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CONTAMINANTS OF CONCERN:
Managing Lead and Manganese
WEBINAR SERIES
May 12th, 2020 | 1:00 - 2:30p.m (Mountain)
An Experiment in Environmental Leadership:
Denver Water Variance Experience
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WEBINAR MODERATOR

Craig McGonagill
Engineering Senior Specialist
Denver Water

Craig McGonagill has been working in the public utility sector since 2007. In 2014 he joined Denver Water and has worked in a variety of water quality roles. Currently he is an engineering senior specialist with the Start-Up, Commissioning, and Optimization team. He was involved in the design and implementation of Denver Water's customer lead sampling program and has played serval support roles in what has become Denver Water's Lead Reduction Program.

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PANEL OF EXPERTS

Nicole Poncelet-Johnson
Director Water Quality & Treatment
Denver Water

Tyson Ingels
Lead Drinking Water Engineer
Colorado Department of Public Health & Environment

Chris Corwin
Water Process Engineer
Corona Environmental Consulting, LLC

Chad Seidel
President
Corona Environmental Consulting, LLC

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AGENDA

I. **Denver Water's Pursuit of a Variance to the LCR Rather Than Accept Orthophosphate as OCCT -** *Nicole Poncelet-Johnson / Tyson Ingels*

II. **What we have Learned with Four Years of Pilot Studies on Harvested Lead Service Lines and Coupon Studies under Identical Conditions -** *Chris Corwin*

III. **A population Weighted Lead Exposure Model to Determine Equivalence between OCCT and the Requested Variance -** *Chad Seidel*

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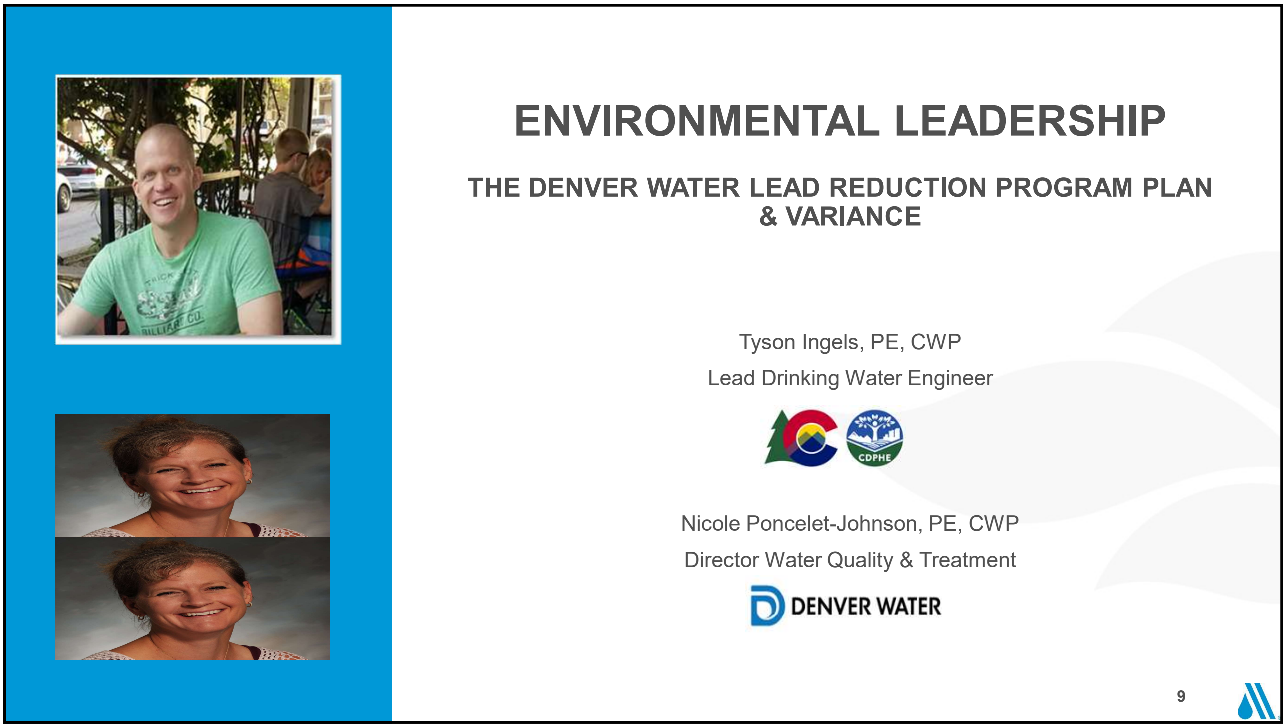
ENVIRONMENTAL LEADERSHIP
THE DENVER WATER LEAD REDUCTION PROGRAM PLAN & VARIANCE
Tyson Ingels, PE, CWP
Lead Drinking Water Engineer
CDPHE
Nicole Poncelet-Johnson, PE, CWP
Director Water Quality & Treatment
DENVER WATER
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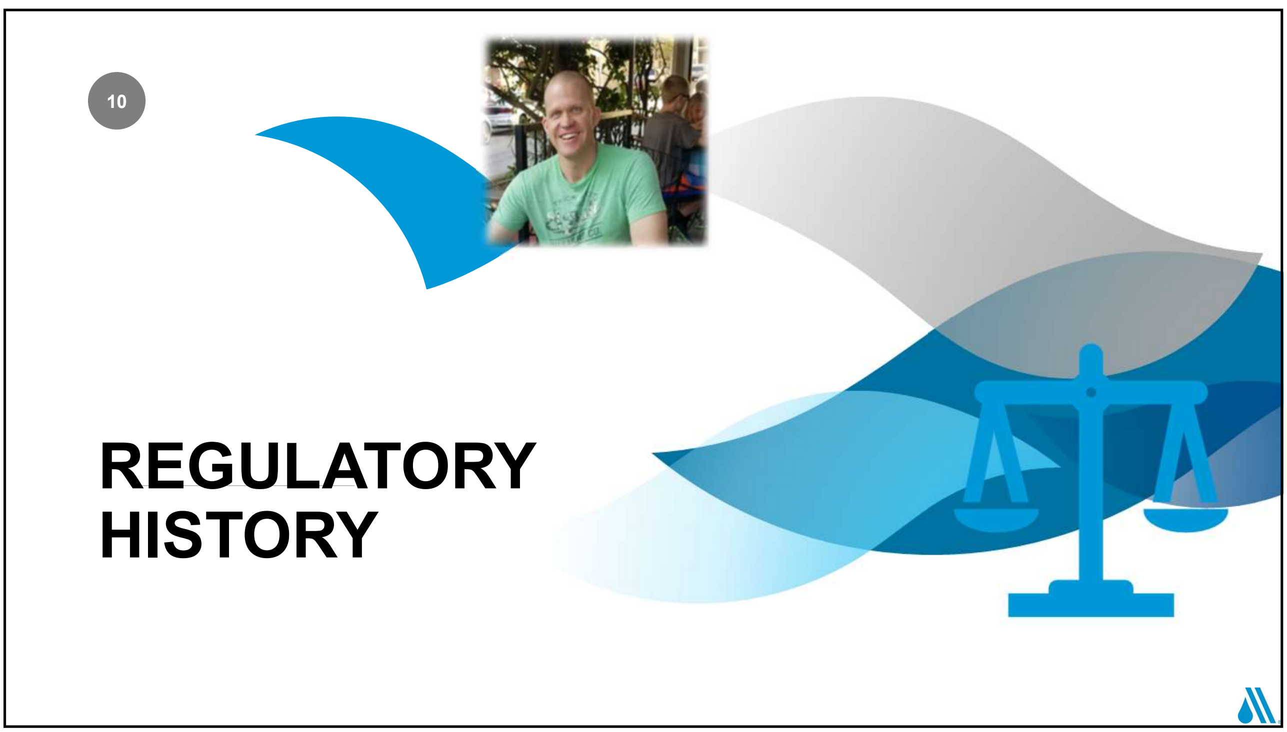
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REGULATORY HISTORY

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LEAD IN DRINKING WATER

- Lead is typically from the corrosion of drinking water service lines and household plumbing materials.
- Lead not present in Colorado drinking water sources like rivers or groundwater.
- Lead service lines were commonly installed in Denver until about 1950.
- Lead solder was used in household plumbing until 1987.

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LEAD AND COPPER RULE

- State follows federal rule closely.
- Rule is very prescriptive.
- Challenging rule due to complicated water chemistry.
- Requires two key items:
  - Monitor for lead and copper inside homes - test plumbing.
  - Use <u>*optimal corrosion control treatment (OCCT)*</u>.

Optimal Corrosion Control Treatment (OCCT) Defined:

means corrosion control treatment that minimizes the lead and copper concentrations at consumers' taps while ensuring that the treatment does not cause the water system to violate any provision of the *Colorado Primary Drinking Water Regulations*

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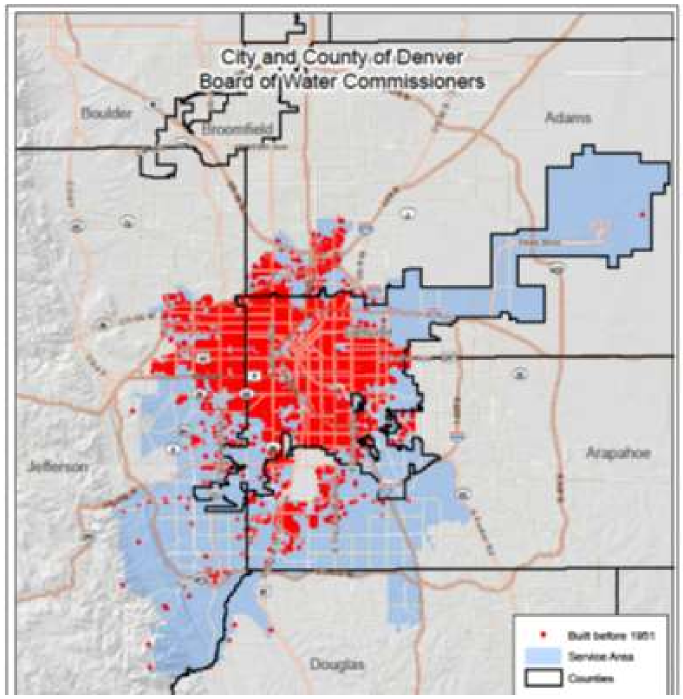
DENVER WATER SERVICE AREA

- Homes in service area that were built before 1951 are more likely to have lead service lines
- Approx 64,000 Lead Service Lines



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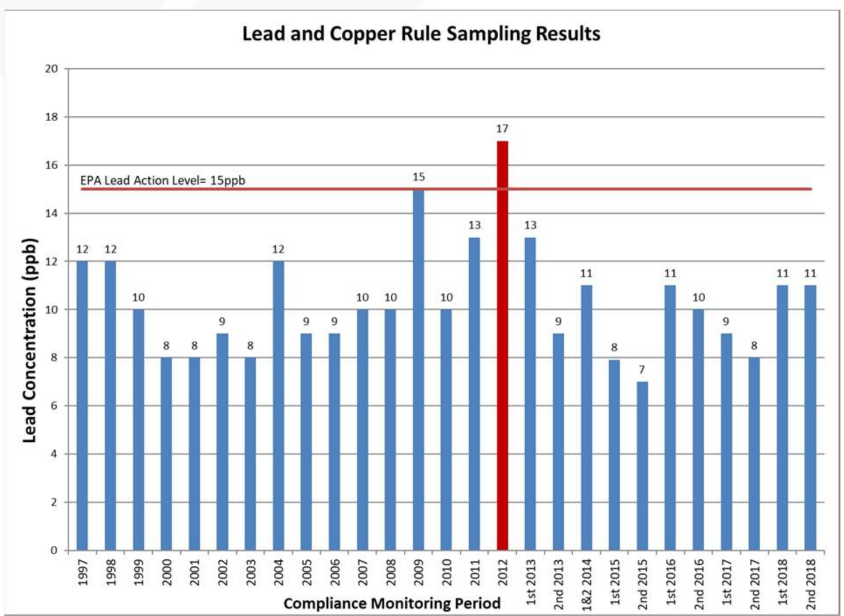
DENVER WATER LEAD AND COPPER RULE COMPLIANCE

- 2012 – action level exceedance
- CDPHE began implementing steps from the Lead and Copper rule
- CDPHE required Denver Water to perform Corrosion Control Studies



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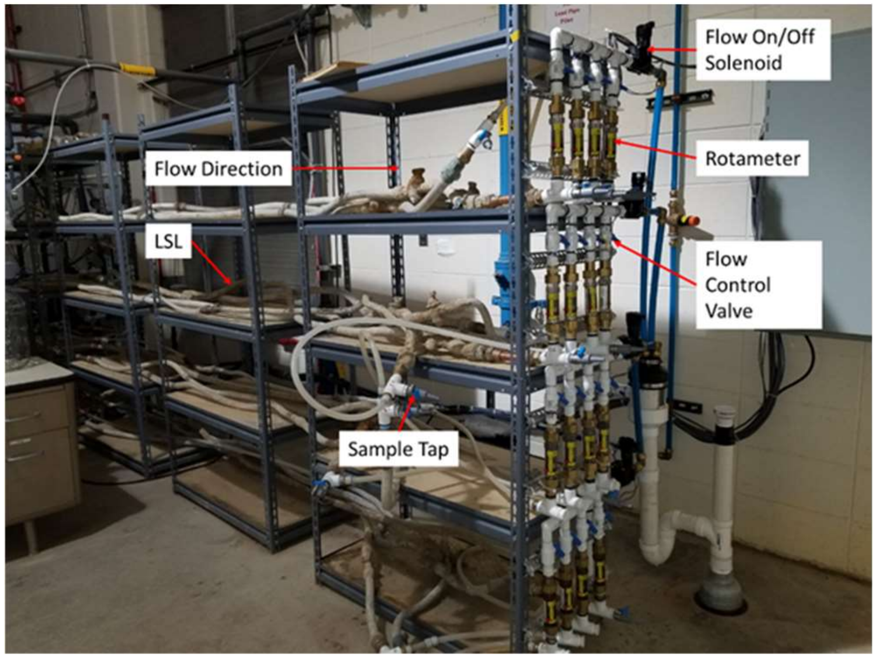
CORROSION CONTROL STUDY

- 2012 - Exceeded Action Level for lead
- 2013 - Preliminary OCCT Bench Top Analysis
- 2014 – Pilot Protocol approved by CDPHE
- 2015 – Pilot started up at Marston WTP
- 2016 – Pilot started up at Moffat WTP



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CORROSION CONTROL STUDY RESULTS SHOWING LEAD REDUCTION PERCENTAGE – SUBMITTED TO STATE IN 2017

Pilot Plant Location	pH 8.8	Orthophosphate
Marston Treatment Plant (representing 80% of Denver Water's supply)	Median Reduction: 35% to 51%*	Median Reduction: 66% to 72%*
Moffat Treatment Plant (representing 20% of Denver Water's supply)	Median Reduction: 57% to 72%*	Median Reduction: 64% to 81%*

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CORROSION CONTROL TREATMENT DESIGNATION

- **CDPHE Designated Orthophosphate as OCCT - March 20, 2018:**
  - Denver Water recommended pH/alkalinity adjustment
- **Construct and implement orthophosphate treatment by March 20, 2020.**
  - Violation if OCCT is not in operation

Marston's Lead Pipe Study, one of our two ongoing treatment pilots.

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INNOVATIVE SOLUTION

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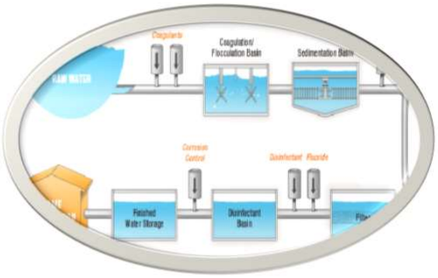
DENVER WATER'S COMMITMENT TO PUBLIC HEALTH & THE ENVIRONMENT

Protecting Public Health
1.4 Million People



Protecting Water Supplies
Wildfire, drought, nutrients, mine drainage

Can we find a solution that supports both SDWA and CWA goals?

DENVER WATER 19

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ALTERNATIVE EARLY INVESTIGATIONS

"What if happens if we combine mitigation strategies?"

8.8 pH/alkalinity CCT
\+ 7% Lead Service Line Replacement
= Equivalent to orthophosphate OCCT?

Ortho vs. Variance (Full LSLR + COE + pH/Alk)

	Current	Ortho	Variance	
Premise ID	1st Draw Prior to Treatment (HD)	80% Ortho	Full LSLR* + COE* + 40% pH/Alk	Full LSLR* + COE* + 65% pH/Alk
Home 1	5	1.0	0.1	0.1
Home 2	9	1.8	0.0	0.0
Home 3	30	6.0	0.6	0.4
Home 4	8	1.6	0.0	0.0
Home 5	2	0.4	0.0	0.0
Home 6	3.5	0.7	0.0	0.0
Average	9.6	1.9	0.1	0.1
Median	6.5	1.3	0	0

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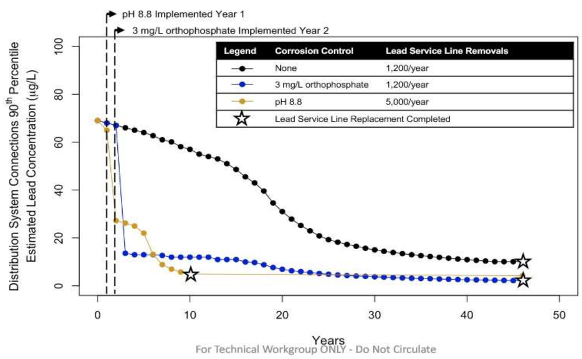
EARLY MODELING OF EQUIVALENCY

"Is this alternative better for public health?"

Distribution System Connections 90th Percentile
Model Estimated Lead Concentration (µg/L)



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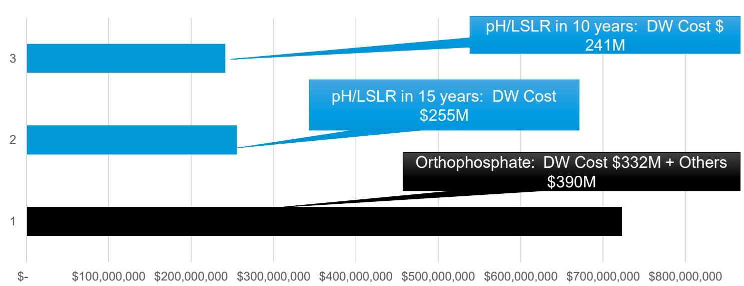
EARLY ESTIMATE OF CAPITAL COST IMPACTS

"What does it cost and who pays?"



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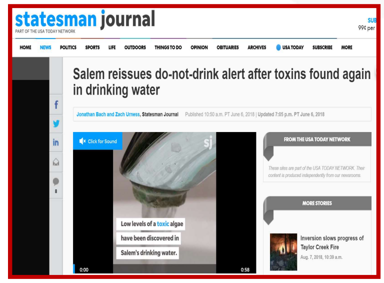
BUILDING INTERNAL CASE – MID 2018



<u>Pros and Cons of OCCT</u>
+Best treatment option to reduce lead levels (
+Relatively low cost to Denver Water
- Estimate a significant cost to regional water entities
-Regional phosphorus levels go up in dry and arid climate.
  - Consecutive water systems (ripple effect)
  - Stormwater: improvements to remove phosphorus
  - Regional WWTP: improvements to remove phosphorus
  - Regional reservoirs and streams impacted
    - Algae: reservoir treatment, drinking water treatment, customer complaints, environmental impacts

<u>Pros and Cons of pH adjustment and Lead Service Line Removal</u>
+ Good treatment option to reduce lead levels
+ Removal of lead service lines creates significant and permanent reductions in lead levels.
+ Mitigates additional phosphorus loading on watershed
- Estimate a significant cost to Denver Water rate payers

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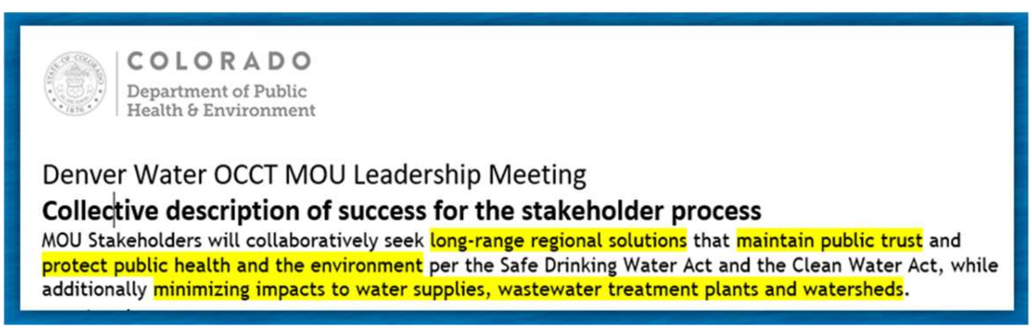
MOU REGIONAL STAKEHOLDERS



COLORADO
Department of Public Health & Environment

Denver Water OCCT MOU Leadership Meeting

Collective description of success for the stakeholder process

MOU Stakeholders will collaboratively seek long-range regional solutions that maintain public trust and protect public health and the environment per the Safe Drinking Water Act and the Clean Water Act, while additionally minimizing impacts to water supplies, wastewater treatment plants and watersheds.

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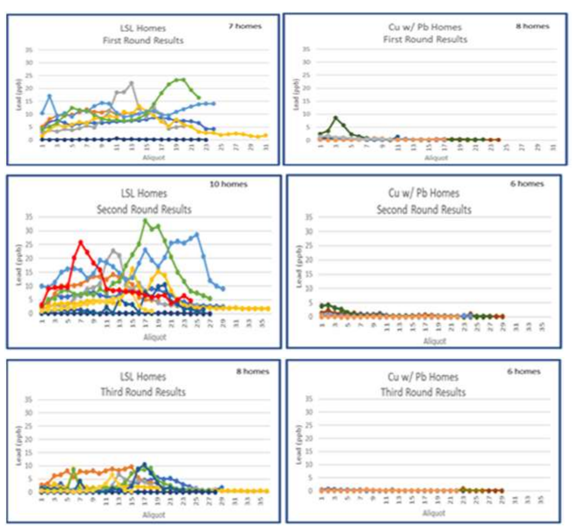
ADDITIONAL RESEARCH: LEAD FROM SERVICE LINES

Lead Lines



Copper Lines

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"Where is the lead coming from?"

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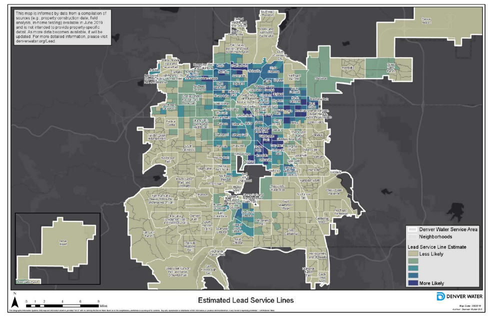
ADDITIONAL RESEARCH: LEAD SERVICE LINE INVENTORY

- Age of home < 1951
- Potholing
- WQ Sampling – 3 bottle test
- Internal Records



"Where is it located?"

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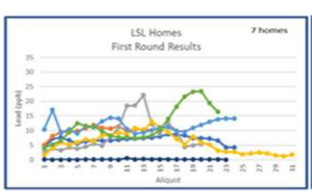
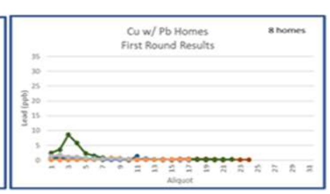
NEGOTIATIONS AND RESEARCH INTERSECT

"How do we protect customers who won't have their service line replaced in year one?"

8.8 pH/alkalinity adjustment
\+ 7% Lead Service Line Replacement
\+ Filters (NSF 53)

= Equivalent Public Health Protection ?





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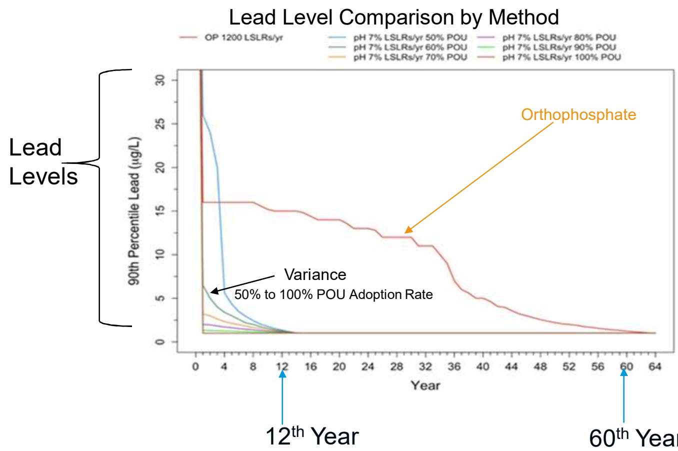
ADVANCED MODELING

- Combine LSLR, pH adjustment, filter adoption
- Achieves lowest lead levels in 15 years vs. 60 years



Based on data from lead pilots, which produces higher lead levels than seen at customer taps.

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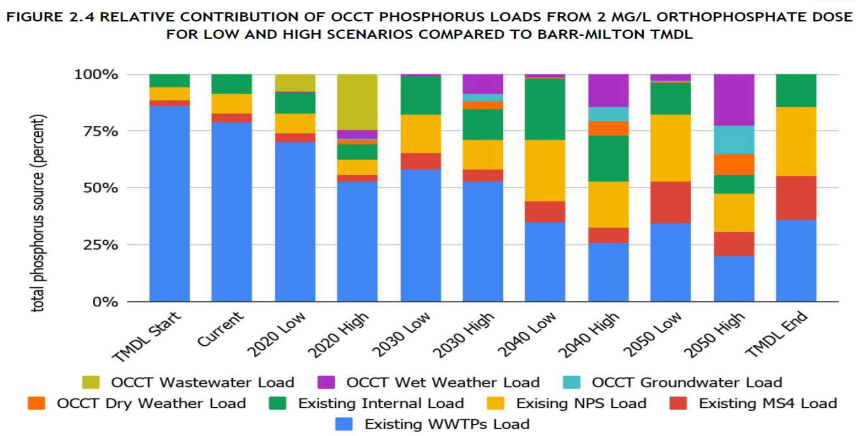
STAKEHOLDER RESEARCH: NUTRIENT LOADING TO WATERSHED*

40% of all water used for irrigation



*Source: Watershed & Wastewater Stakeholder Summary Report, CDPHE, September 2019

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STAKEHOLDER RESEARCH: POTENTIAL IMPACTS OF ORTHOPHOSPHATE

- Harmful algal blooms
- Changes in dissolved oxygen or pH (eutrophication) that could impact aquatic life
- Reduced water clarity
- Alteration of the aquatic food web
- Reduced biodiversity
- Decreased recreational and tourism opportunities that could result in economic impacts
- Changes to reservoir management and operations
- Increased treatment at drinking water facilities due to lower quality
- Impacts to diversion structures

Source: Watershed & Wastewater Stakeholder Summary Report, CDPHE, September 2019

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STAKEHOLDER RESEARCH LIFE CYCLE COST COMPARISON

Assumption	Orthophosphate (at 2 mg/L as PO_4)	Variance
Excluding Existing Service Line Replacement Efforts	$322M to $506M	$265M to $362M
Including Existing Service Line Replacement Efforts	$376M to $582M	$319M to $439M

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VARIANCE COMMITMENTS

- Denver Water submitted treatment technique variance to the Safe Drinking Water Act for Optimal Corrosion Control Treatment:
  - pH corrosion control treatment
    - Going from 7.8 s.u to 8.8 s.u.
  - Accelerated lead service line removal – no charge
    - Going from 1,200 lines/yr to 4,500 lines/yr
  - Pitcher filters for all customers with lead service lines – no charge
  - Development of lead service line inventory
  - Communication, outreach, and education

https://www.denverwater.org/your-water/water-quality/lead

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LEAD REDUCTION PROGRAM (VARIANCE) BENEFITS

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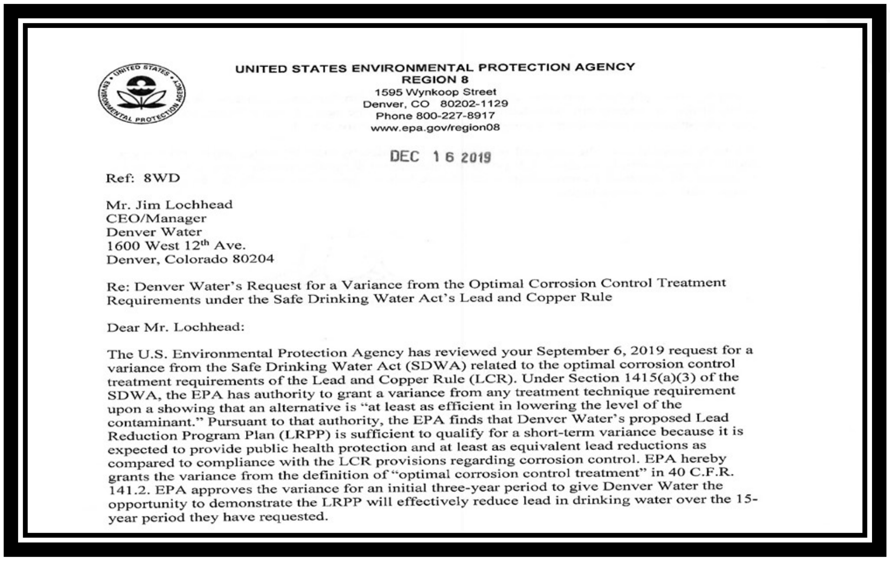
APPROVED BY EPA 12.16.19



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 8
1595 Wynkoop Street
Denver, CO 80202-1129
Phone 800-227-8917
www.epa.gov/region08

DEC 16 2019

Ref: 8WD

Mr. Jim Lochhead
CEO/Manager
Denver Water
1600 West 12th Ave.
Denver, Colorado 80204

Re: Denver Water's Request for a Variance from the Optimal Corrosion Control Treatment Requirements under the Safe Drinking Water Act's Lead and Copper Rule

Dear Mr. Lochhead:

The U.S. Environmental Protection Agency has reviewed your September 6, 2019 request for a variance from the Safe Drinking Water Act (SDWA) related to the optimal corrosion control treatment requirements of the Lead and Copper Rule (LCR). Under Section 1415(a)(3) of the SDWA, the EPA has authority to grant a variance from any treatment technique requirement upon a showing that an alternative is "at least as efficient in lowering the level of the contaminant." Pursuant to that authority, the EPA finds that Denver Water's proposed Lead Reduction Program Plan (LRPP) is sufficient to qualify for a short-term variance because it is expected to provide public health protection and at least as equivalent lead reductions as compared to compliance with the LCR provisions regarding corrosion control. EPA hereby grants the variance from the definition of "optimal corrosion control treatment" in 40 C.F.R. 141.2. EPA approves the variance for an initial three-year period to give Denver Water the opportunity to demonstrate the LRPP will effectively reduce lead in drinking water over the 15-year period they have requested.

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ACKNOWLEDGEMENTS

USEPA OW and HQ

EPA Region 8

Colorado Department of Public Health & Environment (CDPHE)

Metro Wastewater

Greenway Foundation

Aurora Water

Corona Environmental

Mott MacDonald

AECOM

Denver Water Board, Executives and highly dedicated staff

Numerous CDPHE stakeholders, advocacy groups and supporters

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DENVER WATER

CORONA ENVIRONMENTAL CONSULTING

WHAT WE LEARNED FROM PILOT STUDIES ON HARVESTED LEAD SERVICE LINE AND COUPON STUDIES UNDER SIMILAR CONDITIONS

Chris Corwin, Ph.D., P.E.
Water Process Engineer
Corona Environmental Consulting, LLC

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INTRODUCTION

- Denver Water made decision to pursue variance
- Variance relies on determination of "as efficient as"
- Performed research to gather necessary data
  - 4 year pilot
  - 17 week immersion (coupon) study

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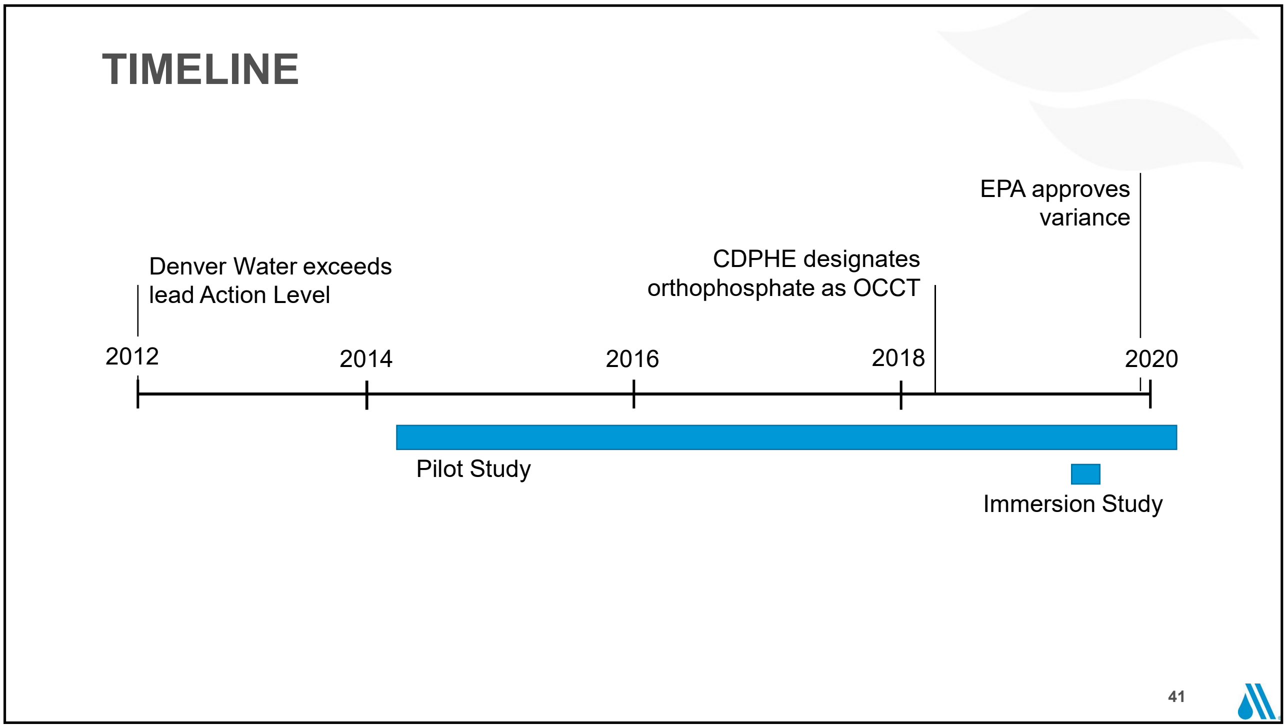
TIMELINE
EPA approves variance
Denver Water exceeds lead Action Level
CDPHE designates orthophosphate as OCCT
2012
2014
2016
2018
2020
Pilot Study
Immersion Study
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PILOT RESULTS
CONTROLLING LEAD RELEASE FROM LEAD SERVICE LINES
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PILOT DESIGN

- Pilot rigs were built at two surface water plants representing the two primary water qualities
- Rack were automated to perform 3 cycles of flush/stagnate/sample each day
- Stagnation period was 5 hours
- Stabilization period before

Rack	Condition	Chem. Add	pH	# Replicates
1	Control	None	~7.8	3
2	Ortho	1, 2, 3 mg/L PO_4	7.8	3
~~3~~	~~Silica~~	~~Si~~	~~7.8~~	~~3~~
4	pH	NaOH	8.8, 9.2	3

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TREATED WATER QUALITY

Parameter	Marston Influent Avg. (range)	Moffat Influent Avg. (range)
Temperature (°C)	13 (4-25)	12 (5-21)
pH	7.8 (7.4-9.1)	7.8 (7.2-8.3)
Alkalinity (mg/L as $CaCO_3$)	64 (36-83)	39 (14-70)
Calcium (mg/L)	30 (7-41)	16 (1-36)
Magnesium (mg/L)	8.0 (1.7-10.8)	2.9 (0.3-9.2)
Conductivity (µS/cm)	325 (35-450)	152 (92-330)
Total Chlorine (mg/L)	1.34 (0.03-8.00)	1.40 (0.12-1.78)

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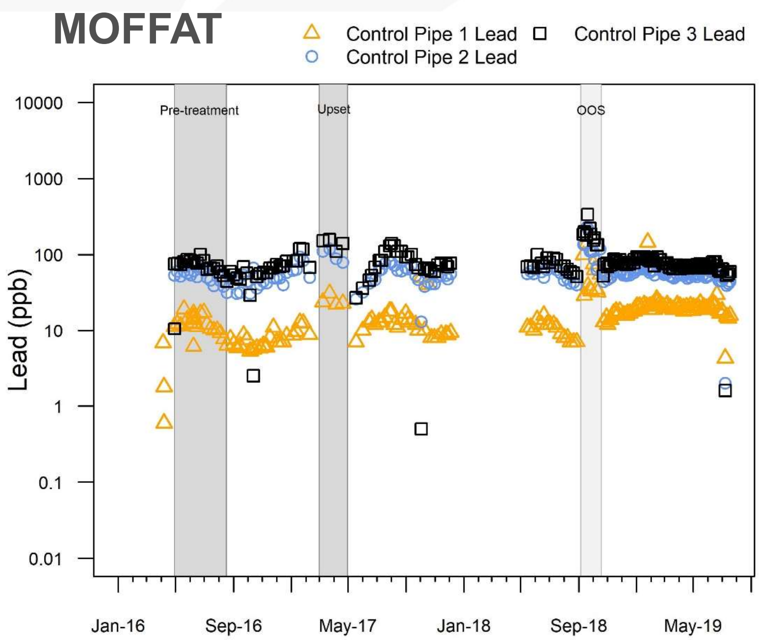
RESULTS- CONTROL RACK

- Observed significant inter-replicate variability
- Pipes responded similarly over time



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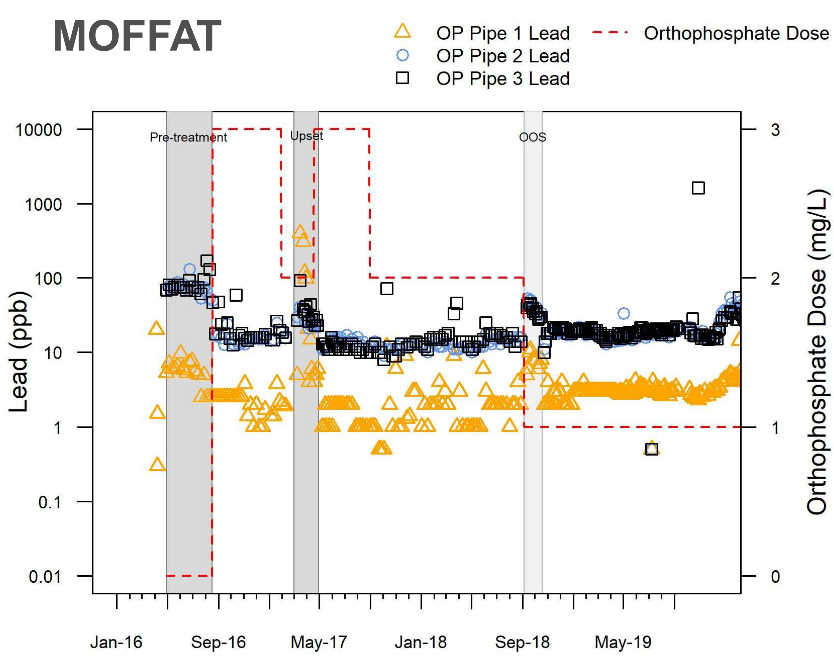
RESULTS- ORTHO RACK

- Observed significant inter-replicate variability



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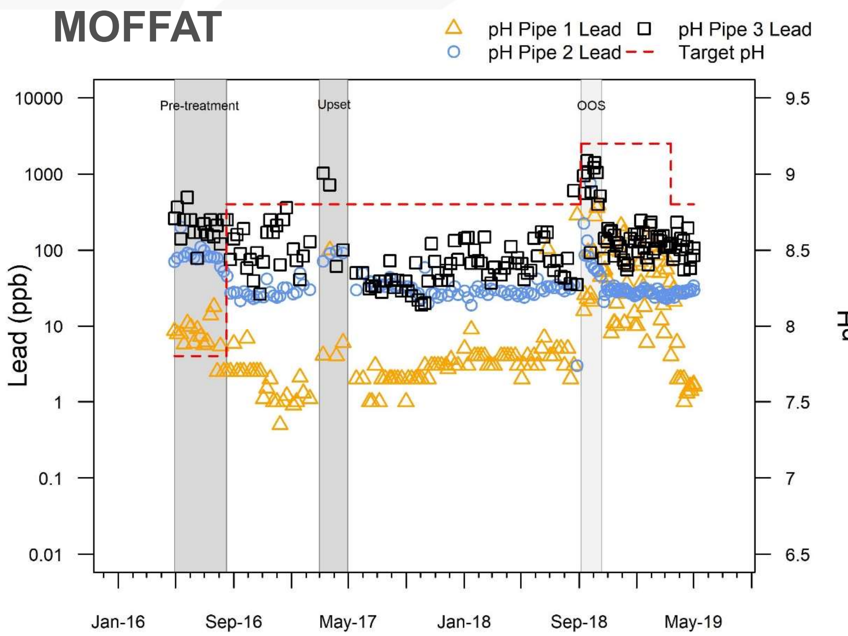
RESULTS- PH RACK

- Observed significant inter-replicate variability
- Pipes 1 & 3 showed much more variability than others
- What is a factor of pH or just of the individual pipes assigned to Rack 4?



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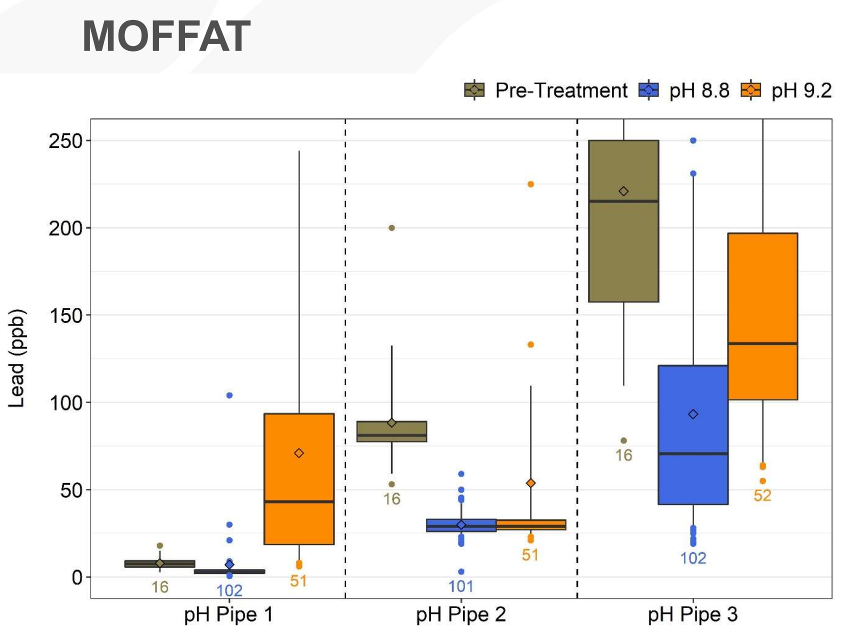
VARIABILITY- PH

- Compare B+W across panels for inter-replicate variability
- The width of the B+W represents the intra-replicate variability



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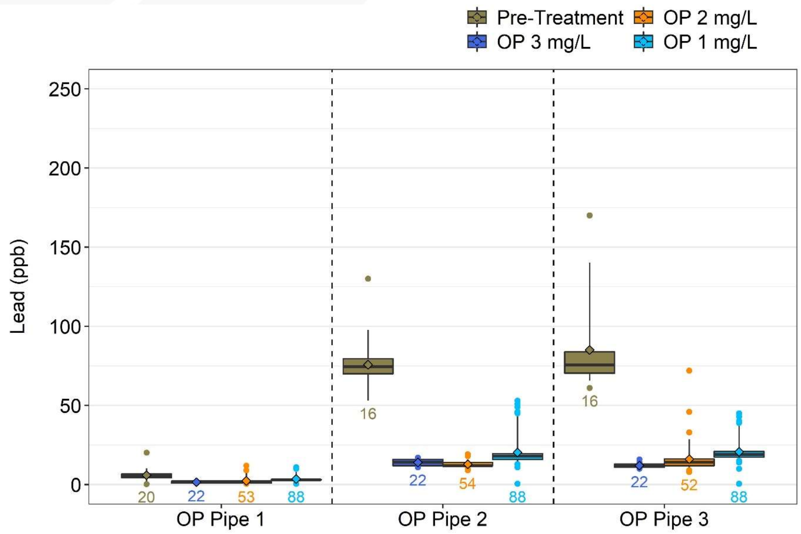
VARIABILITY-ORTHO

- Compare B+W across panels for inter-replicate variability
- The width of the B+W represents the intra-replicate variability



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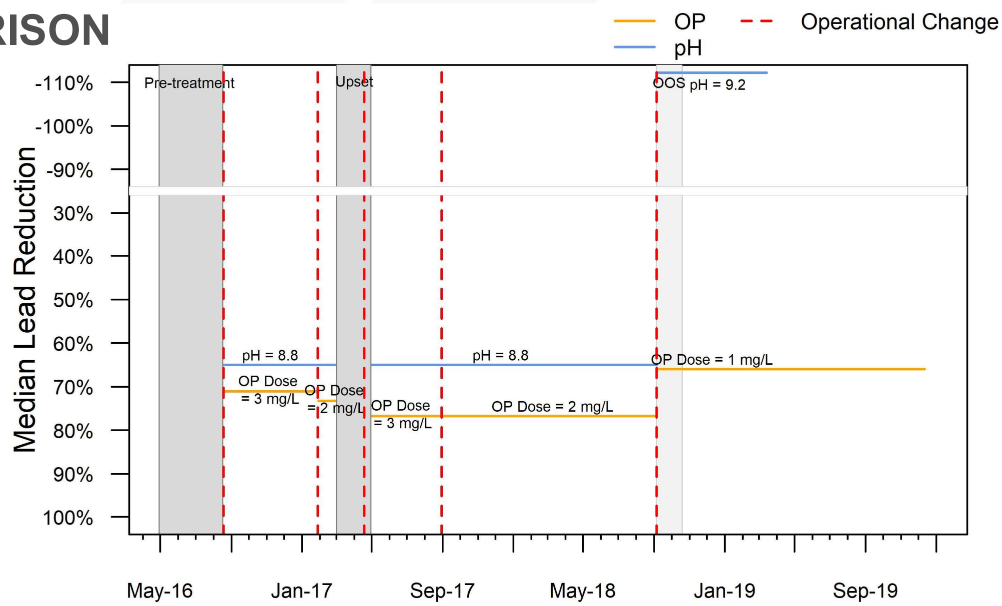
COMPARISON

MOFFAT



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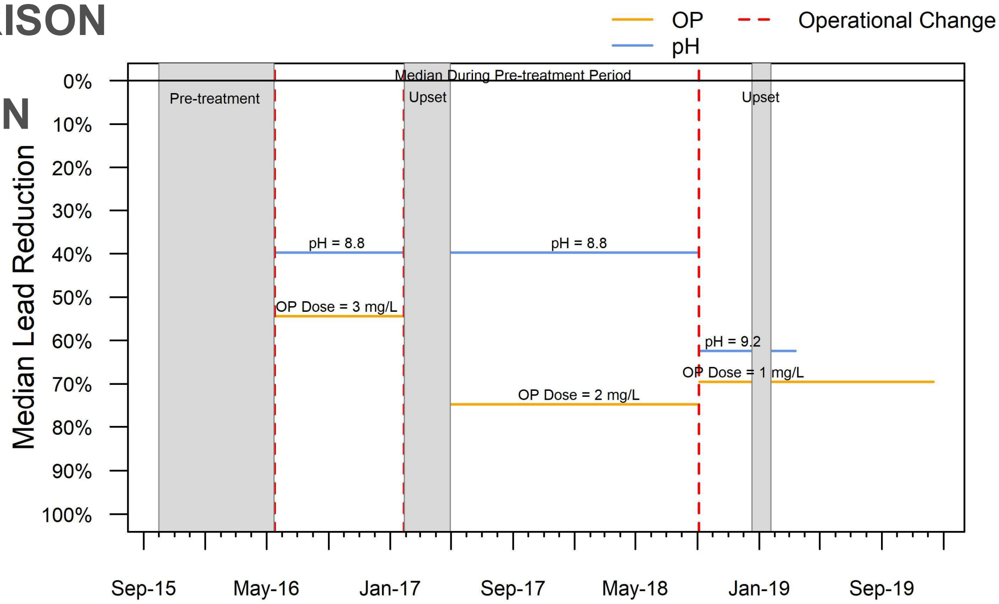
COMPARISON

MARSTON



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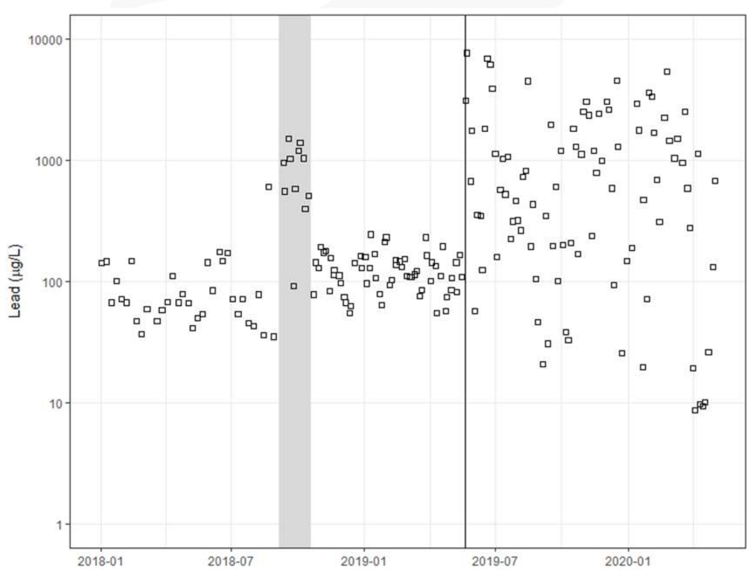
OPERATIONAL COMPLICATIONS



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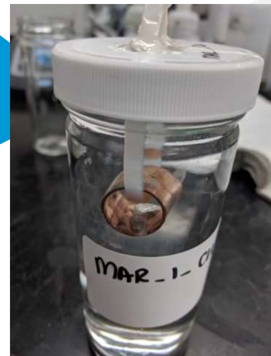

IMMERSION RESULTS

CONTROLLING LEAD RELEASE FROM LEAD SOLDER

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COUPON DESIGN – COPPER W/ LEAD SOLDER

- New copper pipe segments with weighed out 50:50 Lead/Tin solder
- 6 weeks of conditioning (no treatment), 11 weeks of treatment
- 3 water changes per week, with composite sample analyzed each week

Jars	Condition	Chem. Add	pH	# Replicates
1	Control	None	7.8	3
2	Ortho	2 mg/L PO_4	7.8	3
3	pH	NaOH	8.8	3

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TREATED WATER QUALITY

Parameter	Marston Influent	Moffat Influent
pH	7.8	7.8
Alkalinity (mg/L as $CaCO_3$)	61.2	39.9
Calcium (mg/L)	34.5	17.8
Magnesium (mg/L)	8.6	2.0
Chloride (mg/L)	26.4	3.7
Sulfate (mg/L)	65.0	17.9
Sodium (mg/L)	17.0	2.8
Conductivity (µS/cm)	362	139
CSMR	0.41	0.21

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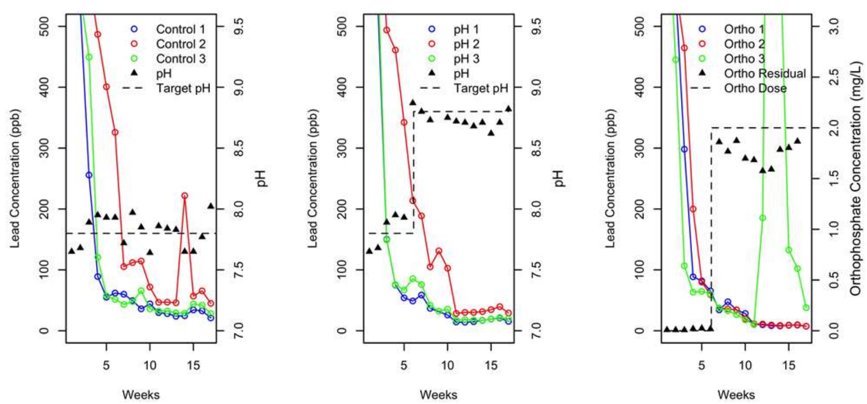
MARSTON

RESULTS- TIME SERIES

- Conditioning continued beyond 6 weeks
- Inter-replicate variability was generally low
- Intra-replicate variability was very low
- Upset conditions can still occur and last over multiple weeks



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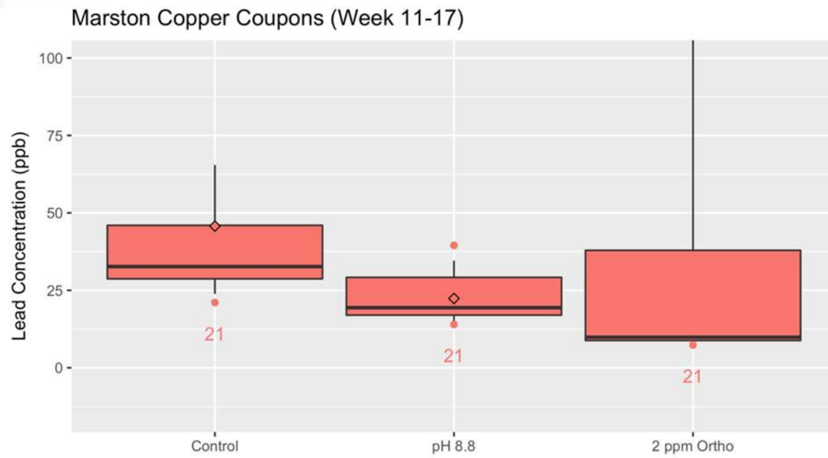
COMPARISON

MARSTON

- Compared last 7 weeks of data from treatment conditions to controls



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COMPARING PILOT & IMMERSION RESULTS

HARVESTED LEAD SERVICE LINES VERSUS NEW, PURE LEAD COUPONS

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PILOT AND IMMERSION TEST CONDITIONS

Condition	Chem. Add	pH	Source Waters
Ortho	2 mg/L PO_4	7.8	2
pH	NaOH	8.8	2

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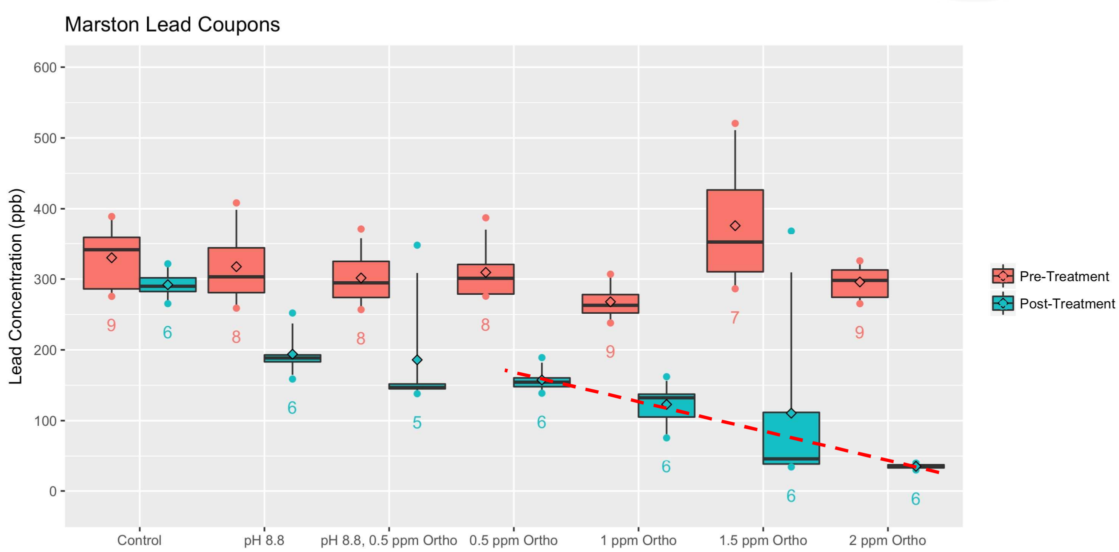
LEAD COUPON PERFORMANCE VS ORTHO DOSE



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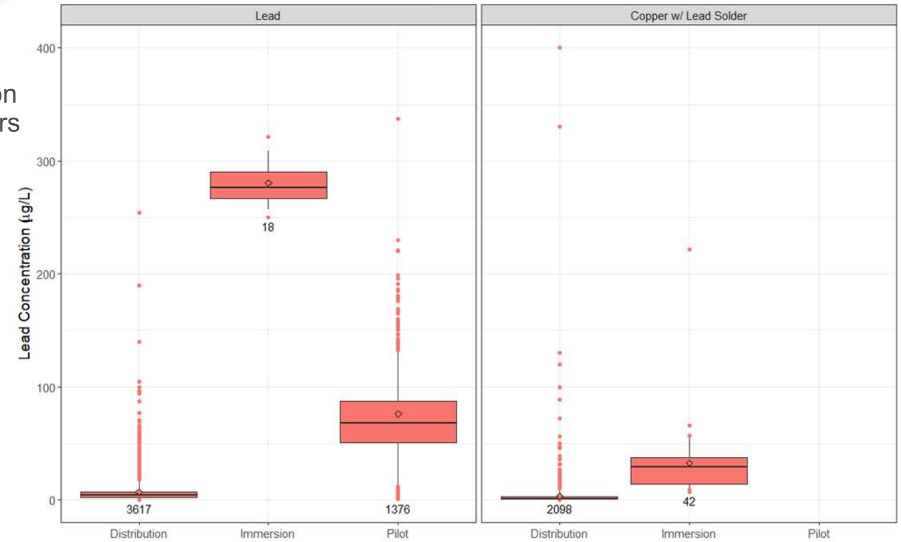
LEAD CONCENTRATION COMPARISON

- Neither pilot or immersion data were good predictors of actual lead concentrations in the distribution system



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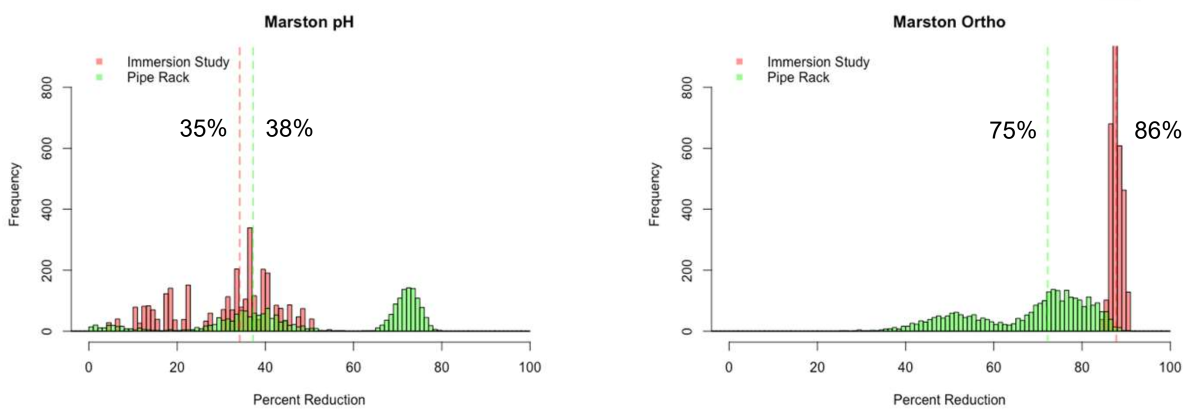
PILOT AND IMMERSION LEAD REDUCTIONS MARSTON



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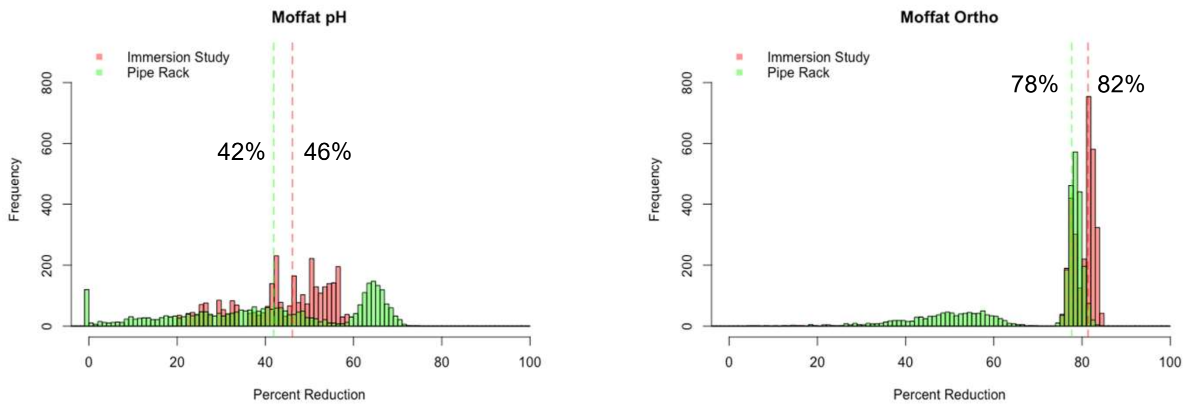
PILOT AND IMMERSION LEAD REDUCTIONS MOFFAT



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LESSONS LEARNED

	Pilot Study	Immersion Test
Captures seasonal changes	Green	Red
Captures in-situ conditions	Yellow	Red
Predicts lead concentrations	Red	Red
Prone to upset	Red	Yellow
Inter-replicate variability	Yellow	Green
Intra-replicate variability	Yellow	Green
Comparison of treatments	Green	Green
Optimize dose/pH	Yellow	Green
Time commitment	Red	Green

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ACKNOWLEDGEMENTS

Denver Water
Nicole Poncelet-Johnson
Alexis Woodrow
Ryan Walsh
Matt Bolt
Russell Plakke
Andrea Song
Cassidi Rosenkrance
Rachel Himyak

Corona Environmental
Chad Seidel
Sheldon Masters
Carleigh Samson
Sierra Johnson

Others
Selene Hernandez-Ruiz
Quirien Muylwyk – AECOM
Vernon Snoeyink
CDPHE
EPA Region 8

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DENVER WATER

CORONA ENVIRONMENTAL CONSULTING

THE EQUIVALENCY MODEL TO COMPARE THE DESIGNATED OCCT TO THE REQUESTED VARIANCE

Chad Seidel
President
Corona Environmental Consulting, LLC

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PURPOSE

Appendix II.A

Comparing Estimated Impacts of OCCT and Lead Reduction Plan Implementation on Lead Exposure at Denver Water Customers

"…**compare** the estimated impacts of the designated optimal corrosion control treatment (**OCCT**) with the Denver Water proposed Lead Reduction Plan (**LRP**) conditions **on lead exposure to Denver Water customers**."

Objective

The objective of this analysis is to compare the estimated impacts of the designated optimal corrosion control treatment (OCCT) with the Denver Water proposed Lead Reduction Plan (LRP) conditions on lead exposure to Denver Water customers.

Approach

Corona has developed and exercised a statistical model to conservatively compare the impacts of orthophosphate addition as OCCT and LRP implementation of increased pH/alkalinity with accelerated

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OVERVIEW

- Probabilistic model of lead concentrations at all service connections in the Denver Water system year-over-year:
  - impacts of orthophosphate addition as OCCT

    vs.
  - Lead Reduction Program (LRP) implementation of increased pH/alkalinity with accelerated lead service line replacement and lead filter deployment

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OVERVIEW

- Based on best data available, not perfect data
- Uses lead data from pilot racks which are known to be higher than those observed in field
- Used to determine equivalence
- ***Not representative of current or future LCR compliance data***

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COMPARING OCCT WITH LRP

OCCT: Orthophosphate

- Corrosion control using orthophosphate
- Continue current lead service line replacement of ~1,200/year

LRP: Proposed Variance

- Corrosion control using pH and alkalinity adjustment
- Accelerated lead service line replacement of 7% per year (5,190/year)
- Pitcher filters for all customers with a lead service line

How do we discern expected lead concentrations?

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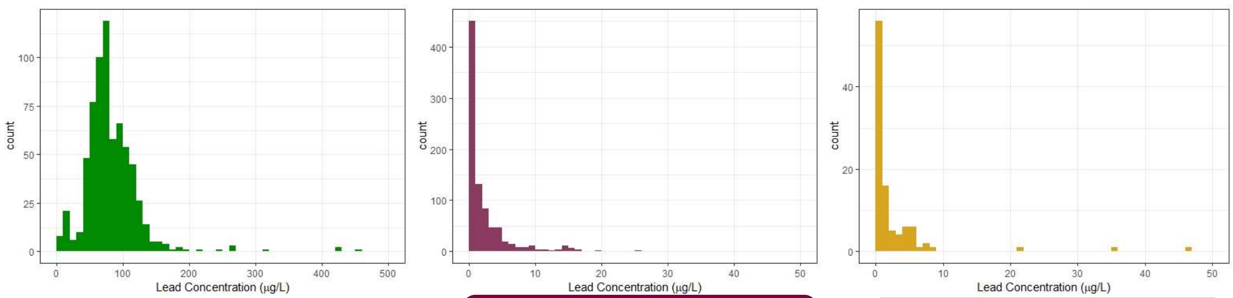
COMPARING OCCT WITH LRP

How do we discern expected lead concentrations?

- Existing service line material and associated lead concentrations

Lead Service Lines — Copper with Lead Solder Service Lines — Other Service Lines



Pipe Rack Control Concentrations

CuLS Service Lines DS Sample Results

Other Service Lines DS Sample Results

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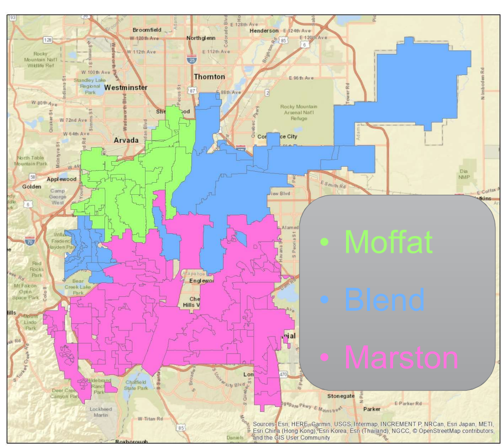
COMPARING OCCT WITH LRP

How do we discern expected lead concentrations?

- Existing service line material and associated lead concentrations
- Water source
  - Moffat
  - Marston
  - Blend



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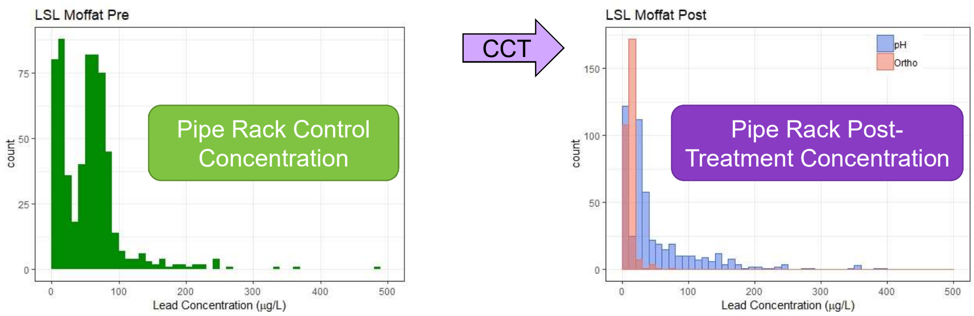
COMPARING OCCT WITH LRP

How do we discern expected lead concentrations?

- Existing service line material and associated lead concentrations
- Water source
- Corrosion control effectiveness: Ortho vs. pH
  - Pipe racks for lead service lines



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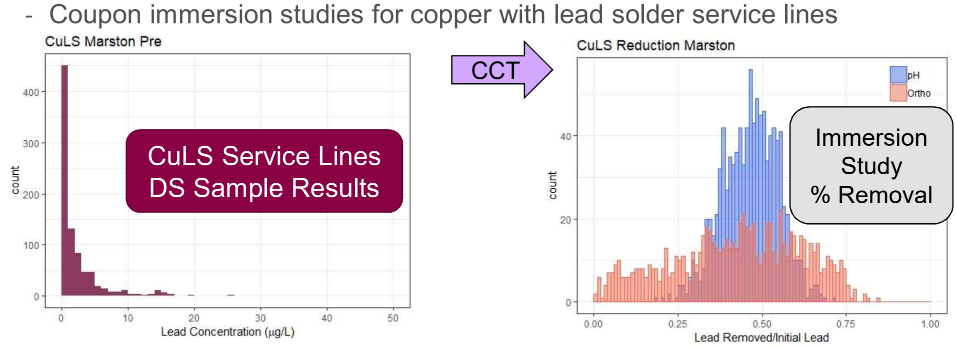
COMPARING OCCT WITH LRP

How do we discern expected lead concentrations?

- Existing service line material and associated lead concentrations
- Water source
- Corrosion control effectiveness
  - Pipe racks for lead service lines
  - Coupon immersion studies for copper with lead solder service lines



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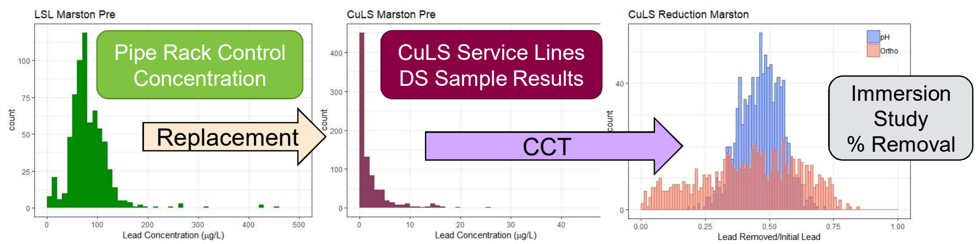
COMPARING OCCT WITH LRP

How do we discern expected lead concentrations?

- Existing service line material and associated lead concentrations
- Water source
- Corrosion control effectiveness
  - Pipe racks for lead service lines
  - Coupon immersion studies for copper with lead solder service lines
- Lead service line replacement



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COMPARING OCCT WITH LRP

How do we discern expected lead concentrations?

- Existing service line material and associated lead concentrations
- Water source
- Corrosion control effectiveness
  - Pipe racks for lead service lines
  - Coupon immersion studies for copper with lead solder service lines
- Lead service line replacement
- Pitcher filter effectiveness and adoption rate

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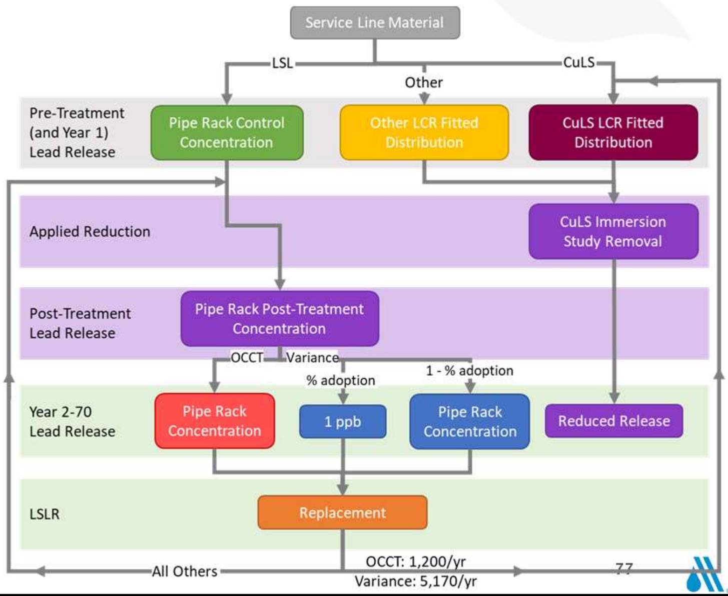
EQUIVALENCY MODEL CONFIGURATION FLOWCHART

- Estimates lead exposure for all connections each year for OCCT and LRP conditions



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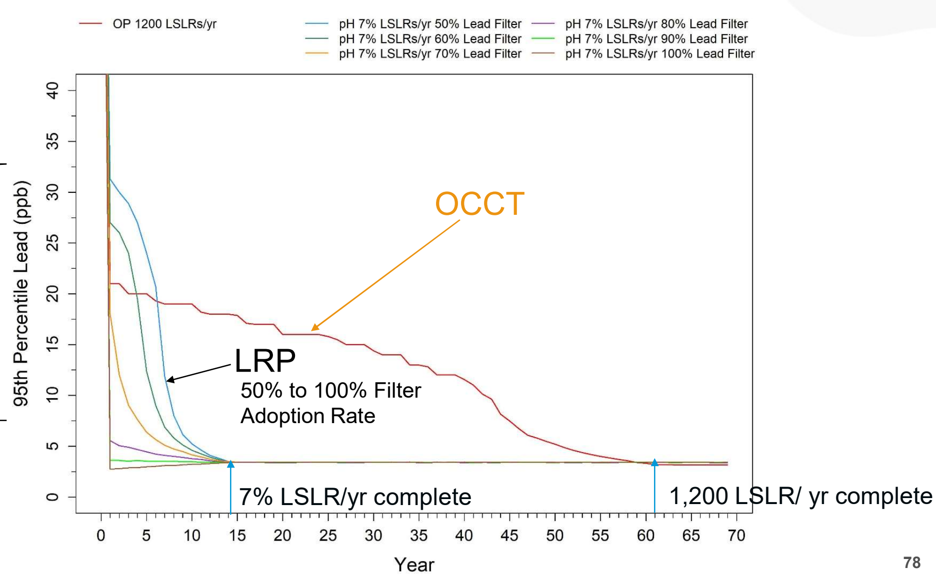
MODEL SUMMARY: 95TH PERCENTILE LEAD CONCENTRATIONS OVER TIME

Model Estimated 95th Percentile Lead Levels



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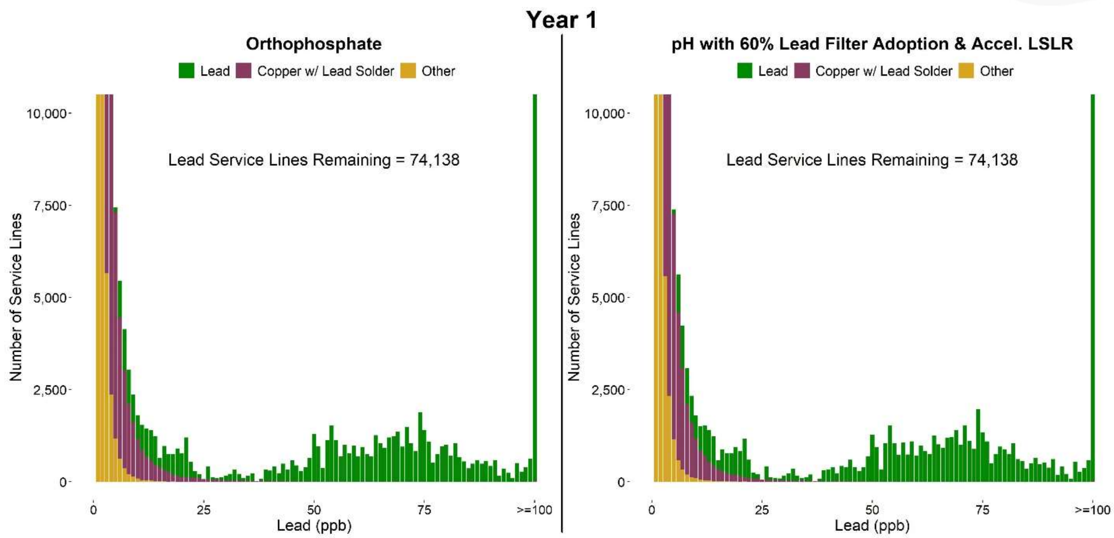
EQUIVALENCY MODEL RESULTS FOR SELECT YEARS AT 60% FILTER ADOPTION



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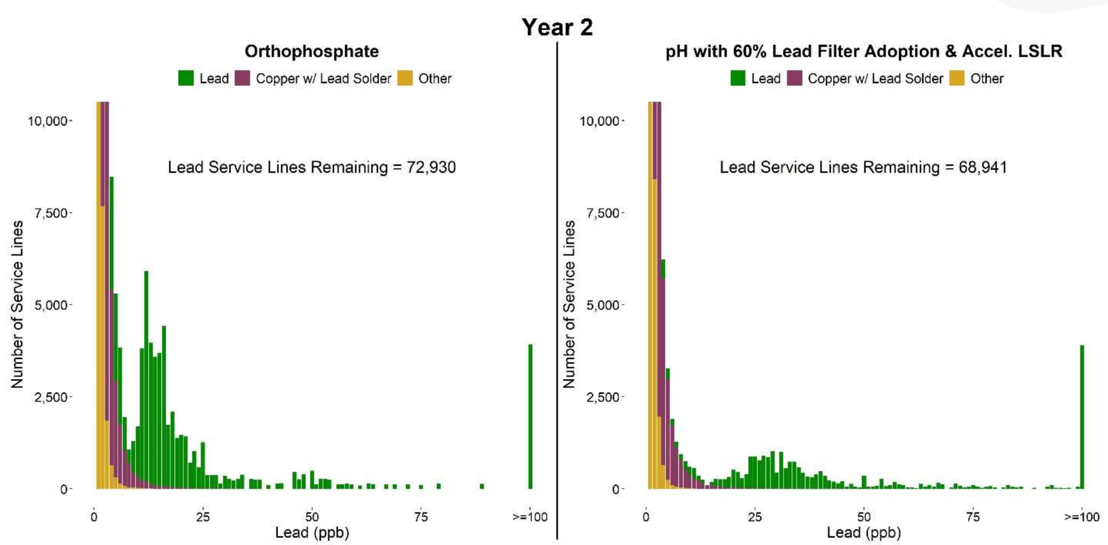
EQUIVALENCY MODEL RESULTS FOR SELECT YEARS AT 60% FILTER ADOPTION



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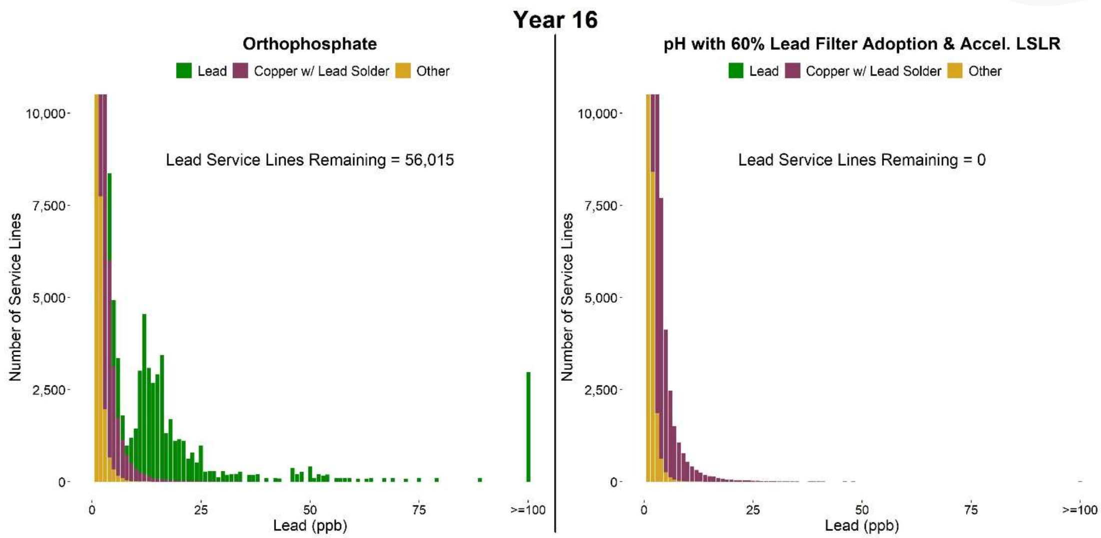
EQUIVALENCY MODEL RESULTS FOR SELECT YEARS AT 60% FILTER ADOPTION



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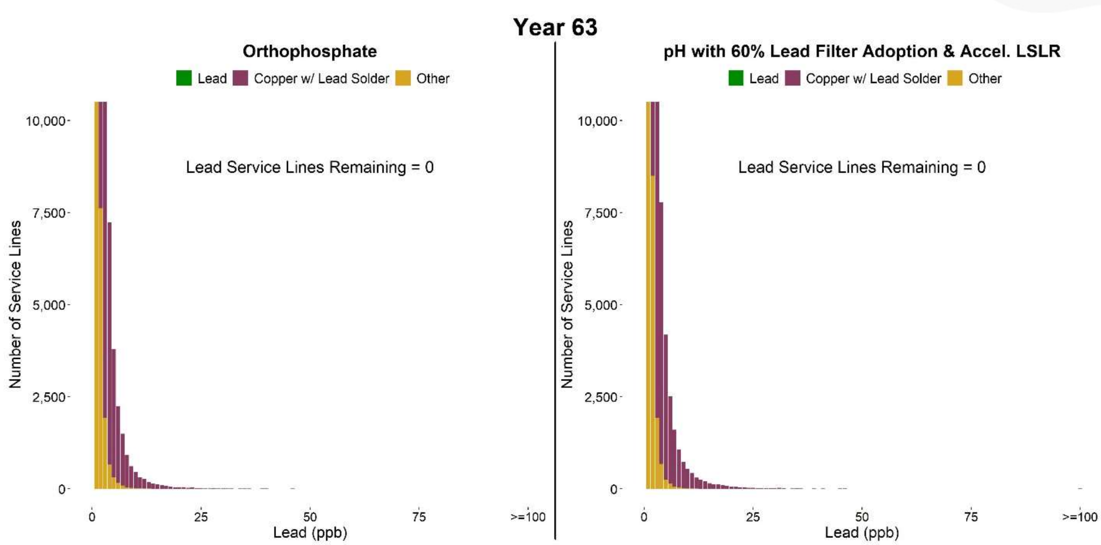
EQUIVALENCY MODEL RESULTS FOR SELECT YEARS AT 60% FILTER ADOPTION



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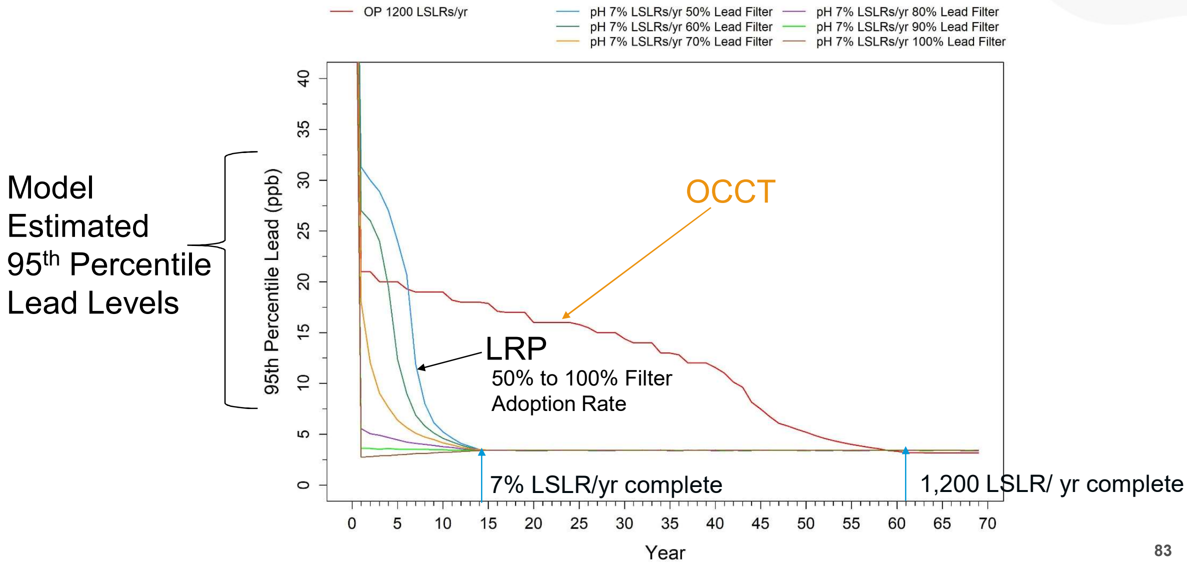
MODEL SUMMARY: 95TH PERCENTILE LEAD CONCENTRATIONS OVER TIME



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SUMMARY

- “Implementing the LRP conditions achieves equivalent or greater lead reductions than OCCT implementation alone”
- Variance Order specifies the use of the Equivalency Model for compliance determination

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CONCLUSION

- "The studies show that the comprehensive approach of accelerated lead service line replacement, filter distribution and pH/alkalinity adjustment will be more efficient at reducing lead releases compared with the use of orthophosphate alone while reducing impacts to wastewater treatment plants and the environment."

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ASK THE EXPERTS

Nicole Poncelet-Johnson
Denver Water

Tyson Ingels
CDPHE

Chris Corwin
Corona Environmental Consulting, LLC

Chad Seidel
Corona Environmental Consulting, LLC

Enter your **question** into the **question pane** at the lower right hand side of the screen.

Please specify to whom you are addressing the question.

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- **Corrosion Control (Contaminants of Concern: Managing Lead and Manganese)**
- **May 22 - 1:00 PM - 2:30 PM**
- **Strategies for Understanding and Managing Risk from Lead (Contaminants of Concern: Managing Lead and Manganese)**
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PRESENTER BIOGRAPHY INFORMATION

- Nicole Poncelet-Johnson is a professional engineer with over 25 years of experience in water and wastewater utility operation, construction, and management and has served as the Director of Water Quality and Treatment at Denver Water since 2017. Starting in 2018, Nicole lead Denver Water's efforts to research and identify an alternative solution to orthophosphate as optimal corrosion control treatment, which has since evolved into Denver Water's Lead Reduction Program and variance. She's a graduate of Purdue University's Civil Engineering program and holds Colorado Class A operator licenses in water and wastewater treatment.

- Tyson Ingels is the Lead Drinking Water Engineer for CDPHE. His responsibilities include technical justification for new policy and regulation, acceptance of alternative technologies (e.g. membranes, UV disinfection) within the State, as well as acting as technical expert both on DW design review issues and inspection issues. Mr. Ingels also is primary contact responsible for Drinking Water emergencies and acute situations within Colorado

- Dr. Chris Corwin has over 15 years of experience as a professional engineer and project manager providing the drinking water community with services in process planning, treatment optimization, bench testing, and pilot testing. His research has been published in ES&T, Water Research, and Journal of American Water Works Association.

- Chad Seidel, Ph.D., P.E. is President of Corona Environmental Consulting, LLC and an active member of the AWWA Inorganic Contaminants Research Committee. He focuses on improving public health protection by solving water-related engineering, science, and policy challenges.

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