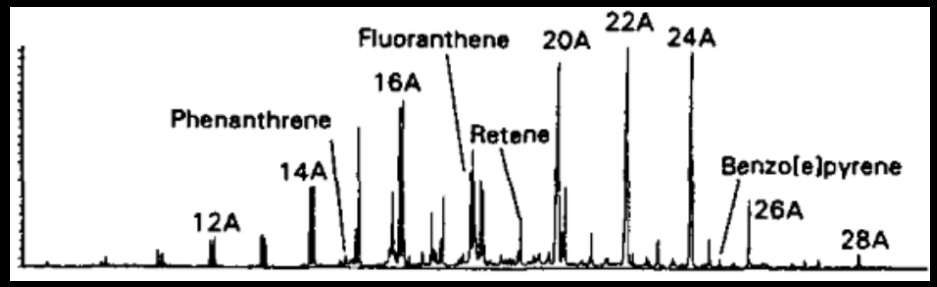
Montaudo & Puglisi (1991)



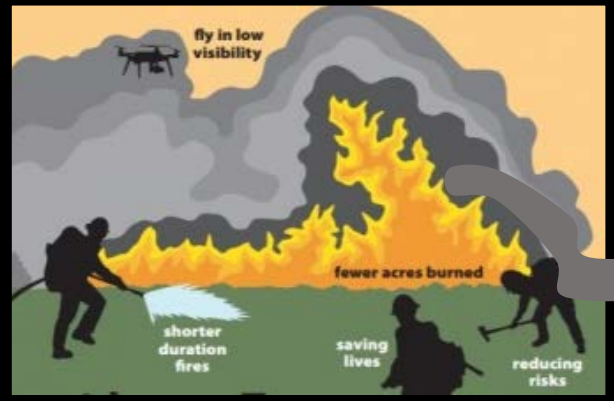
VOCs
SVOCs

Benzene
Naphthalene
Toluene
Styrene
Xylenes
Benzo[a]pyrene
and more…

2. Forest Biomass Combustion



Simonet et al. (1999)



Standing Home Public Health Implications

Water use advisories [Citizens weren't adequately protected]

- 2 DOWC systems contaminated, but no water advisory
- Some PID customers not following water use restrictions
- April 2019 OEHHA analysis showed 26 to 1000^{+} ppb benzene posed an acute exposure risk (Max. >2,217 ppb in PID, 530 ppb DOWC)

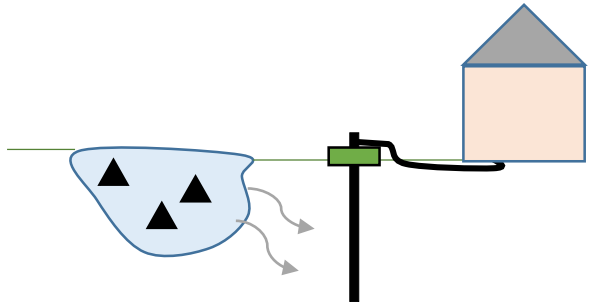
Contaminated water was entering and continues to enter homes

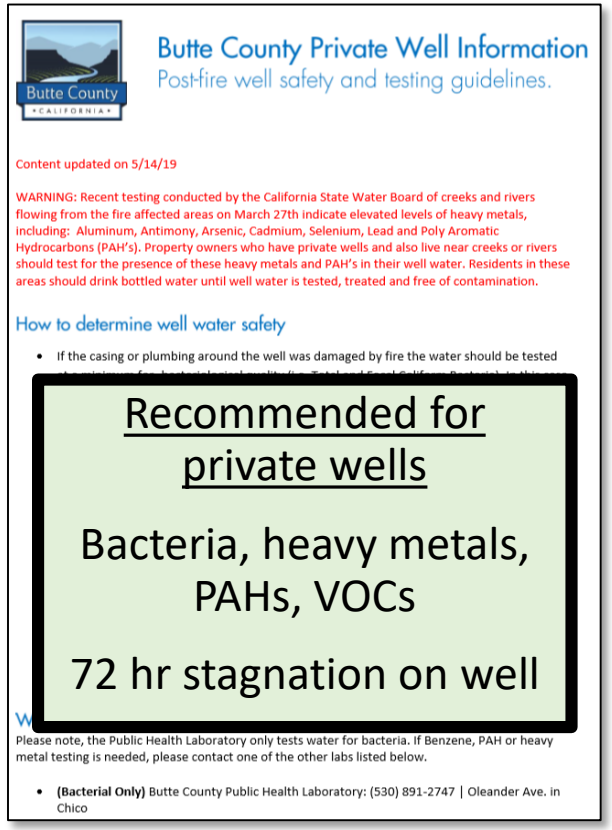
- Utilities still trying to identify their contaminated assets
- Loss of pressure (main break, leak) *could move* contaminated water into a standing home service line

Plumbing has received >6 months of contaminated water

Cold and hot water systems [Now declared nonpotable]
Trunk-and-branch vs. homerun designs
In-home treatment devices
Paying for water testing, results not representative
No credible plumbing testing guidance
Irrigation system contamination
External water tank maintenance and microbiological growth
Some have no economic capacity to purchase bottled water, devices

Insurance companies making decisions about in-home treatment





Butte County Private Well Information

Post-fire well safety and testing guidelines.

Content updated on 5/14/19

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

How to determine well water safety

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

Recommended for private wells

Bacteria, heavy metals, PAHs, VOCs

72 hr stagnation on well

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

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

More Standing Home Inhabitant Challenges

Want to sample their plumbing… but being told to follow lab directions that flush out their plumbing BEFORE sampling.

Commercial Laboratory: "When sampling from a tap, open the tap and allow the system to flush until the water temperature has stabilized (usually about 10 minutes)."

Want to sample their plumbing… but being told to *only* look for benzene at the cold water kitchen sink (no stagnation needed).

This ignores hot water systems, along with basics of plumbing design, operation, chemical desorption, and more.

Many unaware the SWRCB recommended any damaged property have the customer-side service line replaced to Butte County

Estimated $1,000-$7,000 cost per home. Insurance may or may not pay.

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

1 utility alone: Initial estimated removal/replacement cost: $300 million

The County and 1 public utility issued DND-DNB water use restrictions to protect population, but State and 1 private utility said that same water was safe [It wasn't]

A Few Lessons Learned

- State and 1 private utility said that if water doesn't have an odor, it is safe [WRONG]
- Some laboratories incorrectly told survivors how to collect water samples
- Rapid health risk assessments needed, CA OEHHA warned 26 ppb was an acute risk
- More than benzene exceeded acute and chronic exposure limits
- When benzene not present other VOCs exceeded drinking water exposure limits
- State conducted testing on State employees using the contaminated drinking water - documented acute chemical exposure symptoms
- State found lab reproducibility issue: ± 287% benzene difference in duplicates
- Plumbing testing guidance bungled by State, at least 1 Commercial Lab, some Home Water Treatment Companies, at least 1 Insurance Company
- Insurance companies hired "experts". 1 said they didn't believe in or use stagnation

WELCOME

DRINKING WATER AND PLUMBING AFTER THE CAMP FIRE

4 – 6 pm: **Interactive demonstrations of drinking water sampling, testing, and plumbing**

6 – 7pm: **Break**

7 – 8:30 pm: **Purdue University Camp Fire Drinking Water Survey Results**

Hosted by

PURDUE UNIVERSITY

MANHATTAN COLLEGE

Financial support provided by the Paradise Rotary Foundation

Paradise Rotary Foundation

In collaboration with

Butte College

CAMP FIRE ZONE PROJECT

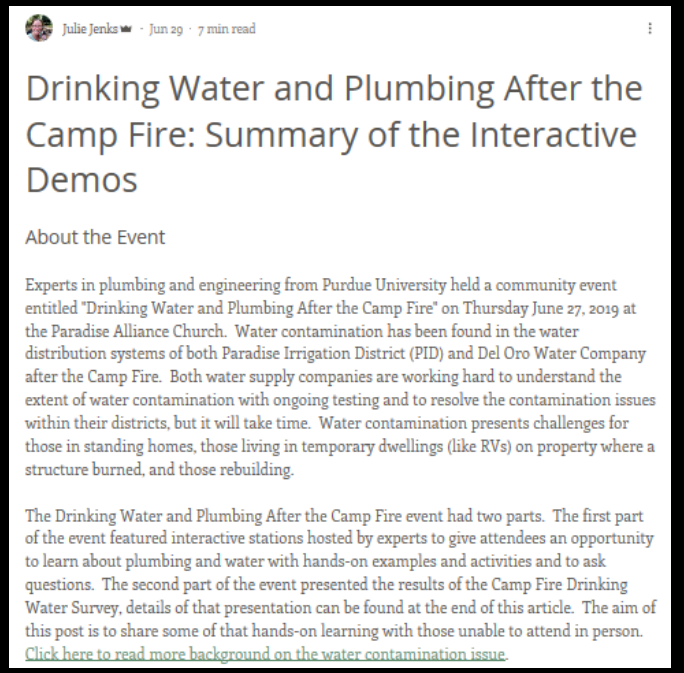
School of Public Health
UNIVERSITY OF CALIFORNIA, BERKELEY

CALIFORNIA STATE UNIVERSITY CHICO

Live stream 7-8:30PM at https://m.facebook.com/campfirezoneproject

Paradise Alliance Church, June 27, 2019, Paradise, California

After drinking water contamination, households need help with plumbing



Julie Jenks · Jun 29 · 7 min read

Drinking Water and Plumbing After the Camp Fire: Summary of the Interactive Demos

About the Event

Experts in plumbing and engineering from Purdue University held a community event entitled "Drinking Water and Plumbing After the Camp Fire" on Thursday June 27, 2019 at the Paradise Alliance Church. Water contamination has been found in the water distribution systems of both Paradise Irrigation District (PID) and Del Oro Water Company after the Camp Fire. Both water supply companies are working hard to understand the extent of water contamination with ongoing testing and to resolve the contamination issues within their districts, but it will take time. Water contamination presents challenges for those in standing homes, those living in temporary dwellings (like RVs) on property where a structure burned, and those rebuilding.

The Drinking Water and Plumbing After the Camp Fire event had two parts. The first part of the event featured interactive stations hosted by experts to give attendees an opportunity to learn about plumbing and water with hands-on examples and activities and to ask questions. The second part of the event presented the results of the Camp Fire Drinking Water Survey, details of that presentation can be found at the end of this article. The aim of this post is to share some of that hands-on learning with those unable to attend in person. Click here to read more background on the water contamination issue.

Post-disaster plumbing education

4,000+ people reached

~$9,000 grant from the Paradise Rotary Foundation

Many volunteers

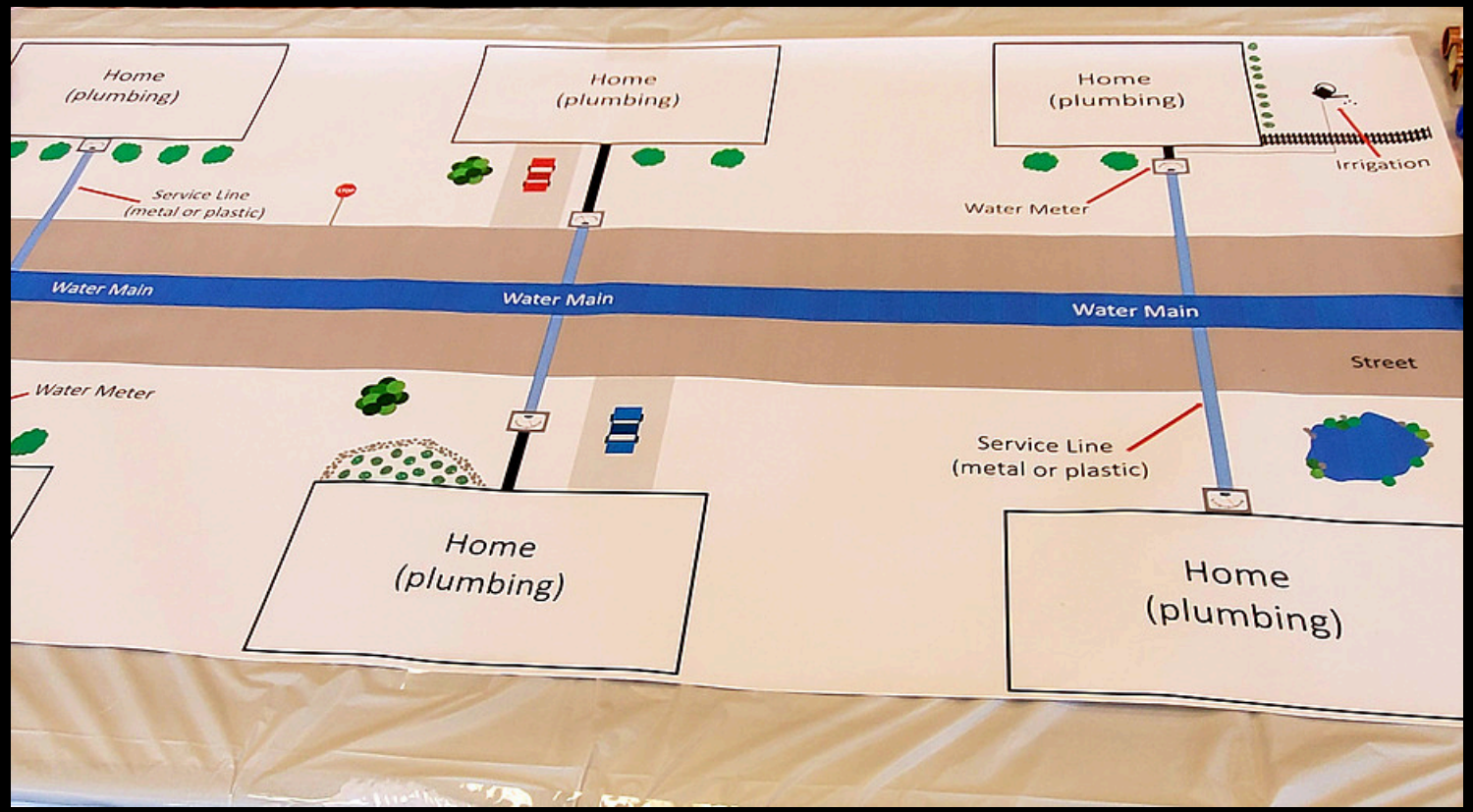
Go to PlumbingSafety.org

"RESOURCES" Tab

"DEMONSTRATIONS" Tab

We helped the community understand plumbing and recovery – plumbing education

Station 1: The Plumbing Zoo



Many survivors as well as contractors, journalists, local, county, and state officials did not understand plumbing. This direct engagement improved their knowledge.

Ask the Experts

The Plumbing Zoo

Water Sampling 101

Ask the Experts

Disasters Expose a Critical Lack of Plumbing Knowledge: Federal, State, County agencies, and in Households

There are direct mental and physical health consequences on the population – More than 60% population reported anxiety, stress, or depression related to drinking water contamination (Camp Fire Community Survey, June 2019)

What's Needed

Basic understanding of plumbing design, use, materials, and aging

What products are in plumbing

How to use damaged plumbing post-disaster

How to test plumbing post-disaster

How to clean plumbing post-disaster

Closing Thoughts

1. Lots of testing results coming out from us in the next 1 year.

2. Go to www.PlumbingSafety.org for information we post online.

3. We want to strengthen partnerships. Collectively we can make a big impact

Let's Dream Big…Together

Impact opportunities

- Disaster support team
- Water, public health, construction sector education
- Science exhibit – technology for healthy living

Innovation and tech development opportunities

✓Full-scale innovation laboratory

✓Pilot testing facility (100 yards away)

✓Access to world-class expertise, capabilities, and education in and outside Purdue

Full-Scale Testing at Purdue with Partner

Plumbing Testing Facility at Purdue

Let's Make an Impact Together

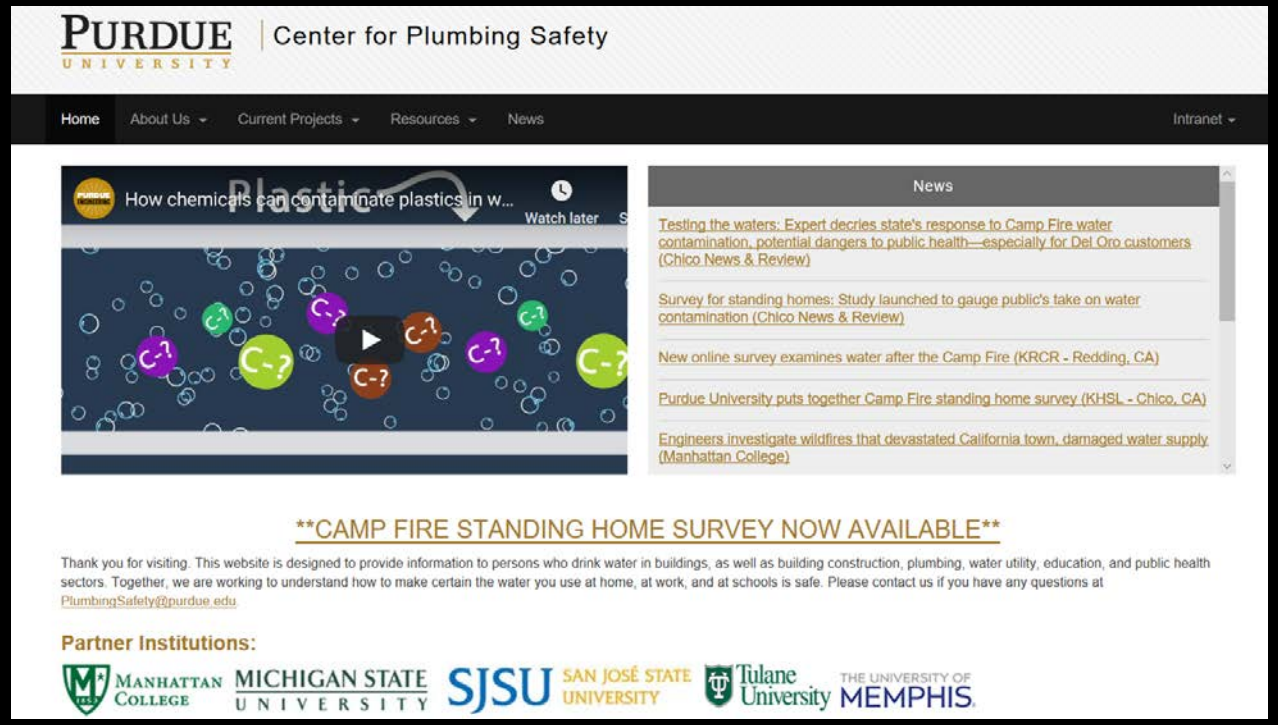
Plumbing contamination disasters occur a lot

You need an independent group to support communities after disaster

Each disaster is an opportunity to help/educate, potentially redo plumbing infrastructure, and learn

A plumbing disaster team should

- ❑ Provide info that agencies can formalize and make recommendations
- ❑ Has reach-back capability to additional plumbing expertise
- ❑ Can deploy education stations



More Info, Visit www.PlumbingSafety.org

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

Extra slides

Our USEPA Study Horizon

- ❑ Predictive fixture water quality models for residential buildings
- ❑ Predictive hot water quality / energy models for residential buildings
- ❑ Reducing and managing pathogen and chemical risks in large buildings
- ❑ Techniques for maximizing safe water in schools
- ❑ Plumbing water quality when rainwater is the source