Virginia Tech's Initiative to Reverse Freshwater Salinization (VT-REFRESH)

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Department of Civil and Environmental Engineering
Virginia Tech

ICPRB (DWSPP Meeting)
February 3, 2021

Outline

- Vision for VT-REFRESH
- Progress so far
- National Science Foundation (NSF) Growing Convergence Research (GCR) Grant
- Nature Sustainability article
- Next steps on the NSF GCR Grant
- Moonshot: NSF Engineering Research Center (ERC) Bid

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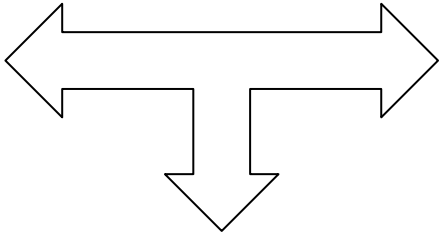
Vision for VT REFRESH

Top-Ten Engineering Program

Civil & Environmental Engineering Program, Virginia Tech

Private, State & Federal Funding



Extremely Successful Academic-Industry Partnership

Occoquan Watershed Monitoring Laboratory (OWML), Virginia Tech

REFRESH

National-Scale Center focused on Reversing Freshwater Salinization

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Progress (since July 2018)

- **National Science Foundation (NSF)** Engineering Research Center (ERC) Planning Grant, **$100K,** 8/1/18-8/1/21
- **VT College of Engineering ICTAS EFO** Opportunity Seed Investment Grant , **$10K**, 10/25/19-10/25/21.
- **Freshwater Salinization Workshop** at Fairfax Water Griffith Auditorium (~100 attendees from universities, utilities, county & city government, private consulting firms), 1/10/20.

Progress (since July 2018)

- **National Science Foundation (NSF)** Growing Convergence Research Grant, up to **$3.6M,** 8/30/20-7/29/25
- **MWCOG** Science Partnership to Understand Freshwater Salinization, **$570K**, 10/1/20-9/30/25 (joint with USGS and University of Maryland).
- **NSF Engineering Research Center on Reversing Freshwater Salinization** (**REFRESH**), pre-proposal submitted 10/1/20 (in process, up to $50M over 10 years if successful).

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Growing Convergence Research (GCR) Program at NSF

- One of NSF's "Ten Big Ideas"
- Our award is for up to $3.6M over five years
- Virginia Tech (lead), University of Maryland, North Carolina State University, Vanderbilt
- PI: Stanley Grant
- Co-PIs: Thomas Birkland, Marc Edwards, Jesus Gomez-Velez, Erin Hotchkiss, Sujay Kaushal, Meg Rippy, Todd Schenk, Peter Vikesland, Kristin Rowles

“Convergence Research”

“Integrates knowledge, tools, and ways of thinking across disciplinary boundaries…to form a synthetic framework for tackling scientific and societal challenges”

National Research Council, “Convergence: Facilitating Transdisciplinary Integration of Life Science, Physical Sciences, Engineering, and Beyond” (2014). doi: 10.17226/18722

Elinor Ostrom's Common Pool Resource Theory—an answer to the 'Tragedy of the Commons'

- **Motivation**: rising salinity in the Occoquan Reservoir implies that its salt budget is out of balance
- **Goal**: to foster collaborative learning and discovery, leading to stakeholder-driven bottom-up management of the salt budget for the Occoquan Reservoir (as opposed to top-down regulatory control)

NSF Grant Timeline

- Grant Awarded 8/30/20
- **Phase I (Years 1 and 2)**: Contribution of UOSA to Occoquan Reservoir Salt Budget
- **Reverse Site Visit** at NSF (June 2022)
- If the reverse site visit goes well, **Phase 2 (Years 2 through 5)**: Contribution of the Bull Run and Occoquan River Watersheds to Occoquan Reservoir Salt Budget

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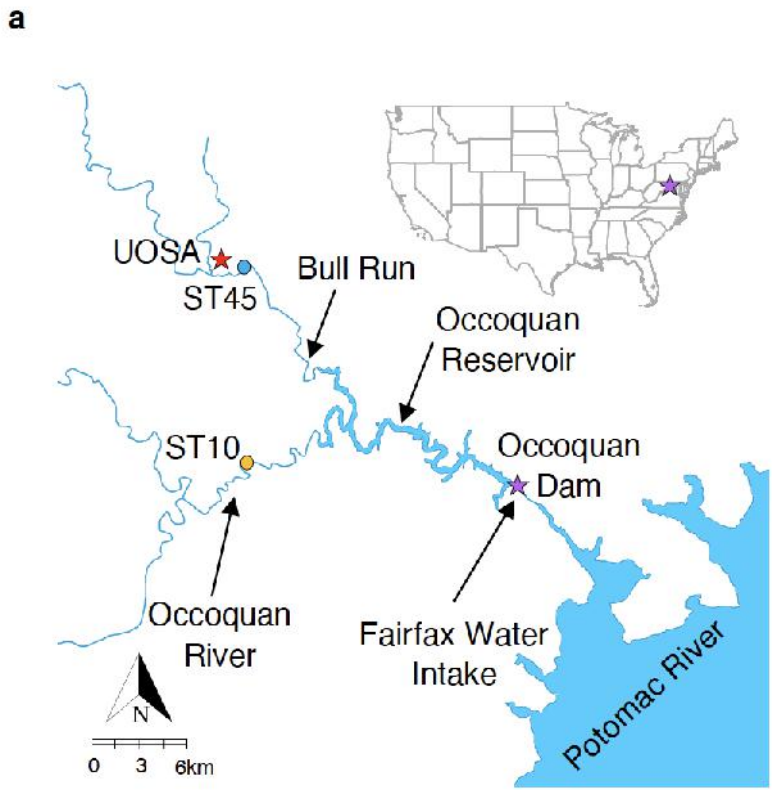
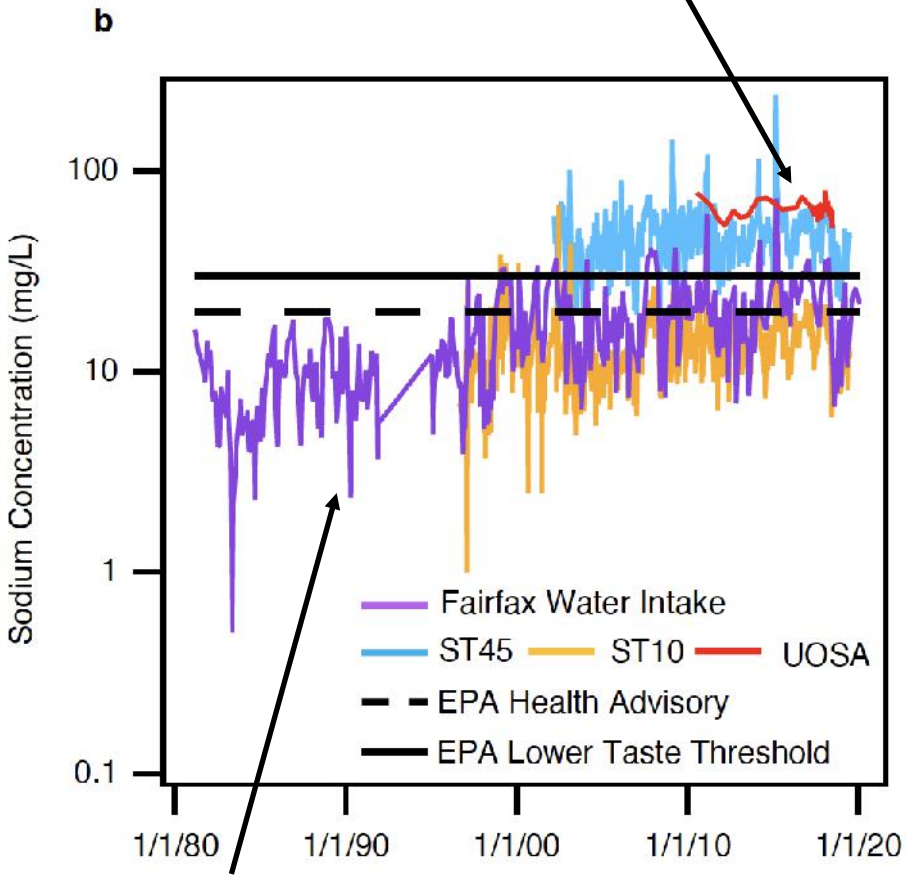
First Phase I Product:

Diverse team of authors, including CEE students and faculty at OWML and Blacksburg campuses, as well as Fairfax Water personnel and faculty on the NSF GCR grant. Accepted for publication yesterday!

Sodium concentration in UOSA composited outflow is generally higher than sodium concentration at all other monitoring stations

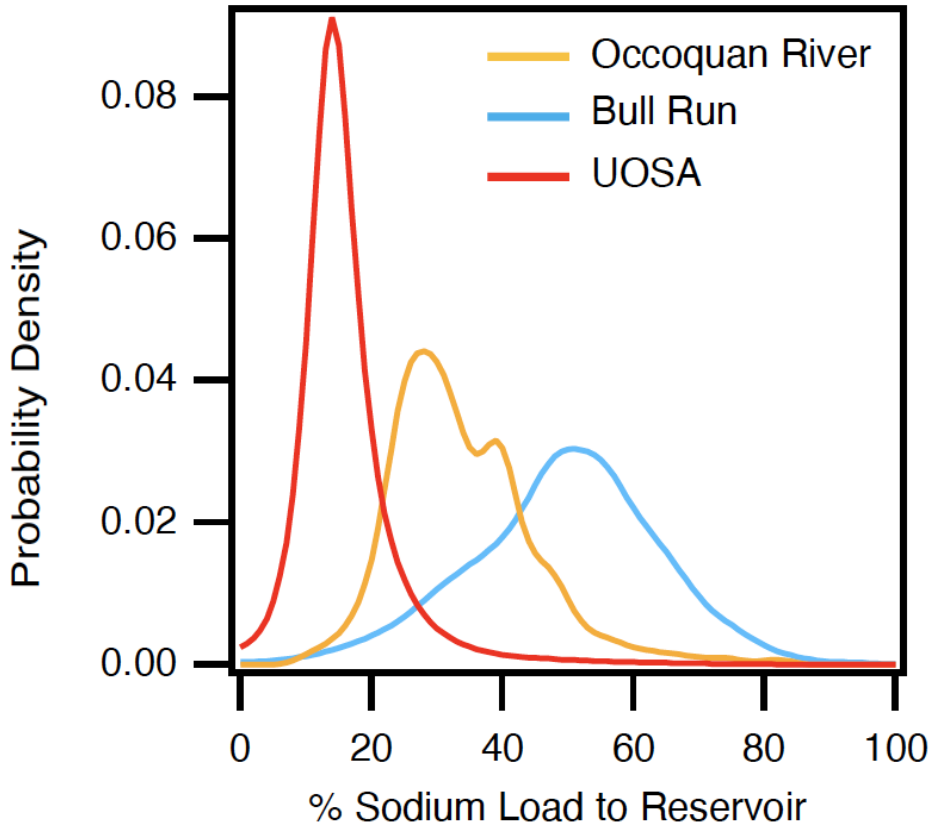




Sodium concentration at the Fairfax Water intake has been increasing over time.

Wet Weather Conditions

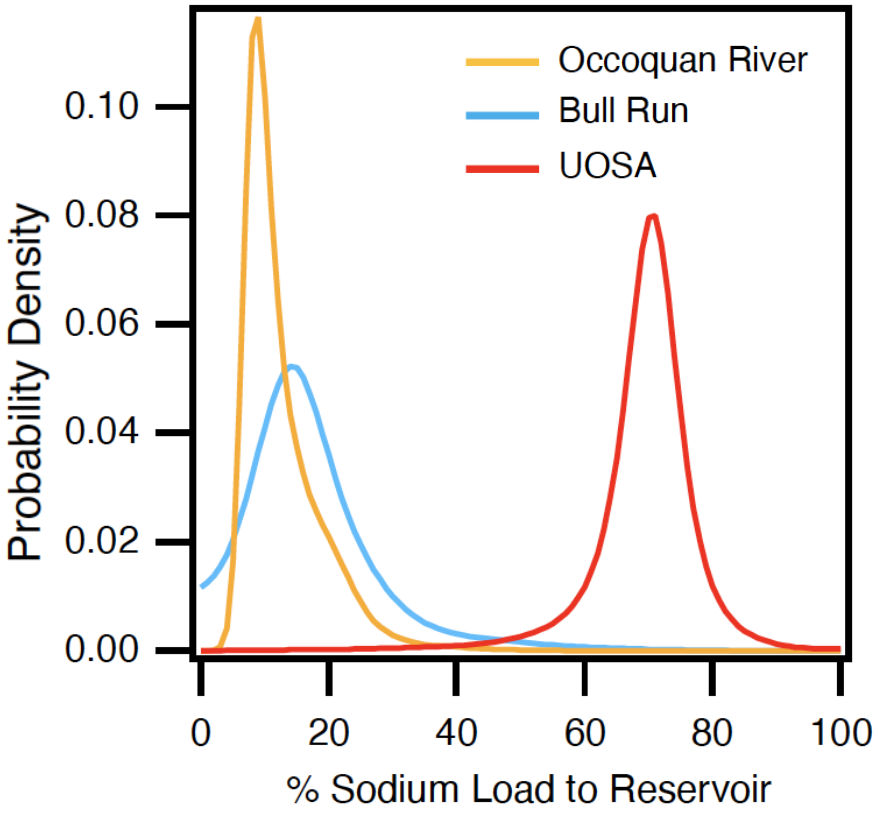
Sodium Load (mass per time) from UOSA < Occoquan River < Bull Run



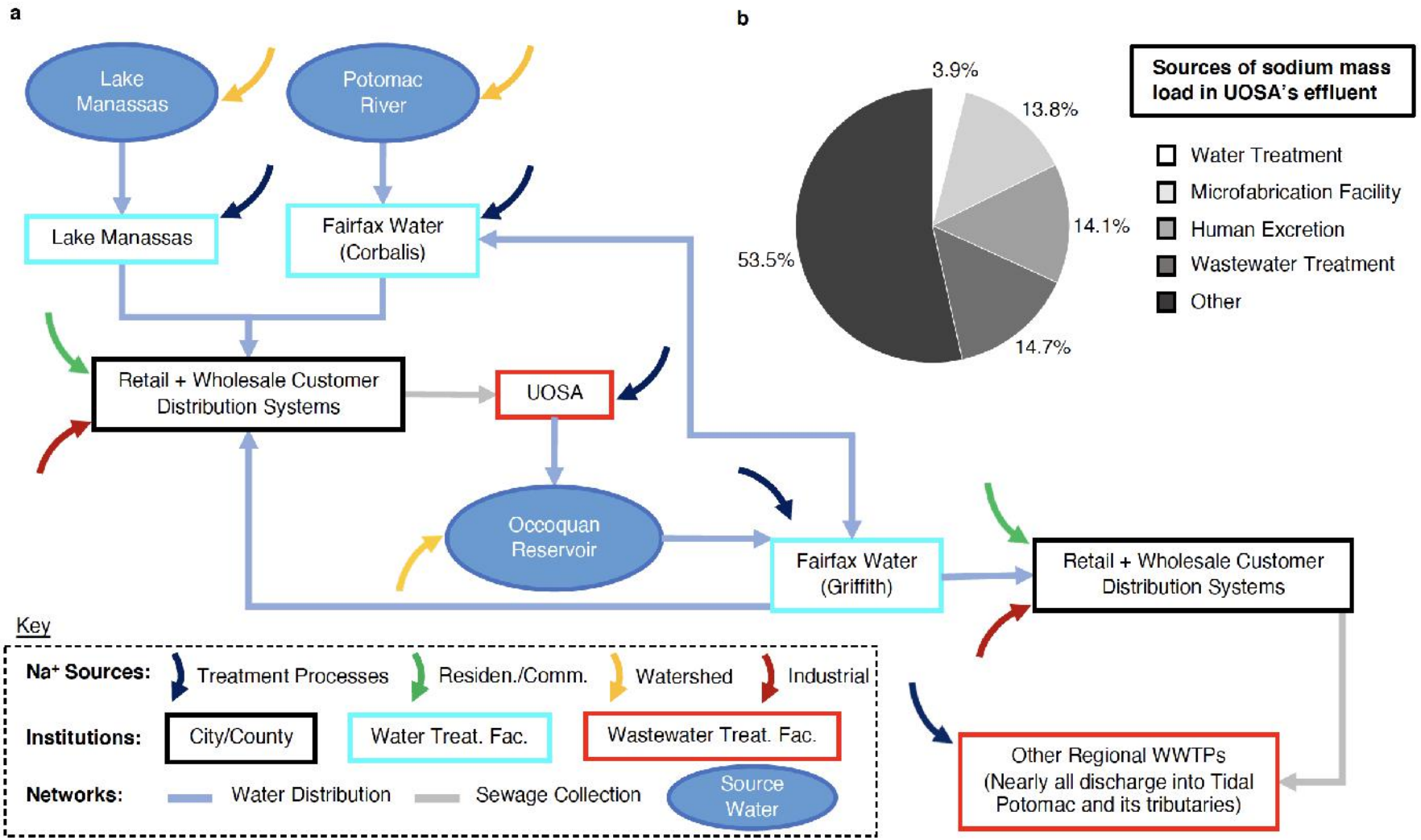
The location of the distribution along the x-axis is what matters (not the height of the peak)

Dry Weather Conditions

Sodium Load (mass per time) from UOSA > Bull Run ~ Occoquan River



Where is the sodium in UOSA's effluent coming from?



Ways to improve "salt productivity" (goods and services produced per unit salt discharged to the environment)

- Reduce watershed sources of sodium that end up in the water supply (e.g., from deicers)
- More stringent pre-treatment requirements on industrial and commercial dischargers
- Switch to low-sodium water and wastewater treatment methods (at UOSA and FW)
- Households adopt low-sodium products and practices (e.g., through social marketing)

Impact of High Chloride on Galvanic Corrosion in Home Plumbing

Kathryn Lopez

PI: Marc Edwards

Changing Water Chemistry

- Chloride levels are rising
- Chloride is an aggressive ion that exacerbates corrosion
- In some areas, sulfate levels are decreasing and alkalinity is changing
  - Other factors that influence corrosion
- Chloride-to-sulfate mass ratio (CSMR) > 0.58 can trigger catastrophic galvanic corrosion of lead solder
  - Thresholds for other metals not yet known

Why We Care

- Galvanic corrosion: corrosion of 2 dissimilar metals, cathode + sacrificial anode
- Galvanic couples present in many residences
  - Copper pipe & lead solder, iron water heaters w/ aluminum or magnesium anodes
- Changing water chemistry triggering the release of lead in many cities (Brick utilities and others)
- Damages infrastructure and home appliances ($)

$1 of road salt → ~$46 in infrastructure damage

Does not include corrosion of public/private plumbing (Stefan et al. 2008)

Anecdotes: Private Wells in Orleans, NY

- Chloride in wells as high as 832 mg/L (compared to 250 mg/L standard)
- Failing appliances and high lead (119 ppb max > 15 ppb standard)
- Wells downgradient of salt barn but state says no → FOIL: no proof
- Water line being installed that will cost residents $900/yr for 30 yrs

Pieper et al. 2018

Initial Studies

Objectives:

1) **How does chloride impact galvanic corrosion of common galvanic couples**
2) **How do inhibitors perform under high chloride conditions**

4 common galvanic couples:

- Lead solder and copper (Pb/Cu)
- Iron and zinc (Fe/Zn)
- Iron and magnesium (Fe/Mg)
- Iron and aluminum (Fe/Al)

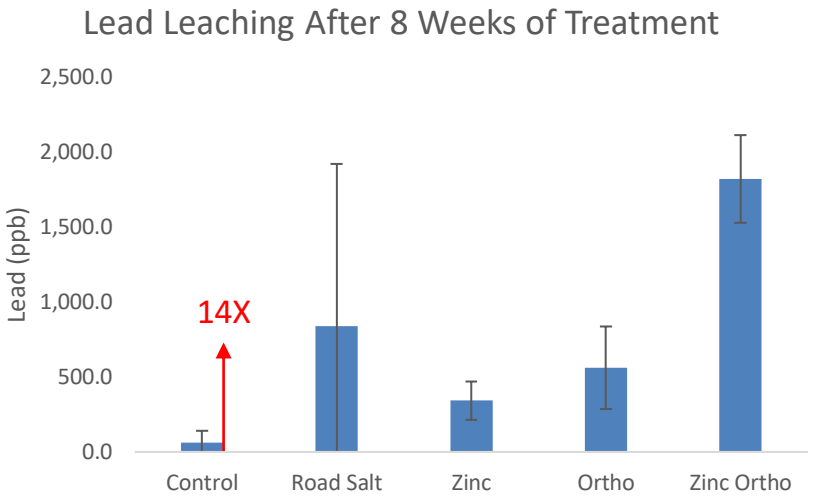
5 water conditions:

- Control
- High chloride (500 mg/L)
- Zinc inhibitor
- Orthophosphate inhibitor
- Zinc-orthophosphate inhibitor

Hypothesized to be effective for Pb/Cu

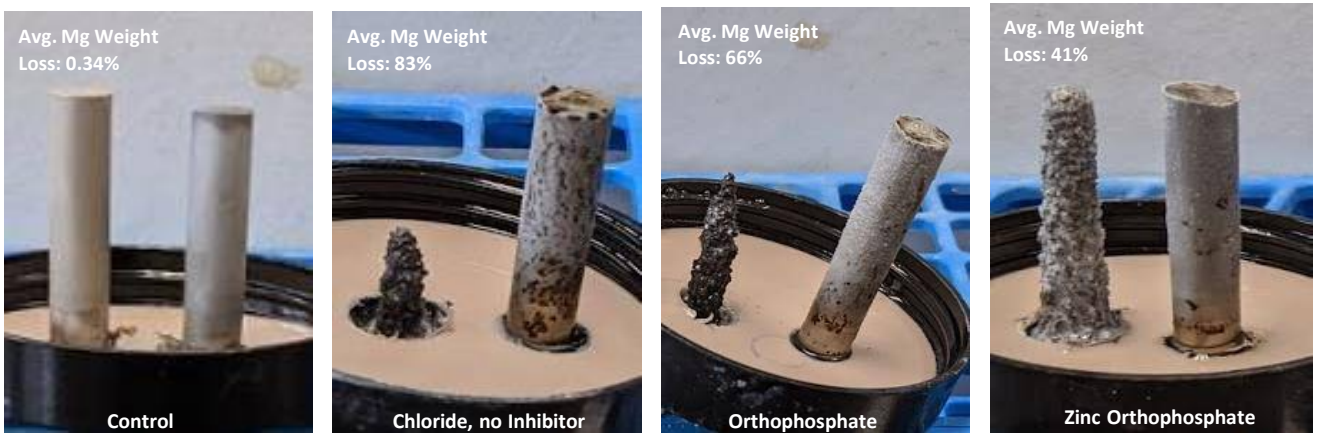
Results: Pb-Cu

- Significantly greater weight loss of Pb when exposed to chloride
- Zinc orthophosphate was most effective at mitigating corrosion of Pb only within the first month



Results: Fe-Mg

- Significantly greater weight loss of Mg when exposed to chloride
- Zinc-containing inhibitors were more effective
- Significant hydrogen generation may have exacerbated corrosion



12 days of treatment, n=5

Chloride Impact on Water Heaters

- If anode wears down, tank can corrode and rupture
- Chloride enhancing hydrogen gas production → highly explosive
- Hydrogen can also be food for bacteria
  - Harmless and smelly H_2S
  - Legionella (can be fatal)

https://mywaterearth.com/can-your-electric-water-heater-explode/
https://www.waterheaterhub.com/water-heater-explosions/

Conclusions

- Chloride exacerbates galvanic corrosion for most galvanic couples
- Inhibitors can sometimes mitigate the effects of chloride
- What are the actual costs of corrosion due to salinization?
  - We may be severely underestimating impacts on drinking water infrastructure

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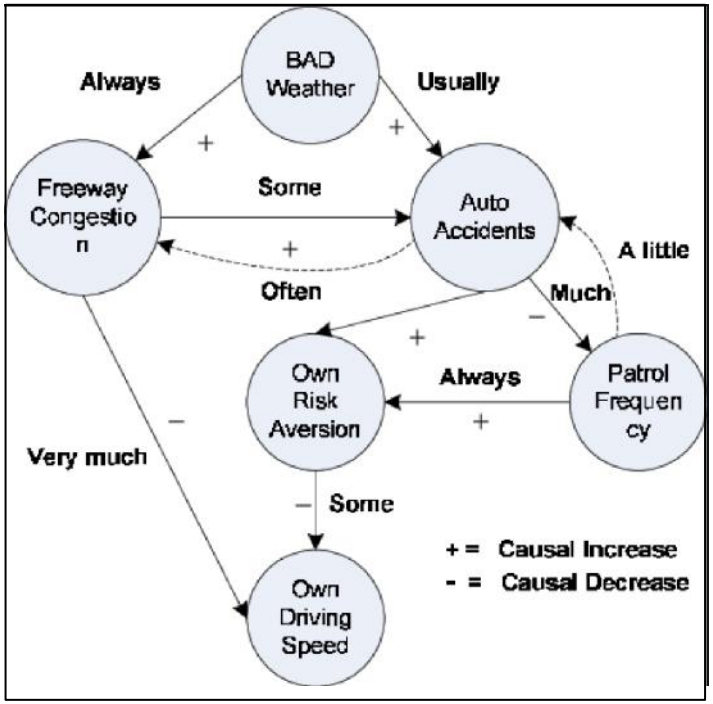
Social Science Team

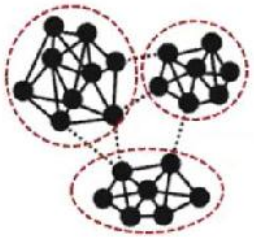
January 2021

IRB Approval

Stakeholder Interviews,
Fuzzy Cognitive Maps

Fuzzy Cognitive Map





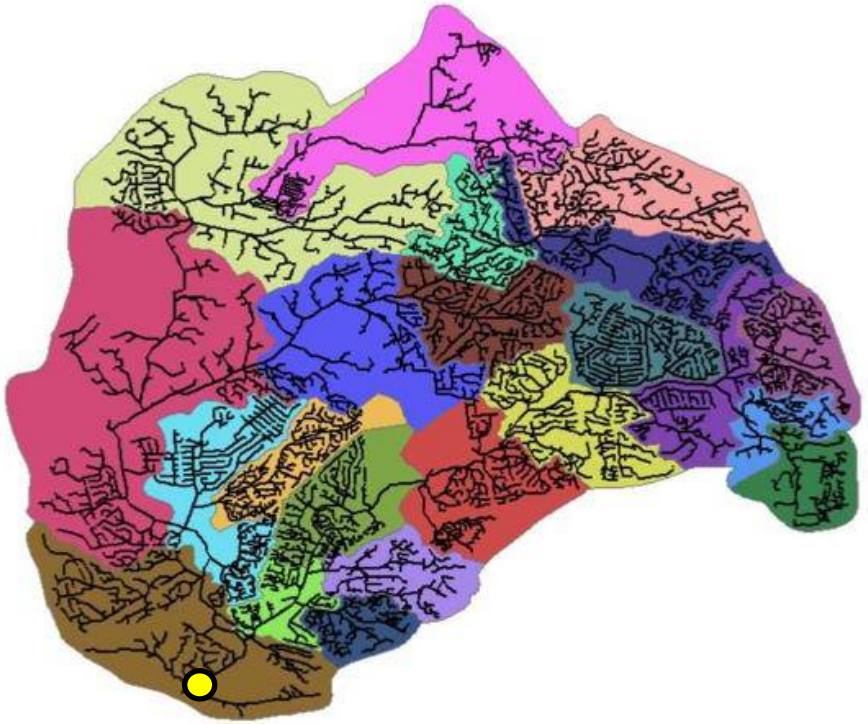
Biophysical/Engineering Team

January 2021

Sanitary Sewer Salinity Flux

Field Measurements & Modeling

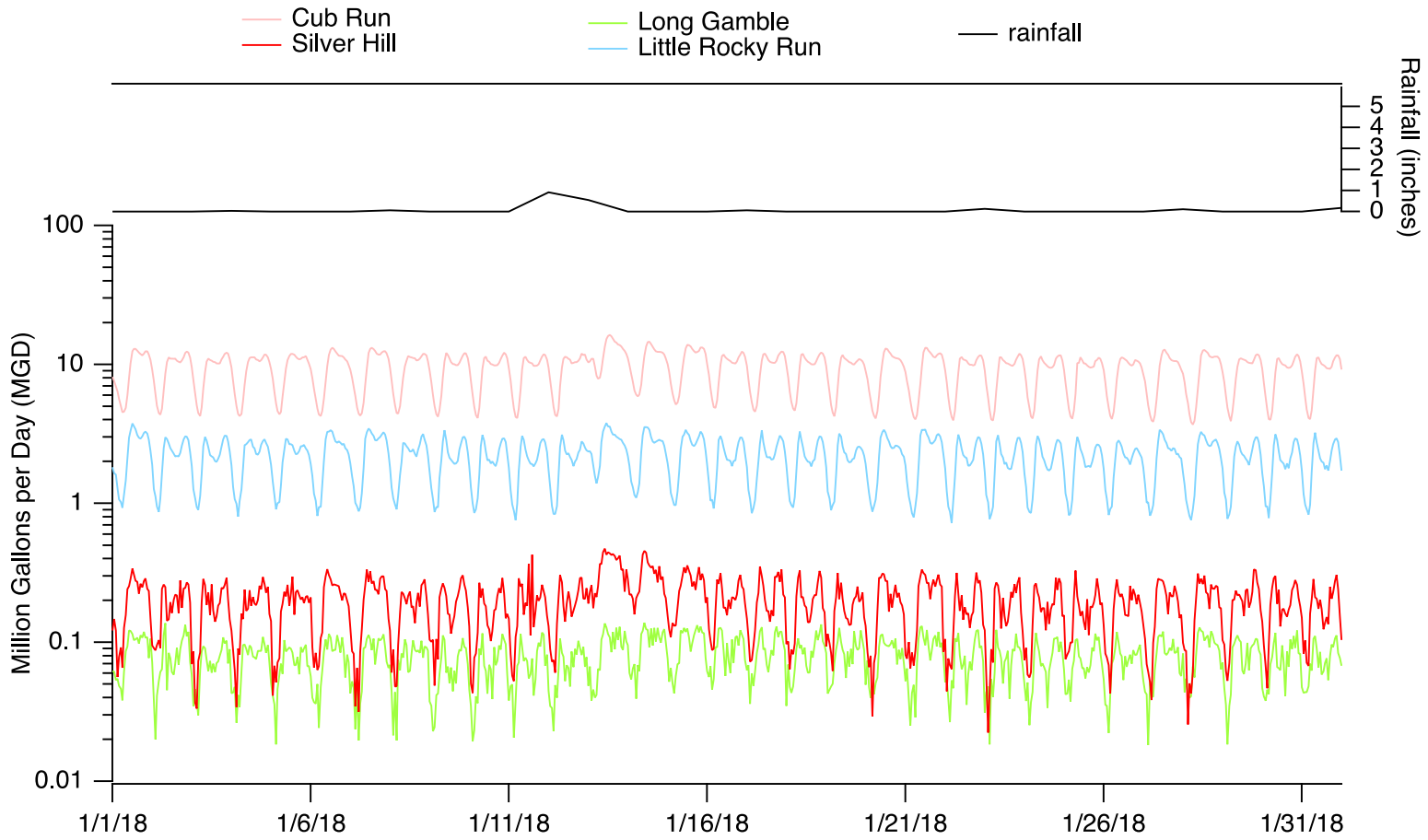
Sewer & Stream



Cub Run Pump Station

Each of these sewer subsheds, under average flow conditions, has same volumetric flow rate, ~20L/s ~ 5 gallons/s

Diurnal Ion & Flow Variability in Sewage Draining Fairfax County



Diurnal Ion & Flow Variability in Sewage Draining Fairfax County

Nathan Wells from UOSA

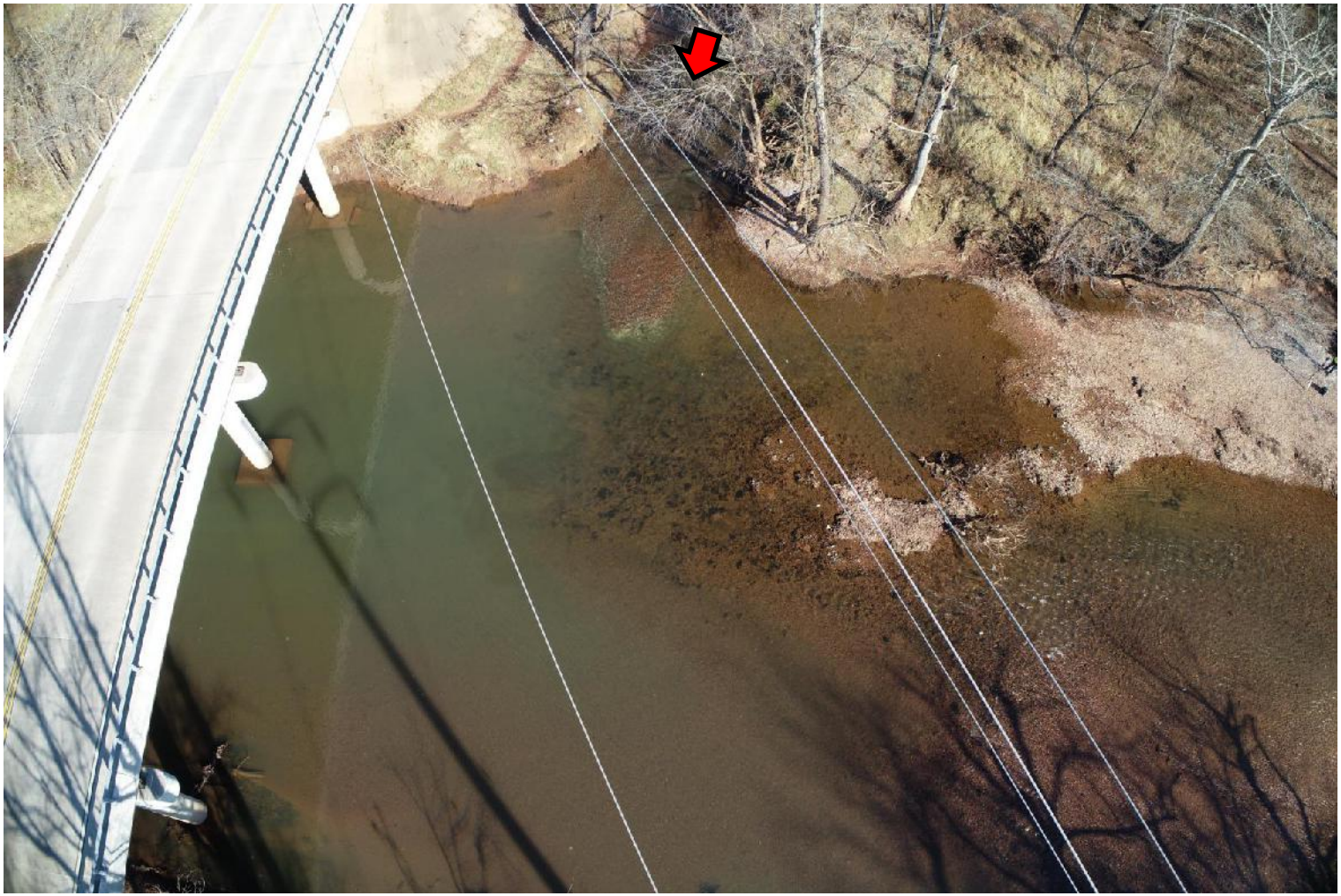
Goal: to characterize the ion composition of the morning and evening flow peaks, as well as the middle-of-night flow minimum (which is primarily groundwater)

Expanding OWML's analytical capability

Fisher Scientific Integrion Ion Chromatograph (IC) System:

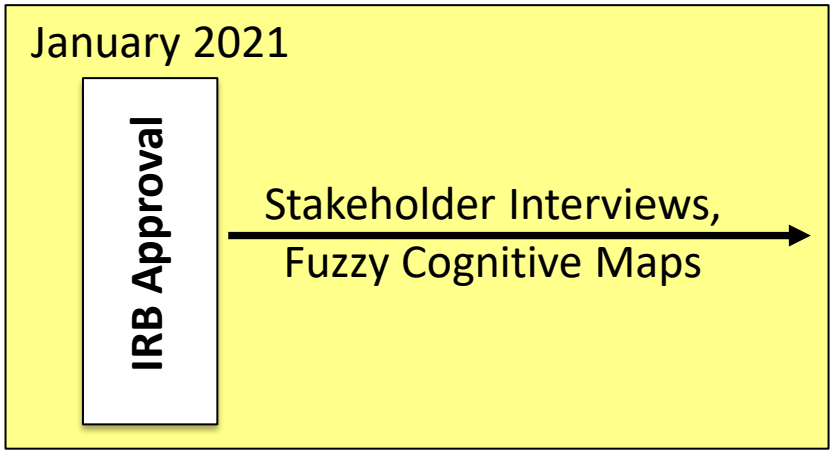
High throughput (~6 min/sample, 24 hours per day) analysis of samples for cations and anions: (Na^+, Ca^{2+}, K^+, Mg^{2+}, Cl^-, SO_4^{2-})

UOSA's Contribution of Salt to Bull Run (and the Occoquan Reservoir)



UOSA's Contribution of Salt to Bull Run (and the Occoquan Reservoir)

Social Science Team



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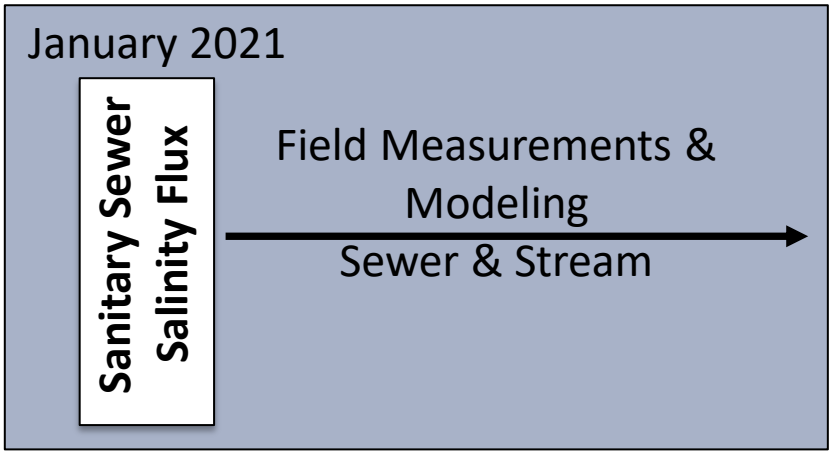
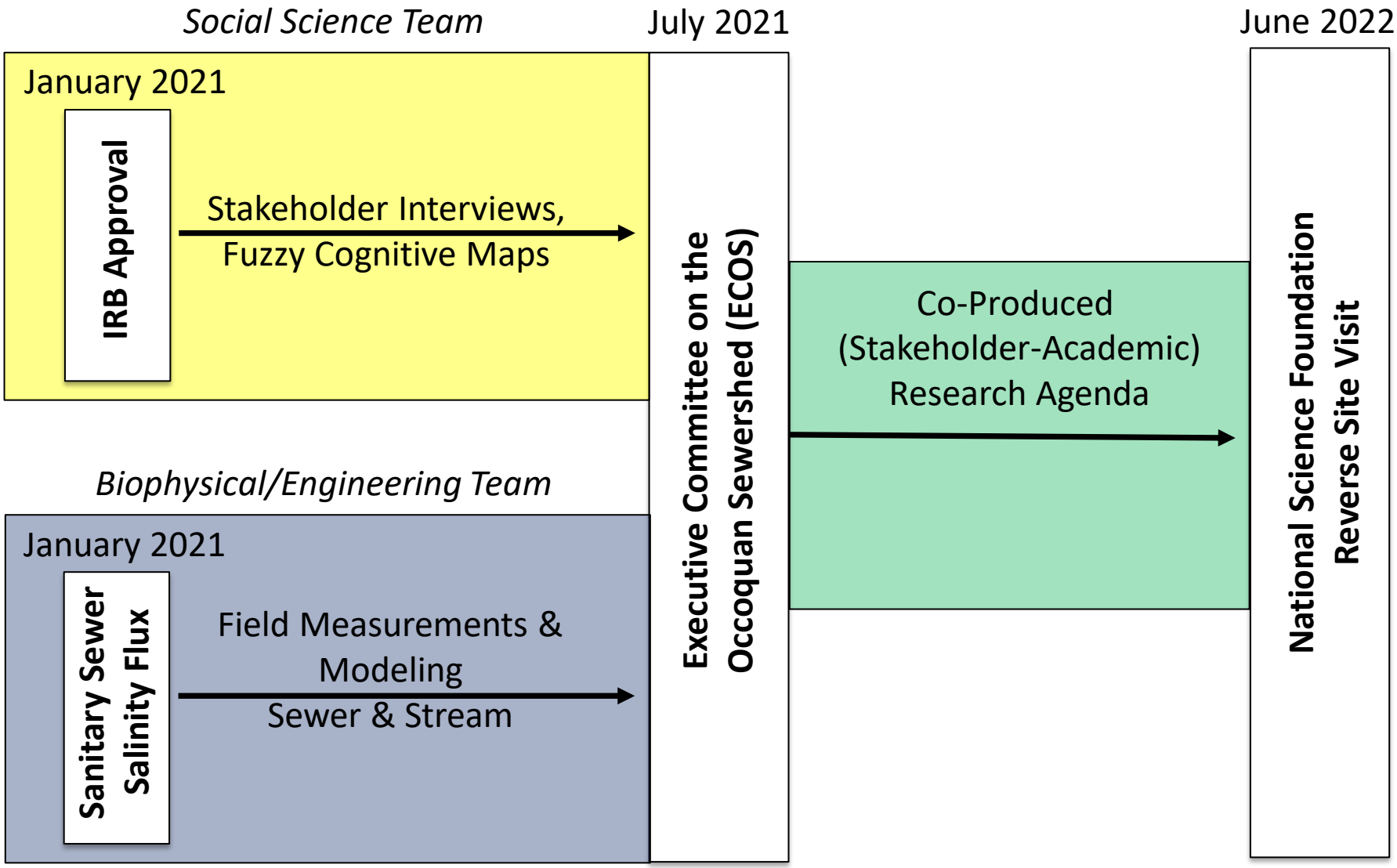


Multi-disciplinary, but not convergent


Social Science Team
July 2021
June 2022
January 2021
IRB Approval
Stakeholder Interviews,
Fuzzy Cognitive Maps
Executive Committee on the Occoquan Sewershed (ECOS)
Co-Produced
(Stakeholder-Academic)
Research Agenda
National Science Foundation
Reverse Site Visit
Biophysical/Engineering Team
January 2021
Sanitary Sewer
Salinity Flux
Field Measurements &
Modeling
Sewer & Stream
Multi-disciplinary, but not convergent
Convergence happens here

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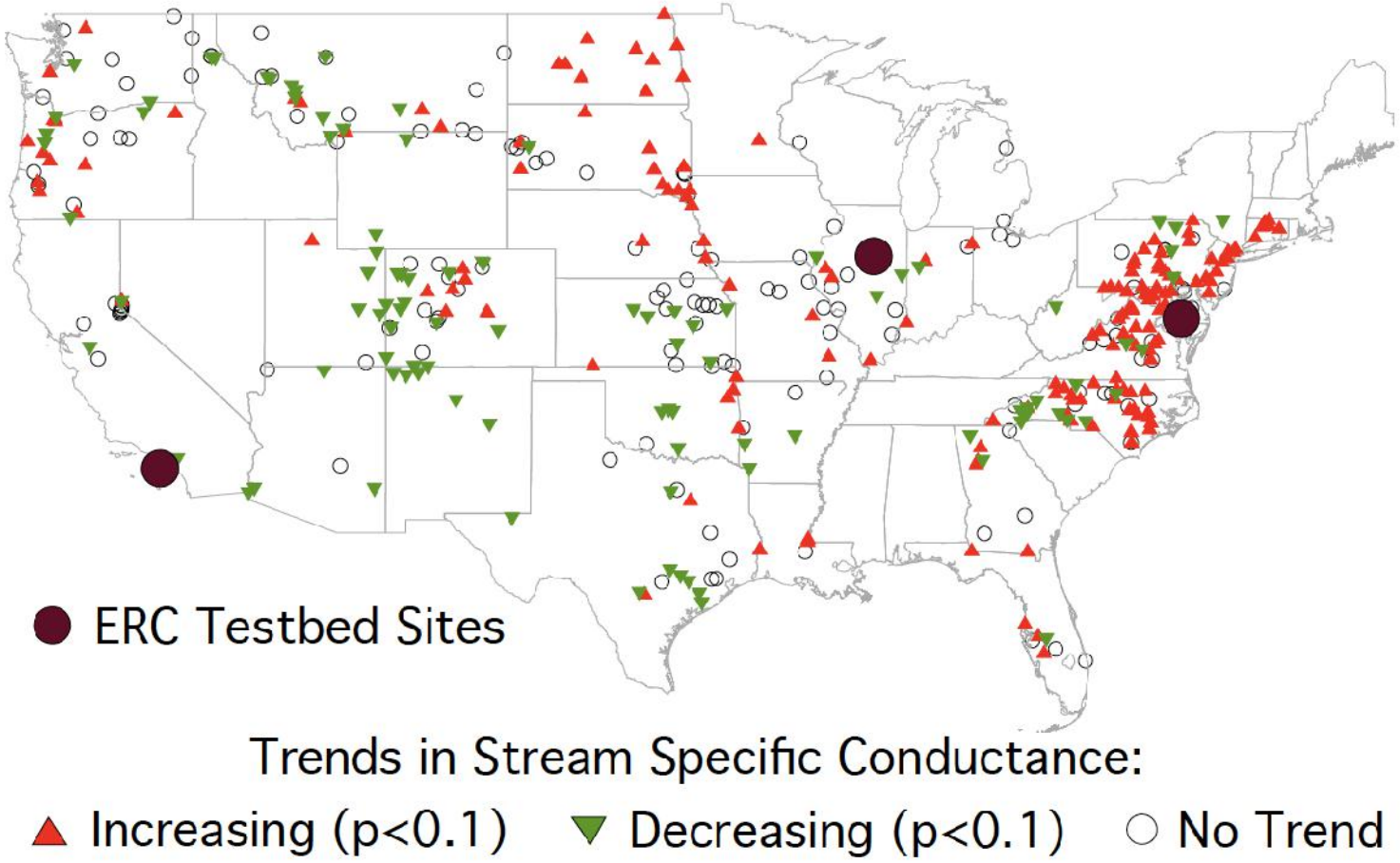
NSF Engineering Research Center to Reverse Freshwater Salinization (REFRESH)

Basic idea: take what we're doing in the Occoquan Reservoir and scale-up nationally and internationally.

Salinity is rising in streams across the U.S., but especially in the Mid-Atlantic and Upper Midwest US



REFRESH Vision Statement

Reverse freshwater salinization by transforming the nation's engineered systems (for water, transportation, agriculture, and resource extraction) through cost-effective and sustainable technological and behavioral interventions

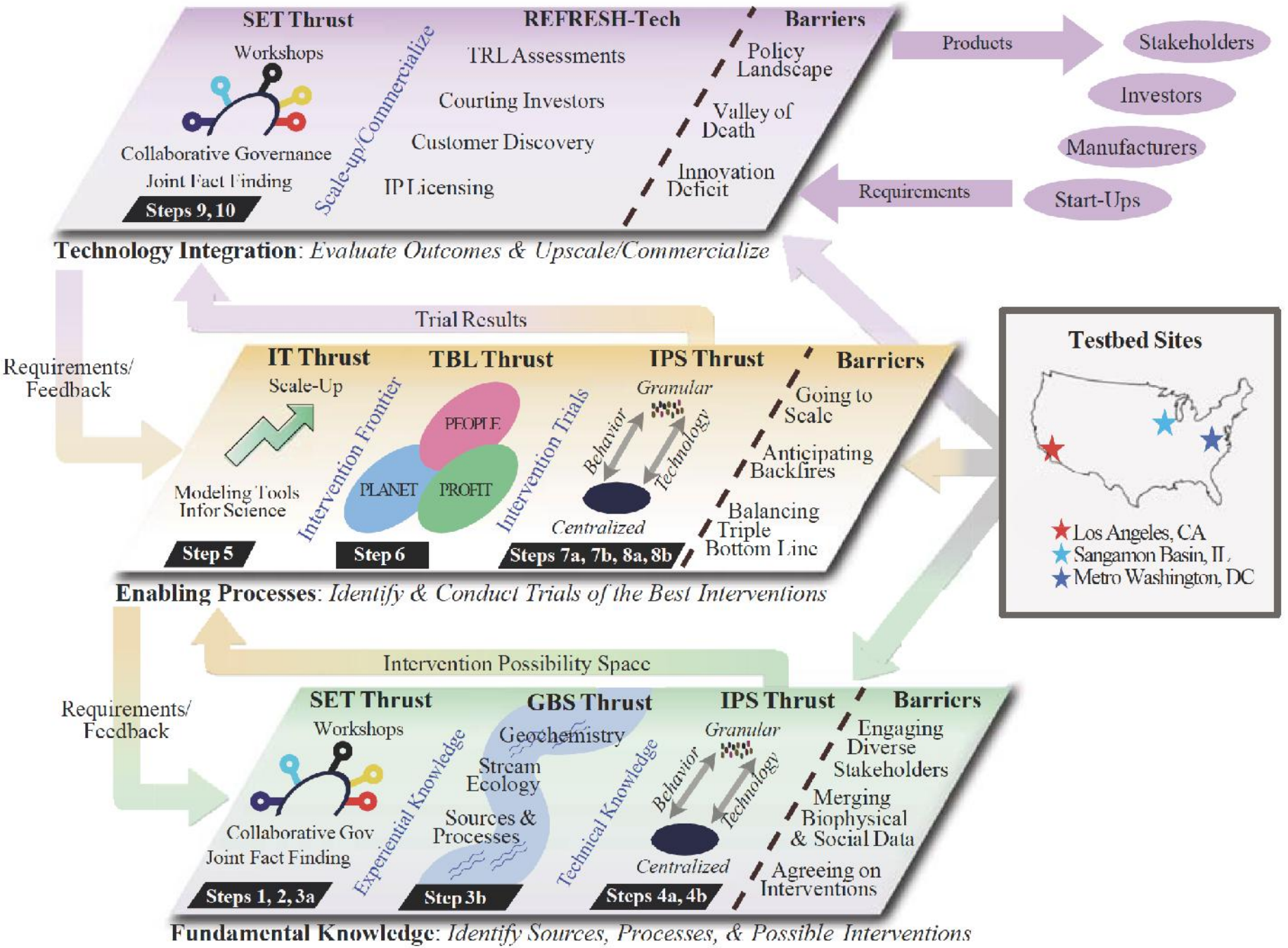


Fig. 4. Three-Plane strategic planning diagram for reversing freshwater salinization (start lower left).

Order of Operations

- **Pre-proposal** was submitted in October 2020 (from ~1000->~50 bids across all fields of engineering)--should hear about our pre-proposal in the next couple of weeks
- If pre-proposal is successful, **full proposal** is submitted in May 2021 (from ~50 bids to ~10 bids)
- If full proposal is successful, **site visit** sometime late 2021, early 2022. Awards in 2022/23.
- Funding level: $50M over 10 years plus expectation of external matching

And that's OWML's plan to save the world!