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Water Quality of Air Conditioning Condensate: Implications for Onsite Use

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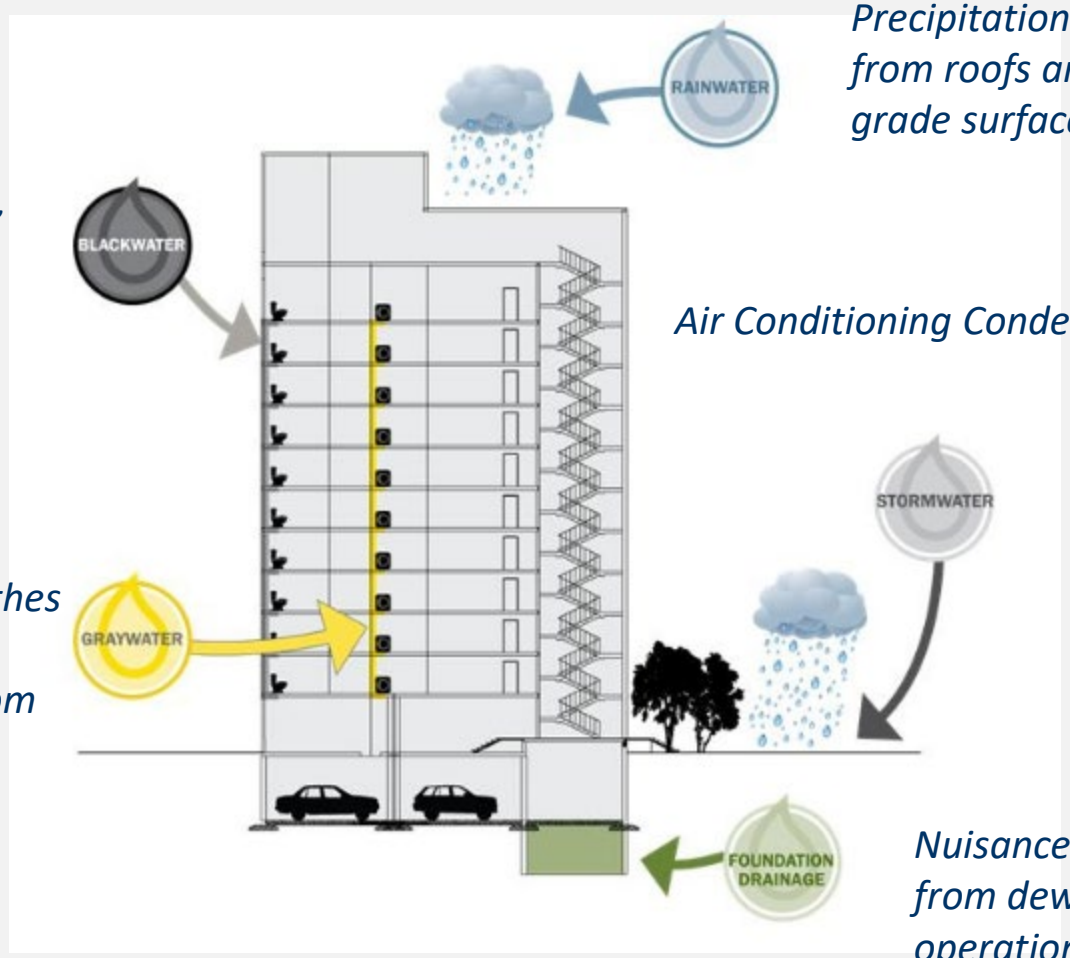
Motivation: From Waste to Resource

Precipitation collected from roofs and above-grade surfaces

Wastewater from toilets, dishwashers, kitchen sinks, and utility sinks



Air Conditioning Condensate

Precipitation collected at or below grade

Wastewater from clothes washers, bathtubs, showers, and bathroom sinks

Nuisance groundwater from dewatering operations

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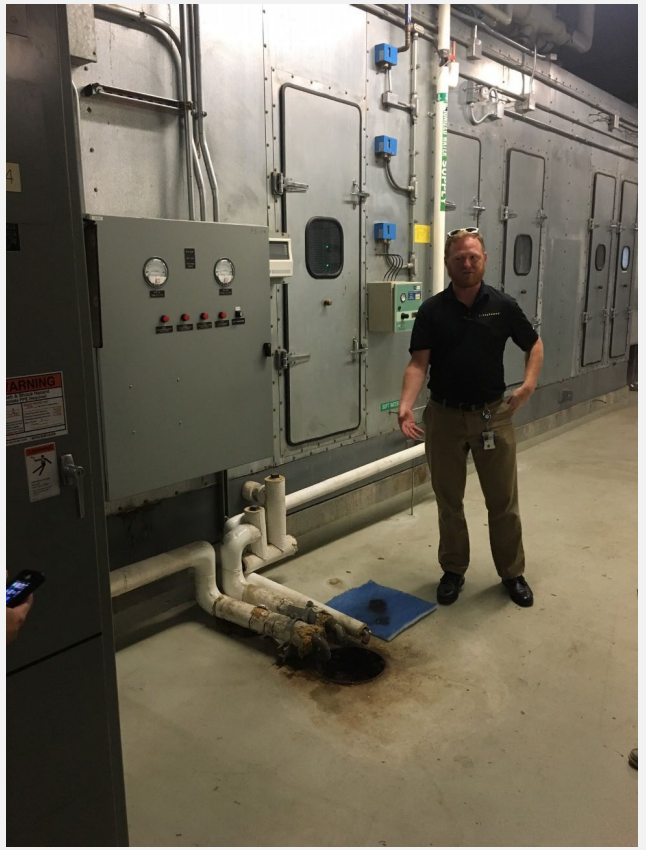
Why Collect AC Condensate?

- Significant quantities of high-quality water produced
  - Estimated 3-10 gpd per 1000 ft^2 cooled space
  - Forms as essentially distilled water
  - Low TDS ideal for cooling tower applications
- Climate conditions that drive AC use correlate with water scarcity (*e.g.*, southern United States)
  - Peak production during peak demand
- Water and energy conservation potential through on-site collection and use
  - Reduced potable demand and wastewater load
  - Associated economic and environmental benefits



Condensate Quality – Safe for Use?

- Potential concerns:
  - Chemistry: metals leached from components
  - Microbes: *Legionella* and *Mycobacterium* spp.
- Initial study at EPA-RTP (NC) campus
  - Condensate use for cooling towers and green roof irrigation
  - 40 samples across 4 systems; outdoor air/return
  - Additional 36 biofilm samples from coils, pipes, and drains
- Expanded under WRAP
  - 3 additional sites in FL, TX, and IN
  - 42 samples across 9 systems; outdoor air/return
  - Various levels of reuse (current, planned, none)

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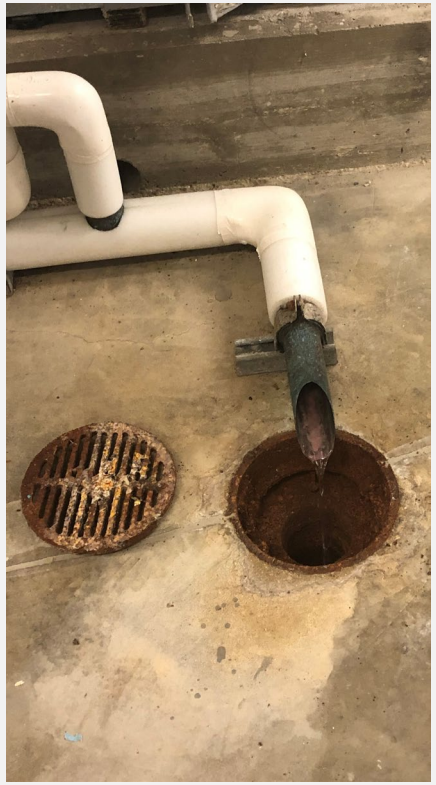

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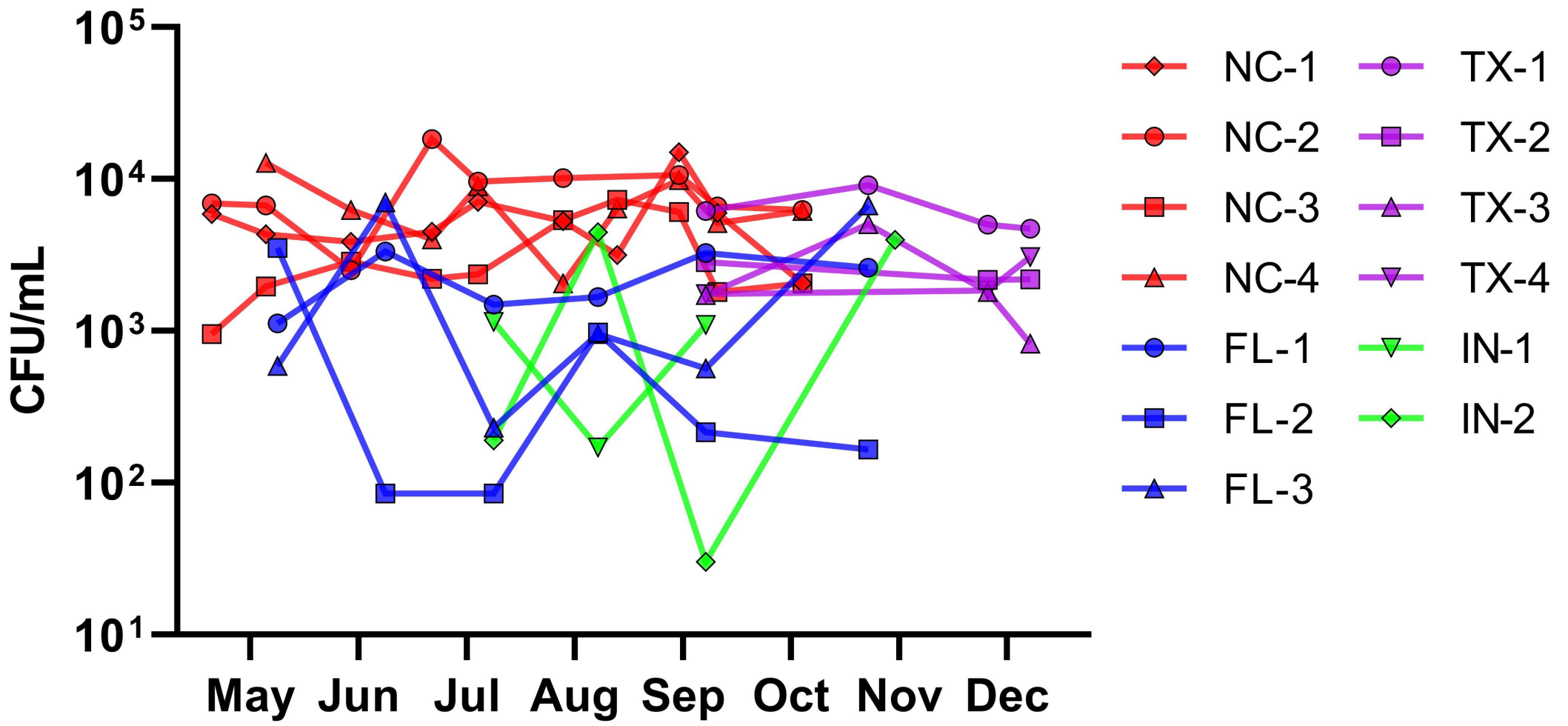
Preliminary Results: Heterotrophic Bacteria



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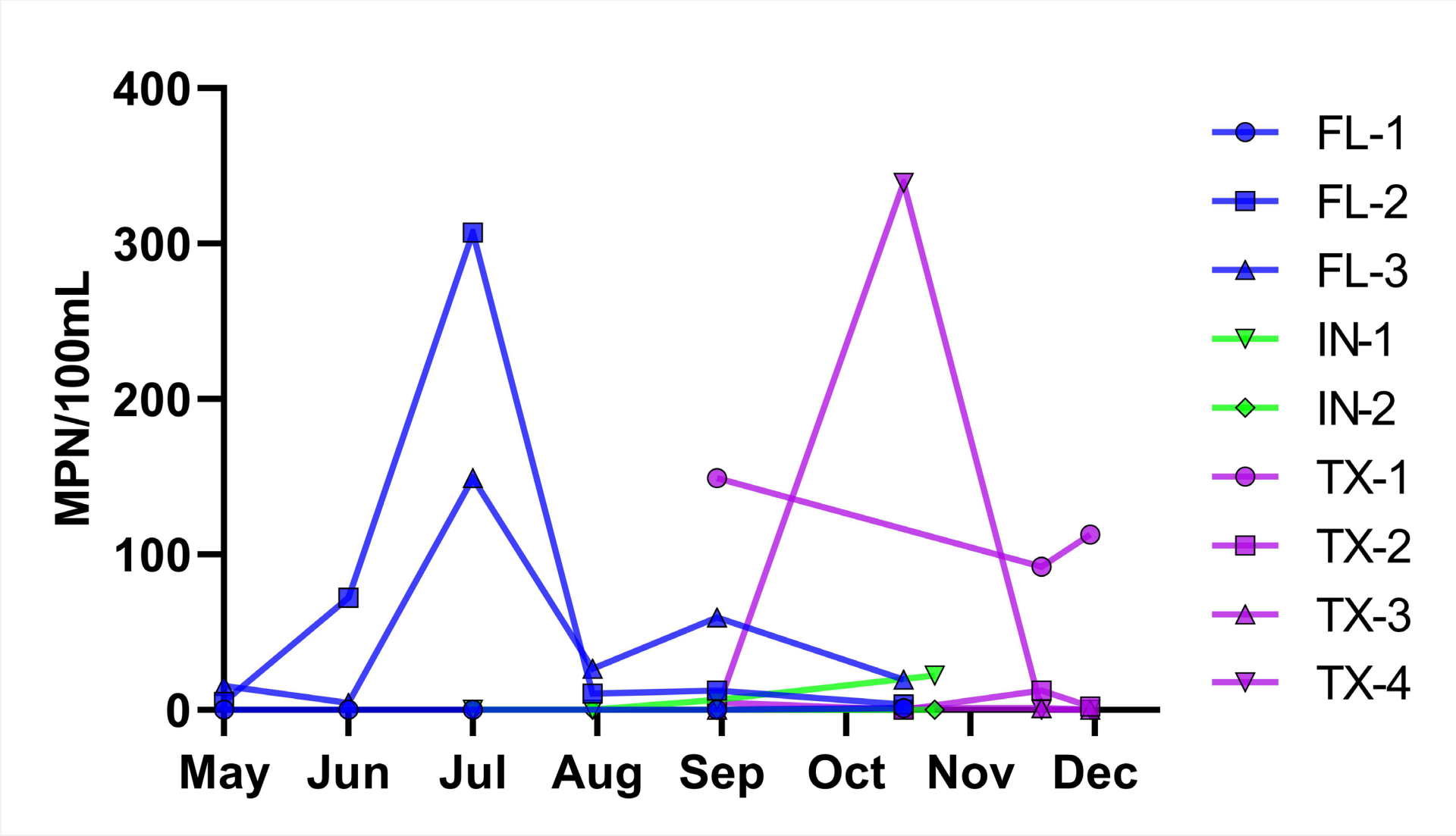
Preliminary Results: *Legionella* Culture



Preliminary Results: Pathogens by qPCR

	Legionella pneumophila serogroup 1		*Mycobacterium avium*		*Mycobacterium intracellulare*	
	Detections	Concentrations (gc/L)	Detections	Concentrations (gc/L)	Detections	Concentrations (gc/L)
FL-1	0/6	-	0/6	-	0/6	-
FL-2	1/6	BLQ	0/6	-	0/6	-
FL-3	1/6	BLQ	0/6	-	0/6	-
IN-1	0/4	-	0/4	-	3/4	BLQ to 400
IN-2	0/4	-	0/4	-	3/4	BLQ to 3900
TX-1	0/4	-	0/4	-	0/4	-
TX-2	0/4	-	0/4	-	0/4	-
TX-3	0/4	-	0/4	-	0/4	-
TX-4	0/4	-	0/4	-	0/4	-
NC-1	0/10	-	1/10	200	0/10	-
NC-2	0/10	-	0/10	-	0/10	-
NC-3	1/10	BLQ	0/10	-	0/10	-
NC-4	0/9	-	0/9	-	3/9	BLQ to 1000
NC-1 BF	0/10	-	0/10	-	0/10	-
NC-2 BF	0/6	-	0/6	-	0/6	-
NC-3 BF	0/10	-	0/10	-	0/10	-
NC-4 BF	1/10	BLQ	0/10	-	2/10	BLQ to 100

BLQ = Below limit of quantification: <50 gene copies/L for *M. avium* and *M. intracellulare*; <100 gene copies/L for *L. pneumophila* serogroup 1

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Preliminary Results: Metals and Major Ions

- Trace metal analyses of 50 elements by High Resolution ICP-MS
- Major soluble anions (fluoride, chloride, bromide, nitrate, nitrite, sulfate, and phosphate) by ion chromatography
- Rare Cu and Pb detections near or above drinking water MCLs
  - From TX location only; all other samples notably lower
  - Cu: 1/4 samples from oldest building and 2/4 from its receiving plant
  - Pb: 3/4 samples from oldest building, increasing over time to 7X MCL
  - Known copper piping with likely lead solder given age of construction
- Low levels of scale compounds (Ca, Fe, Sr, Ba, sulfate)
  - Elevated in one TX sample only that also contained yellow particulate
  - Unique characteristic: enthalpy wheel
  - Live oak or cedar pollen bypassing air filter?

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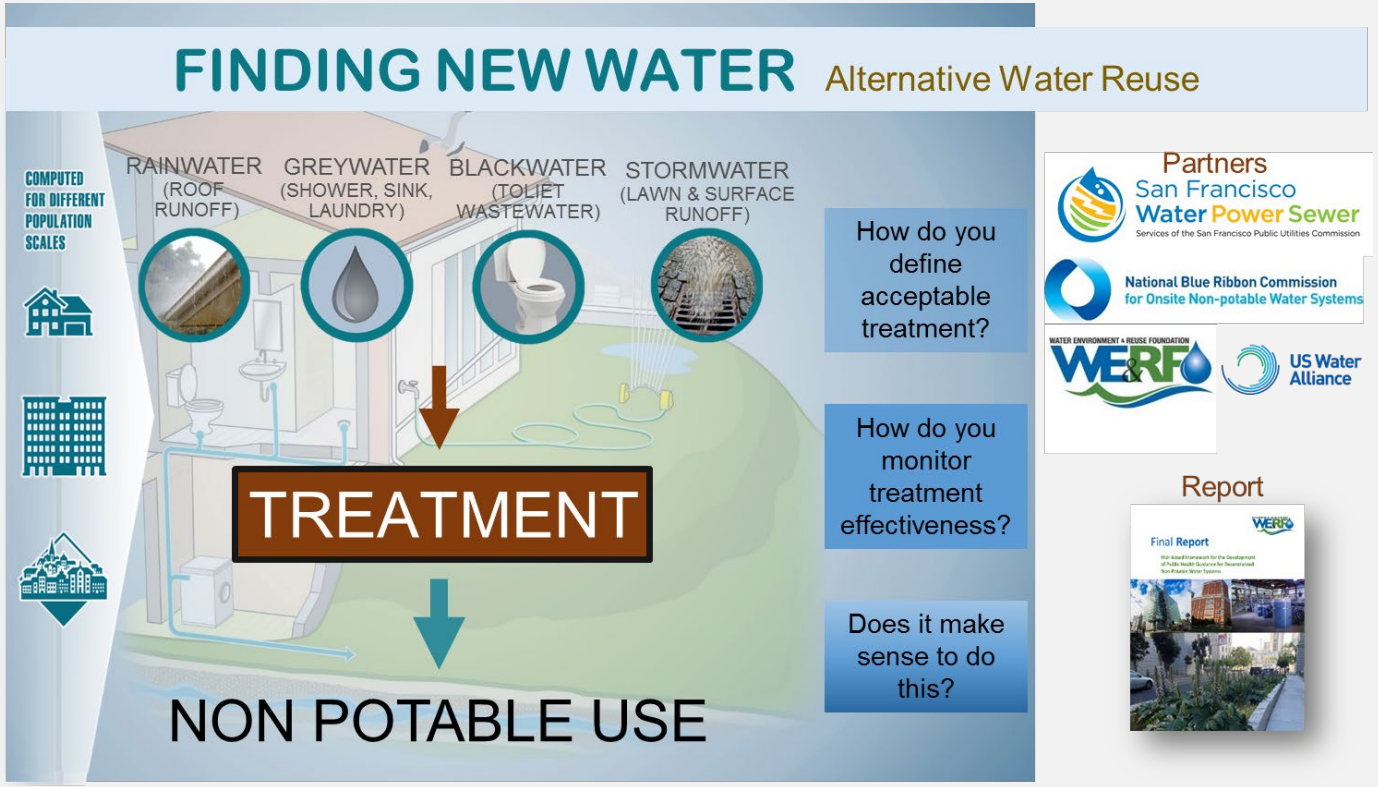
Best Management Practices for Reuse

- Data indicate potential for opportunistic pathogens in AC condensate
  - Cooling towers known source of legionellosis outbreaks
  - OSHA guideline *Legionella* spp. <10 CFU/mL
- Disinfection of collected condensate prior to distribution is important
  - 0.2 mg/L free chlorine residual at point of use
  - Biocides already included in cooling tower makeup
- Care and maintenance of AHUs
  - Disinfection of collection surfaces and drainpipes
  - Management of storage and distribution systems
  - Appropriate plumbing materials and corrosion control
- Bottom line: Same requirements for all water distribution systems, regardless of source – including potable

Ongoing Work and Next Steps

- Publish work in peer-reviewed journal for reference in code development
  - IAPMO, ASHRAE, ICC
  - Results consistent with conventional knowledge and previous guidances but provide supporting data
- Other presentations?
  - WateReuse Symposium (March 2023)
- Additional data analysis of metal and ions
  - Dimensionality reduction to assess overall site differences and trends
- Molecular analysis of broader microbial community
  - 16S gene sequencing of bacterial genera
  - Metagenomics for deeper characterization (e.g., antibiotic resistance)
  - Fungi?

Thank you – Questions?



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