Evaluation of Risk Factors for Integrating a New Supply

AWWA-PNWS Quarterly Webinar

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confluence
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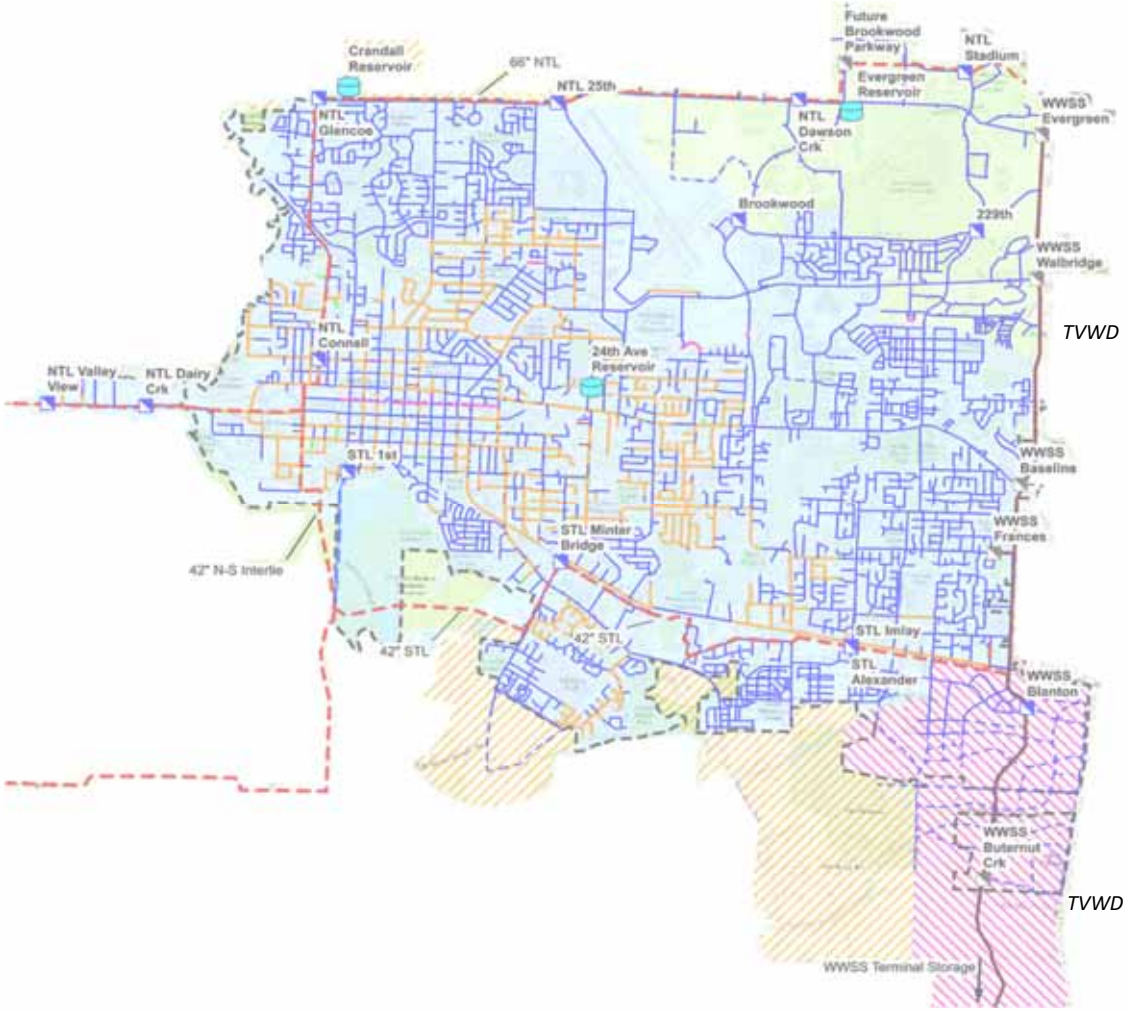
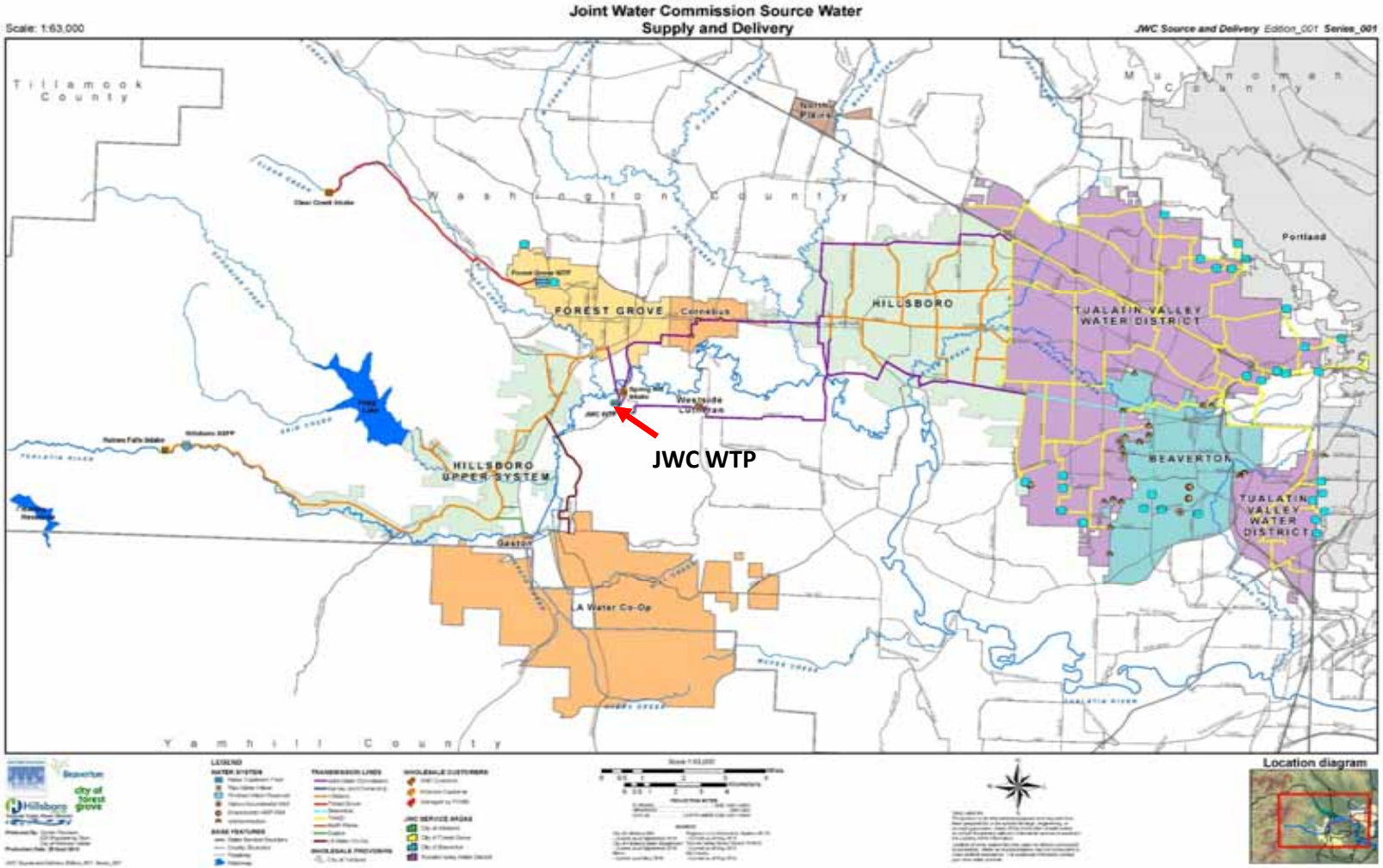
Hillsboro OREGON

System Information

- JWC is currently the only supply, 12 turnouts from NTL & STL
- WWSS introduced from the east side of the system
- Three in-town reservoirs:
  - 30.5 MG total, booster chlorination systems



Joint Water Commission



JWC Finished Water Quality

- Sources are Tualatin River, Hagg Lake, and Barney Reservoir
- Average free chlorine residual is 1.21 mg/L
- Average pH is 7.7 s.u.
  - WQP is pH 7.2 s.u.
- Average Total Organic Carbon is 0.79 mg/L

Hillsboro OREGON

Water Quality

- Average chlorine residual is 0.81 mg/L
- Average pH in system is 7.9
  - WQP of pH 7.2
- LCR Compliance - typical 90th% is
  - Pb: 2 ppb
  - Cu: 85 ppb
- DBPs typically 50% of MCLs
- Historically conventional flushing in response to WQ readings and customer calls
- Typical water age range 3-14 days

Anticipated changes with WWSS introduction

Flow Direction & Max. Velocity

- Flow reversals expected in eastern portion of system
- Velocities are not expected to change

Water Age

- Water age not expected to change
- Potential to develop a stagnation zone, reservoir operations will be key to controlling water age

Chemistry

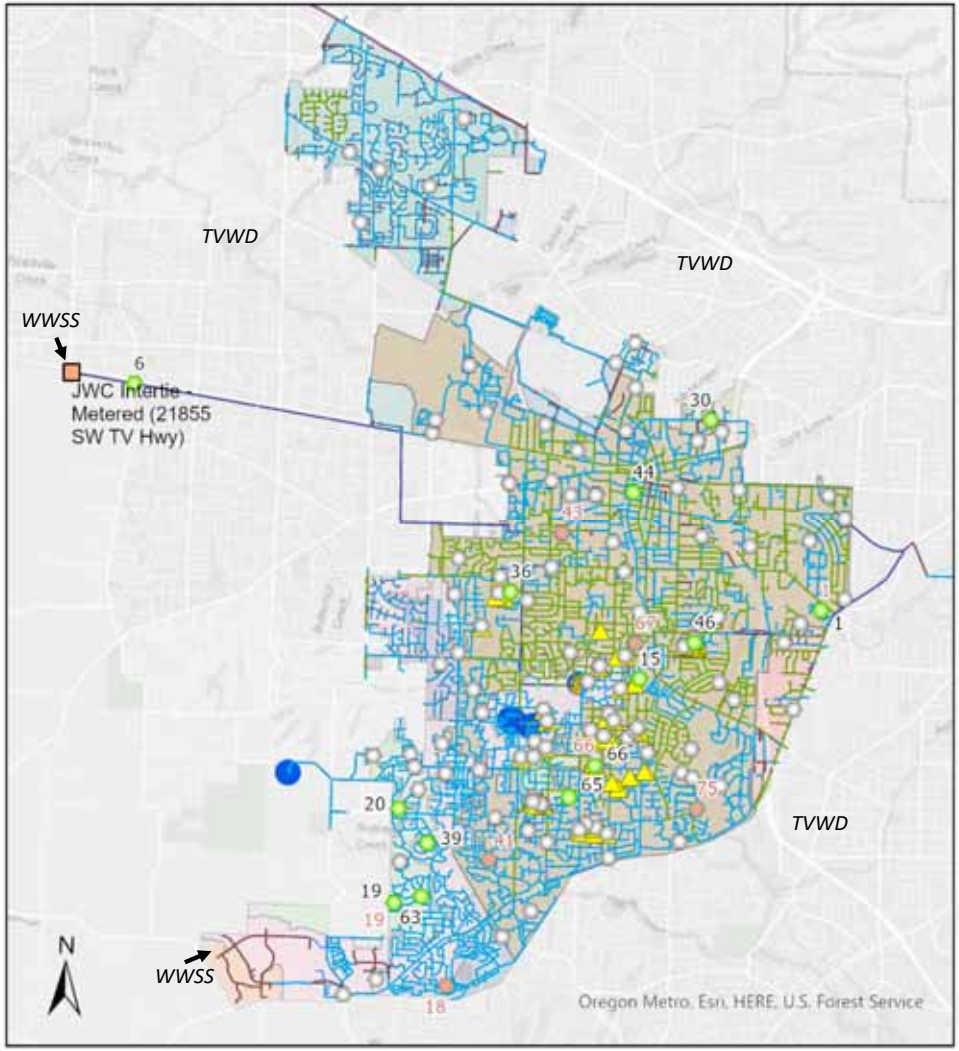
- Currently stable, blending zone will be created
- WWSS will bring quality water similar to JWC

Source Contribution

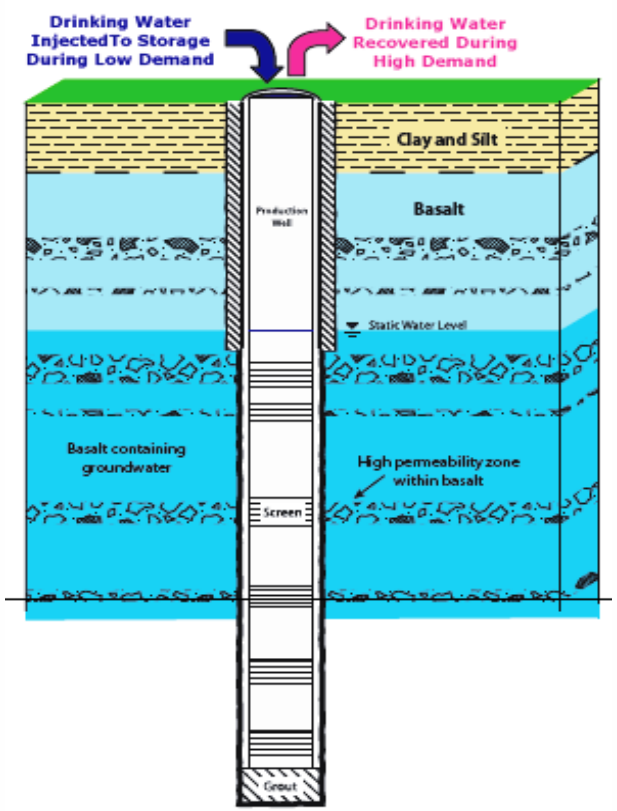
- UDF recommended prior to WWSS introduction in localized areas

System Information

- Existing Supplies:
  - JWC
  - Two ASR Wells (Sorrento Site)
- WWSS will be a new supply that will be fed from the south and through current JWC intertie.
- Booster chlorination at JWC POE, Sexton and Cooper Mountain Reservoirs (blue circles)



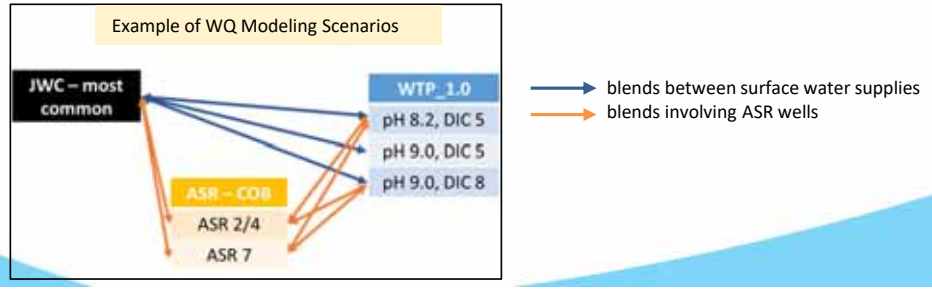
Aquifer Storage and Recovery (ASR) Wells



- Second municipality in Oregon to develop ASR, and have been successfully operating ASR wells since 1998.
- Two active ASR wells (ASR2, ASR4), 5 mgd capacity
- Currently in ASR expansion phase with three future ASR wells (ASRs 5, 6, 7)

ASR Water Quality (WQ)

- Recovered WQ varies over time (Beginning vs End of recovery)
- Modeling conditions included WQ near end of most recent recovery cycles



Anticipated changes with WWSS introduction

Flow Direction & Max. Velocity

- Flow reversals are normal in the system currently, no change expected
- Velocity increase likely in one area

Water Age

- Water age expected to reduce slightly

Chemistry

- Currently stable
- WWSS will bring similar quality water

Source Contribution

- Additional information on existing deposits needed
- UDF or swabbing trials will likely be recommended

TUALATIN VALLEY
WATER DISTRICT

TVWD existing supplies

- Portland Water Bureau (PWB)
  - pH target = 8.2 – 8.5*
  - Chloramines = 2.2 – 2.5 mg/L
  - Currently unfiltered
  - Surface and groundwater
- JWC & ASR

TVWD future supplies

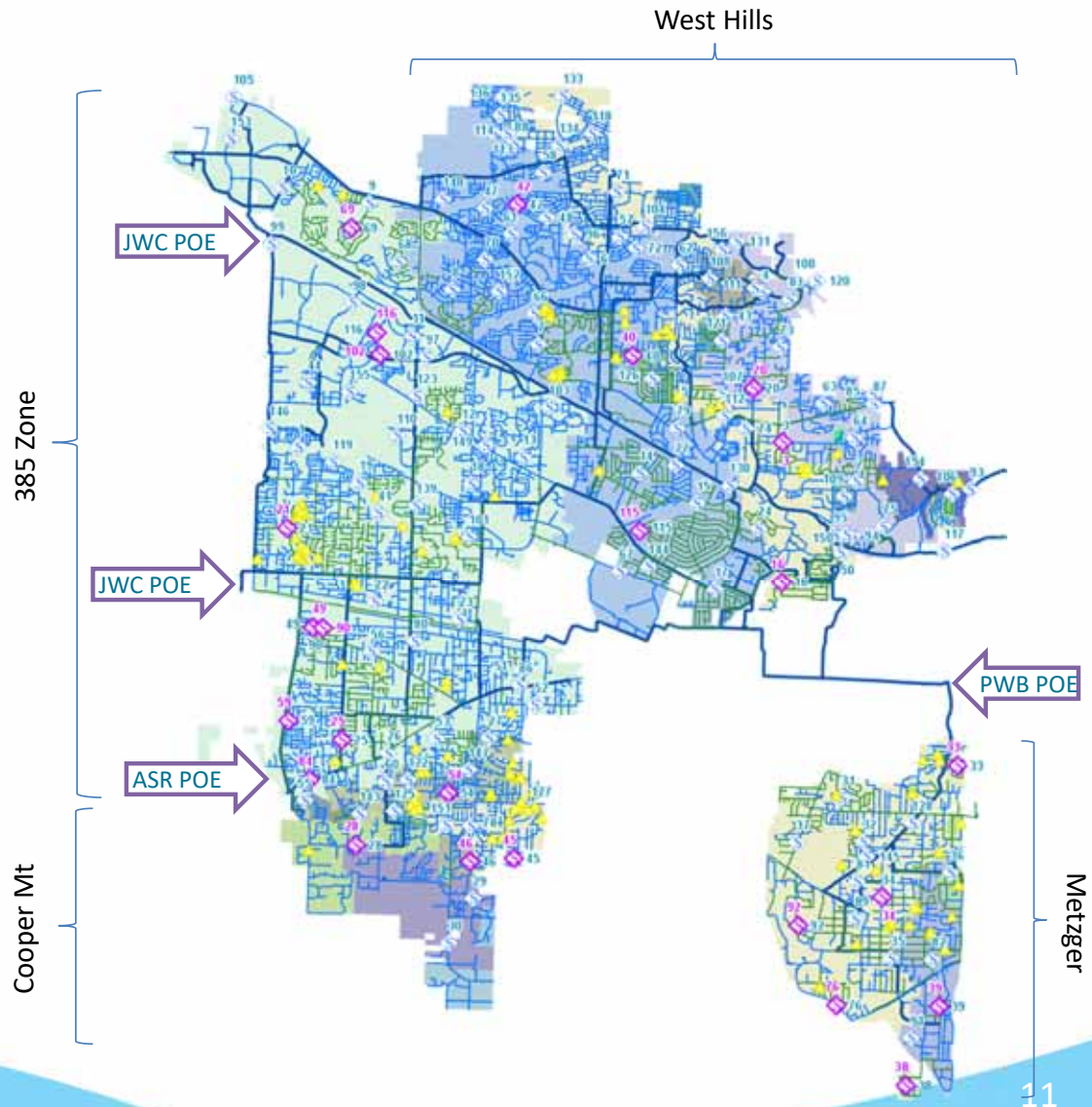
- WWSS, JWC, & ASR

*pH 8.5 being implemented in April 2022 by PWB under OCCT

TUALATIN VALLEY
WATER DISTRICT

Current system information

- WWSS will fully replace PWB supply
- System divided into operational areas and blending zones for WSI Project
  - Metzger — PWB
  - West Hills — PWB & JWC
  - 385 Zone — PWB, JWC, & ASR
  - Cooper Mt — PWB, JWC, & ASR



TUALATIN VALLEY
WATER DISTRICT

Continuous monitoring occurs at EPs and system facilities (50+ analyzers)

- PWB and JWC EPs, ASR facility, pump stations, reservoirs
- NTU, pH, free and total Cl2, conductivity, temp, fluoride

System sampling at over 150 strategic locations (350-500+ monthly)

- Coliform/*E. coli*, pH, temp, conductivity, total Cl2
- Special or periodic (DBPs, ATP, nitrification, ORP), 120 LCR homes annually
- Nearly 20 years of proactive UDF

TUALATIN VALLEY WATER DISTRICT

Anticipated changes with WWSS introduction

Flow Direction & Max. Velocity

- Flow reversals expected in eastern portion of system
- Velocities are not expected to change

Water Age

- Water age increases in West Hills, investigating operational controls
- Water age decreases in most of Cooper Mtn and Metzger
- Potential to develop areas of stagnation

Chemistry

- Currently variable chemistry will stabilize
- WWSS will bring similar quality water to JWC
- WWSS pH needs to be higher than JWC to prevent lead release

Source Contribution

- Adjusted UDF schedule being developed to support WWSS introduction
- Swabbing trials will likely be recommended to investigate existing biofilm accumulations

Risk Factor Assessment Approach

- Review available system information
  - Water quality data in the distribution system
  - Deposit/pipe wall accumulation and inventory
  - Hydraulics and information on distribution system mains
  - Key customers
  - Customer complaints
- Develop rationale for selection of monitoring locations for detailed assessment
- Conduct detailed evaluation of available data
  - Statistical approach for assessing key water quality parameters
    - Box and whisker plots
    - Seasonal and spatial assessment
  - Assessment of regulatory compliance parameters
  - Comparison with the Partnership for Safe Drinking Water Distribution Systems Optimization Program (performance indicators)
- Identify gaps
- Summarize and rank risks

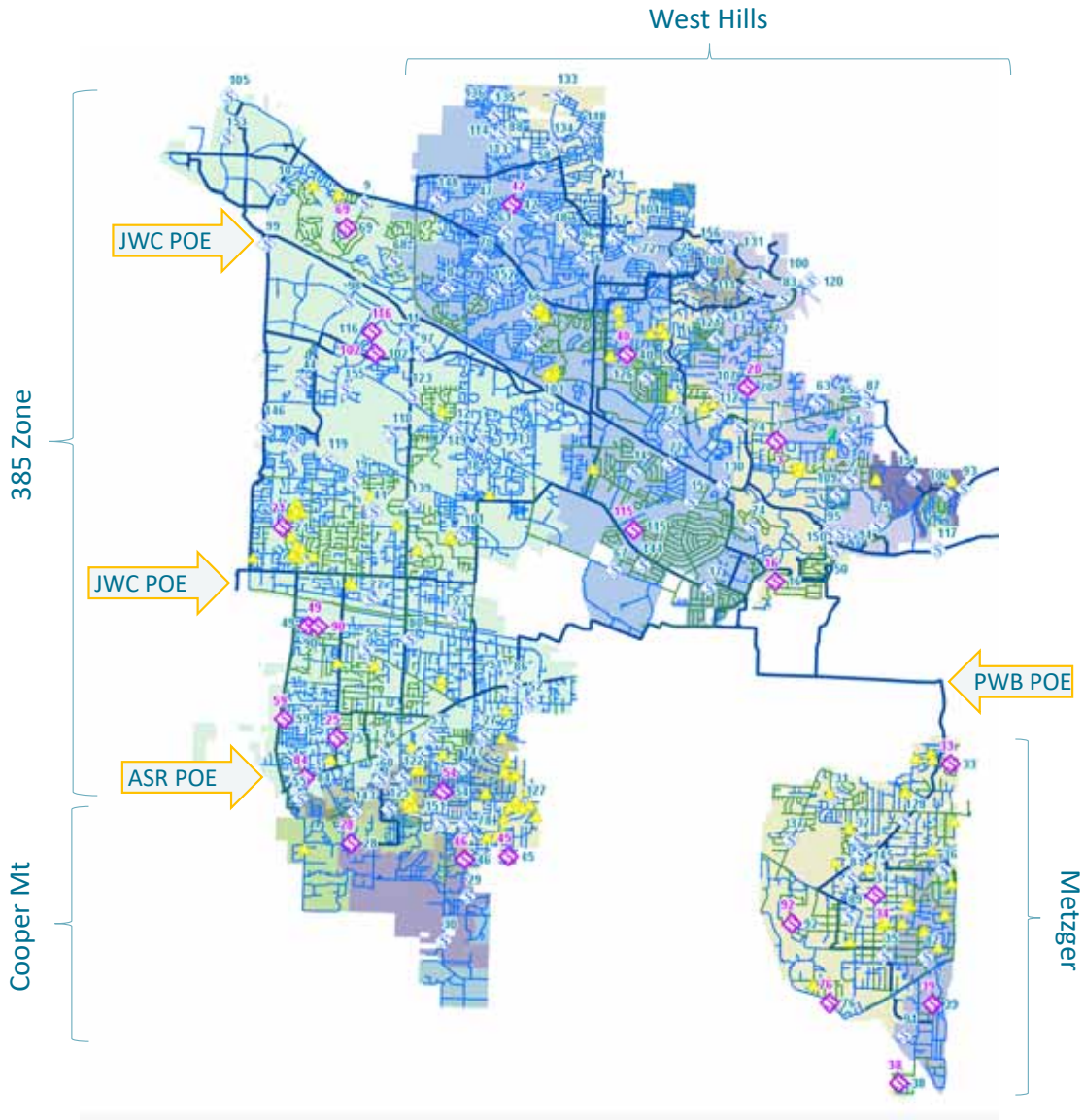
The frequency of monitoring, equipment, staffing, and purpose varied resulting in large data sets collected over different ranges of dates with different monitoring frequencies

Statistical approach to compare trends and stability

Selected locations to represent different system conditions

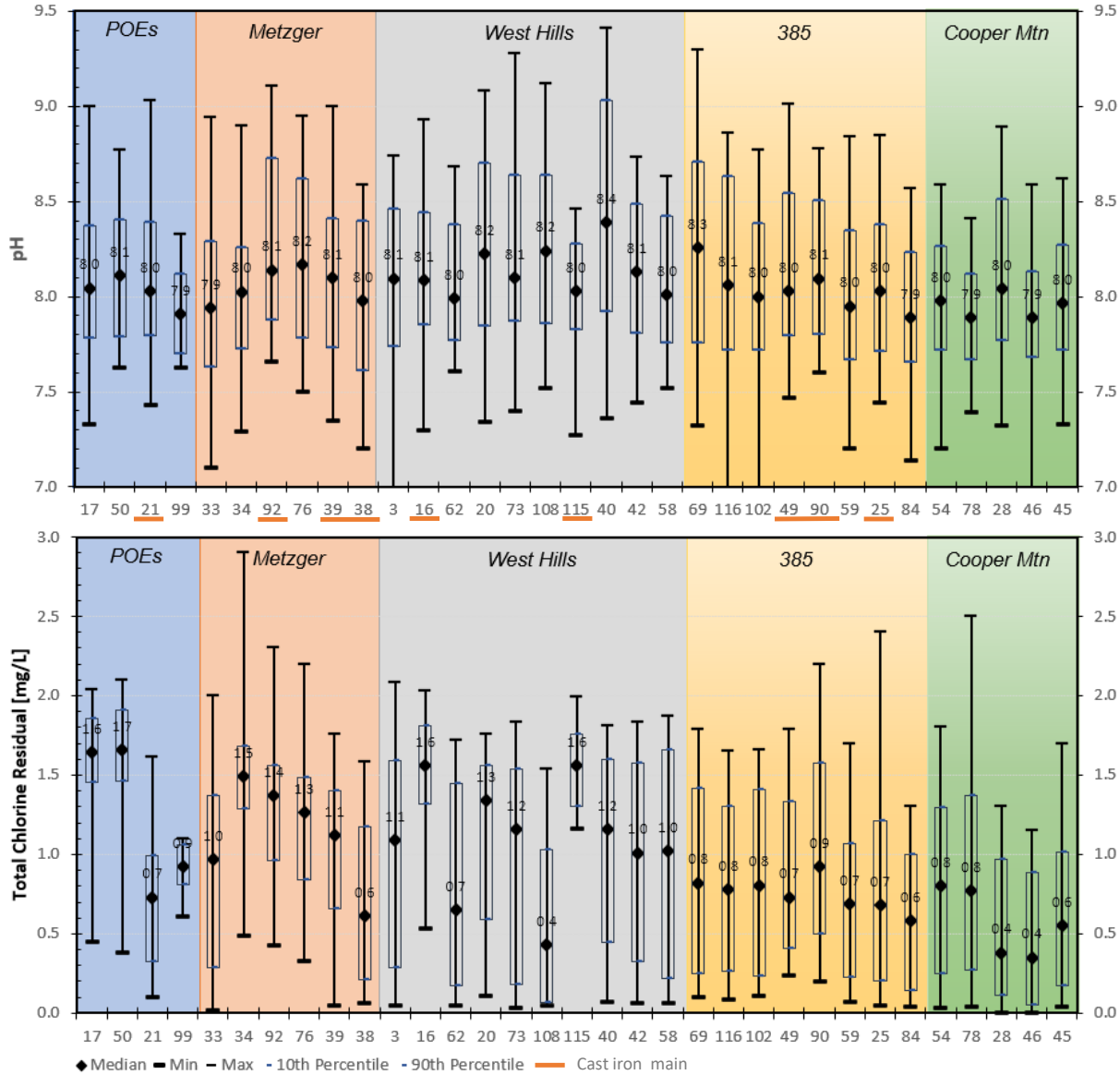
TVWD

- System divided into operational areas and blending zones
  - Metzger – only PWB water
  - West hills – PWB & JWC
  - 385 Zone – JWC & PWB
  - Cooper Mt – PWB & ASR
- Ductile (blue) and cast iron (green) mains
- Tier 1 homes (▲) are all copper pipe with lead solder
- 29 DS and 4 POE sites selected (pink) from 145 sample stations for detailed evaluation to represent:
  - Different supply areas & blending zones
  - DI and CI mains of different installation years
  - 4", 6", 8", and 12" mains
  - DBP and OWQP monitoring sites
  - Different water age areas
  - Several in Metzger since the pipes have not seen a water quality change before, PWB the only supply
  - 12 sites near Tier 1 homes and three sites near key customers



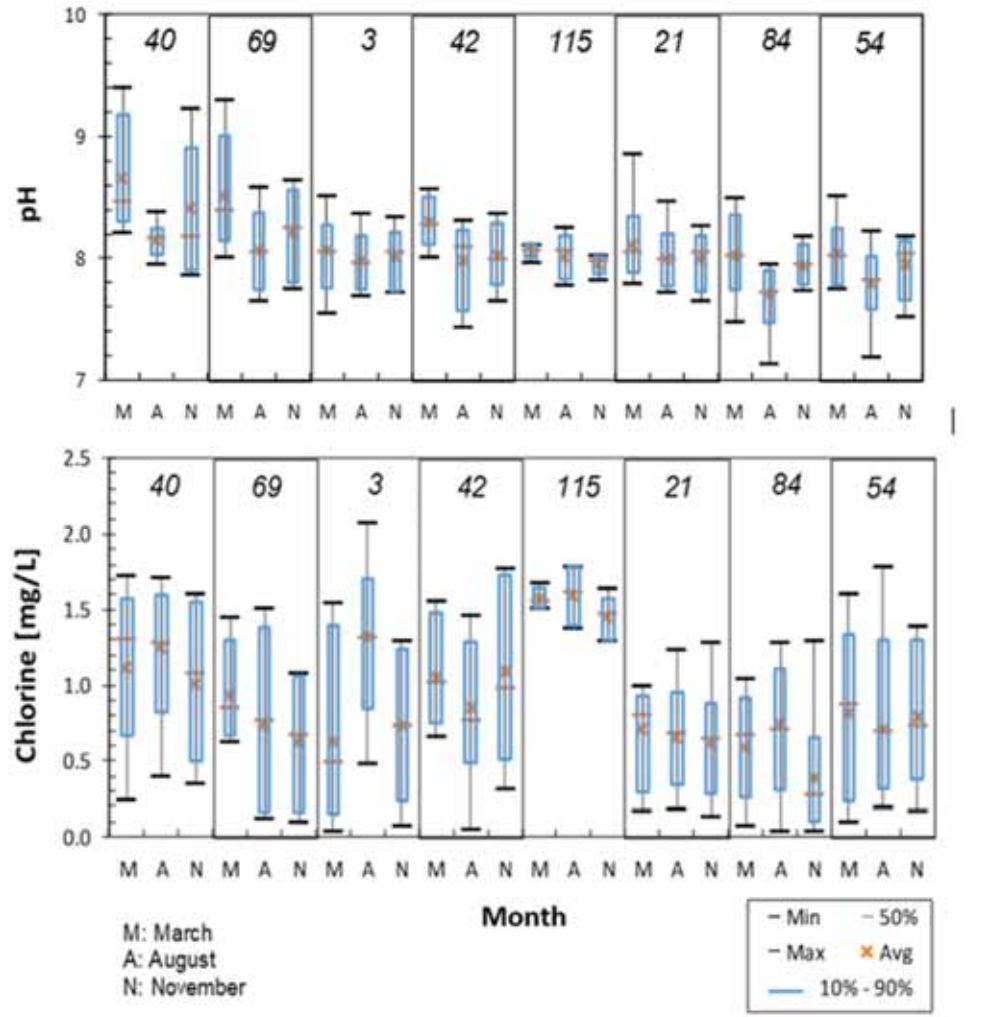
Chemistry Stability - TVWD

- Highly variable bulk water chemistry
- Several possible reasons for fluctuating chlorine levels



Seasonal Evaluation at Selected Sites - TVWD

- Sites with highly variable pH: Sites 40 and 69
- Sites with highly variable chlorine residual: Sites 3 and 42
- A site with more stable pH and chlorine residual: Site 115
- POEs: Site 84 representative of TVWD-ASR and Site 21 representative of the JWC-STL
- Blending zone of all supplies: Site 54

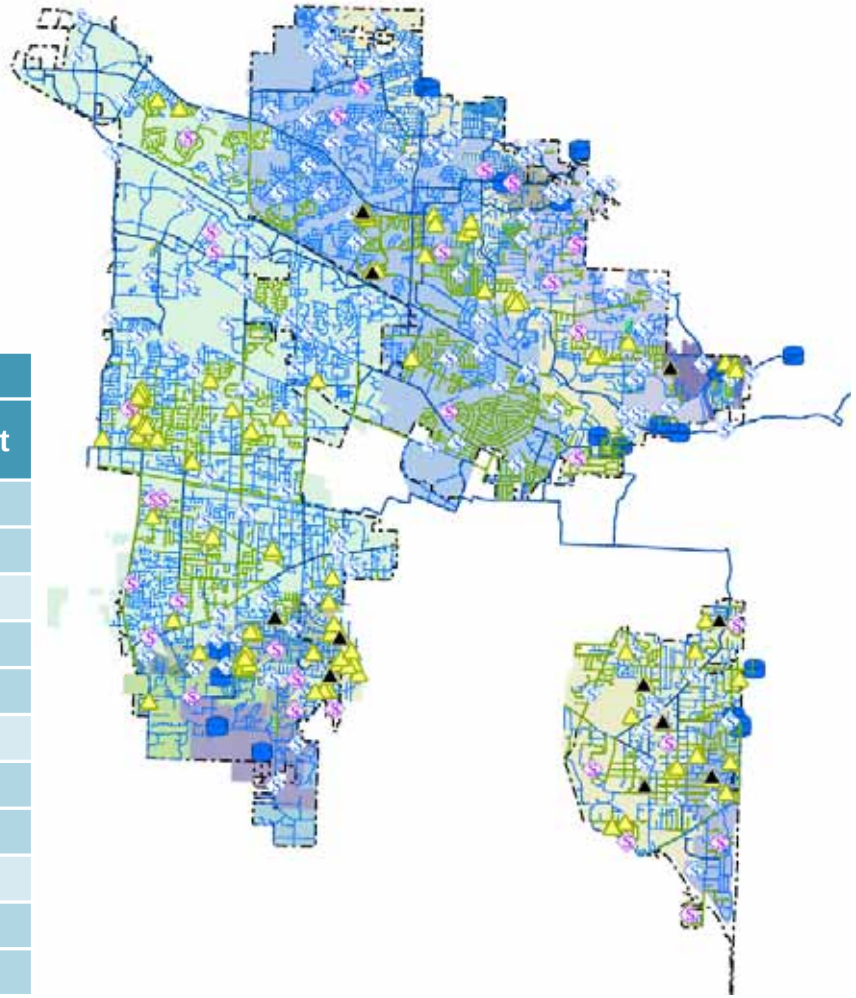


(West Hills: 40, 3, 42, 115; 385 Zone: 69, 21, 84; Cooper Mountain: 54)

LCR - TVWD

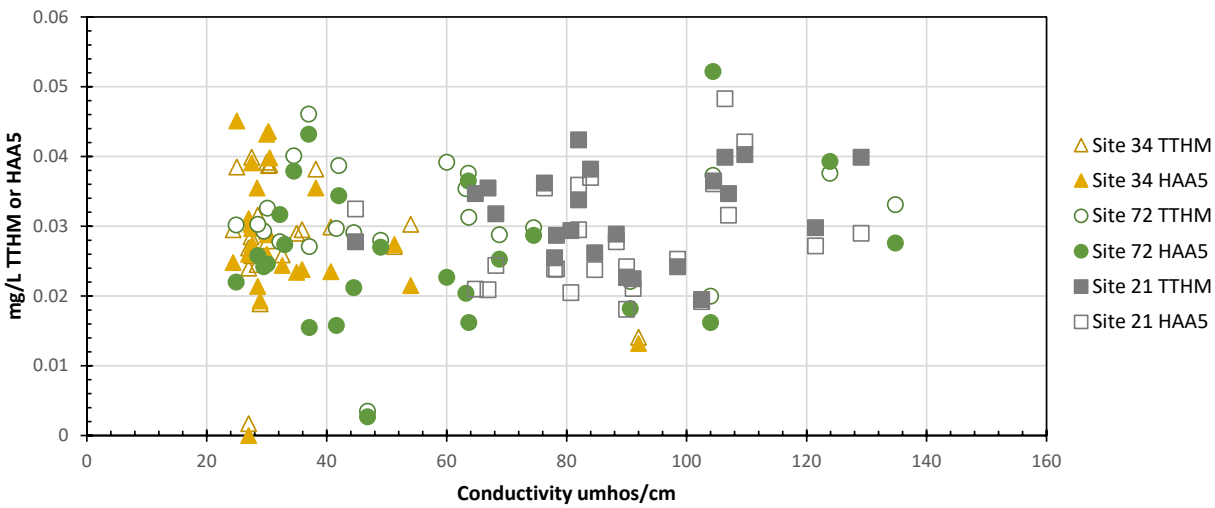
- Optimal Water Quality Parameter (OWQP) set as minimum pH of 7.4 throughout the distribution system
- Very low copper results
- 12 sites with lead results > 0.015 mg/L (▲)
- No known lead service lines or goosenecks

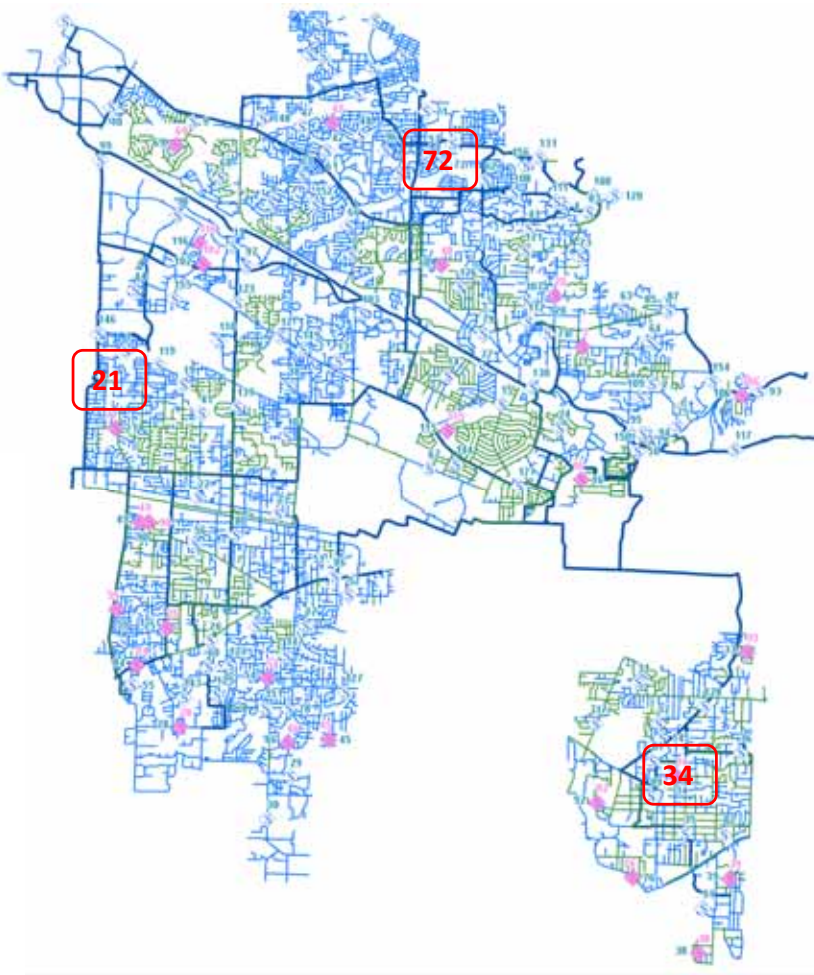
Sampling Event	# of Samples	Lead (mg/L)		Copper (mg/L)	
		90th Percentile	Max. Result	90th Percentile	Max. Result
Aug-19	100	0.012	0.033	0.199	0.364
Aug-18	99	0.010	0.274	0.274	0.482
Sep-17	112	0.009	0.060	0.024	0.460
Apr-17	111	0.0077	0.0225	0.173	0.313
Oct-16	42	--	0.113	--	0.269
Nov-15	40	--	0.0226	--	0.338
May-15	39	--	0.0454		0.290
Oct-14	42	--	0.023	--	0.462
May-14	36	--	0.0283	--	0.232
Nov-13	37	--	0.0145	--	0.560
May-13	40	--	0.0473	--	0.291



TVWD - DBPs

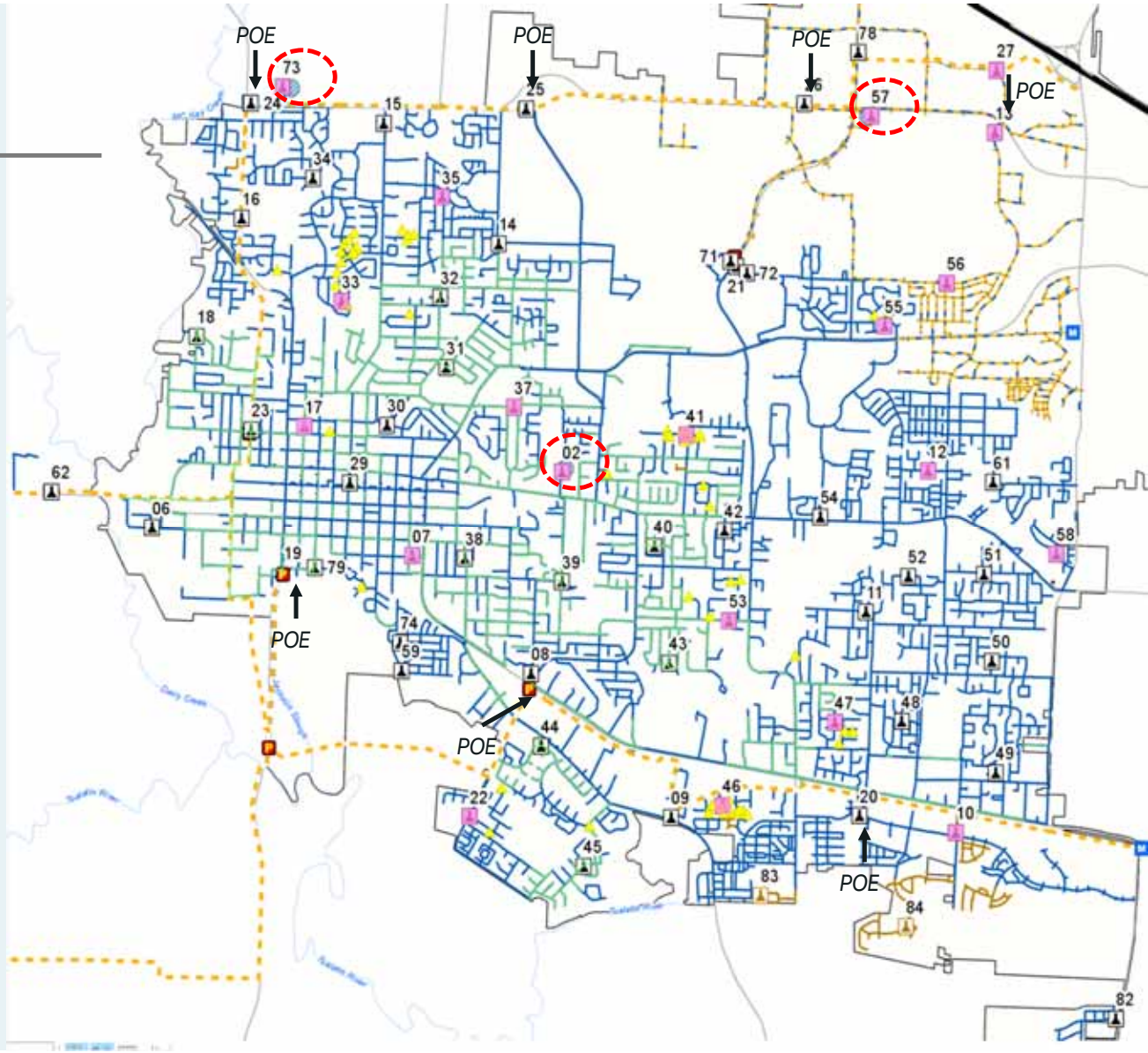
- DBP formation patterns similar across the system
- Highest results in December
- HAA-formation more challenging





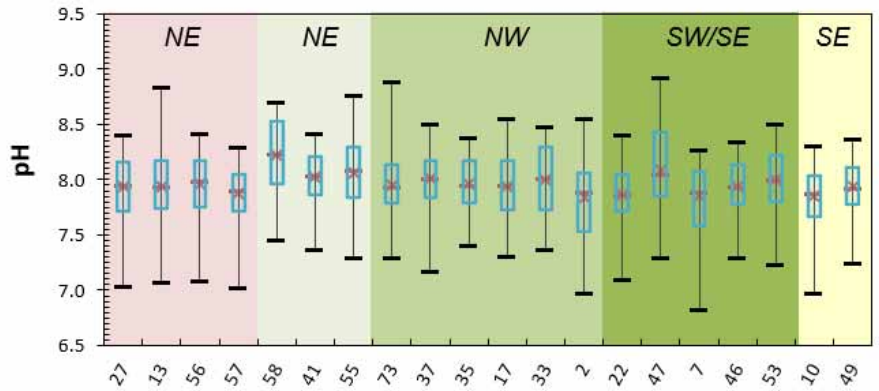
Hillsboro

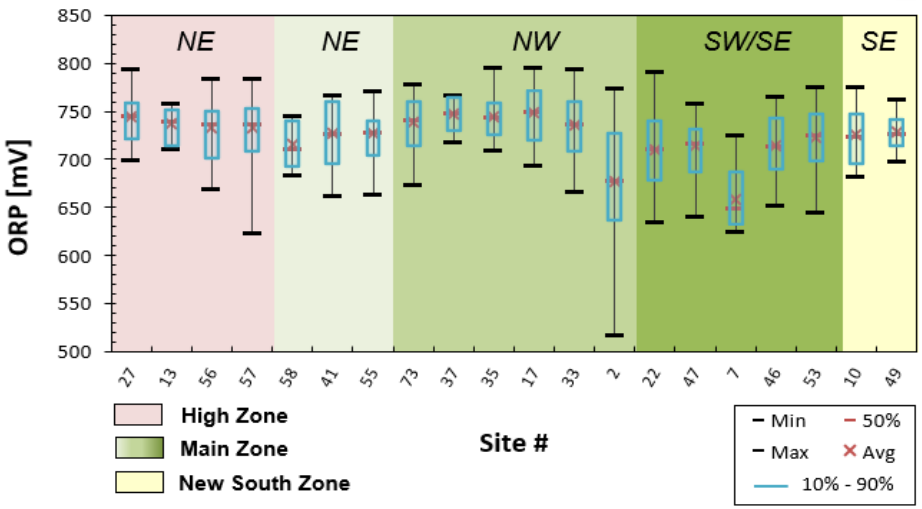
- 12 turnouts from JWC transmission mains
- Ductile (blue) and cast (green) iron mains; no UCI
- Booster chlorination at each in-town reservoir (red circles)
- Tier 1 homes (▲) are copper pipes with lead solder
- 21 (pink) out of 54 DS monitoring locations selected for detailed evaluation
  - Geographic distribution (5 in high zone, 2 in new south zone)
  - 4-18” DI (15) & CI (4) mains with installation dates ranging from 1960 to 1997
  - In-town Reservoirs
  - Seven sites near Tier 1 homes
  - Four sites near key customers
  - Three sites near future WWSS POEs
  - Water quality ranges (incl Two sites with higher median pH and one site with lower ORP)

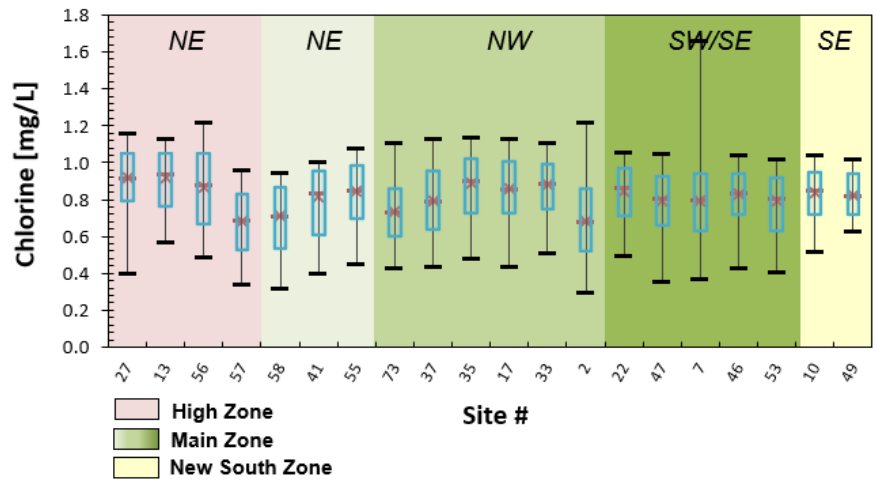


Chemistry Stability – Hillsboro

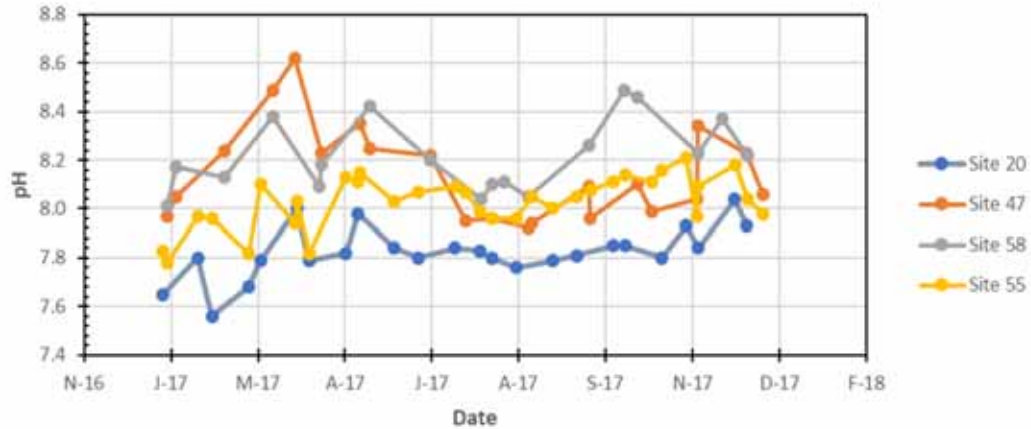
- Stable bulk water chemistry
- High chlorine levels and strong ORP
- Tendency for upward drift in pH
- "Met" Partnership for Safe Water Optimization Criteria for chlorine residuals in 2017

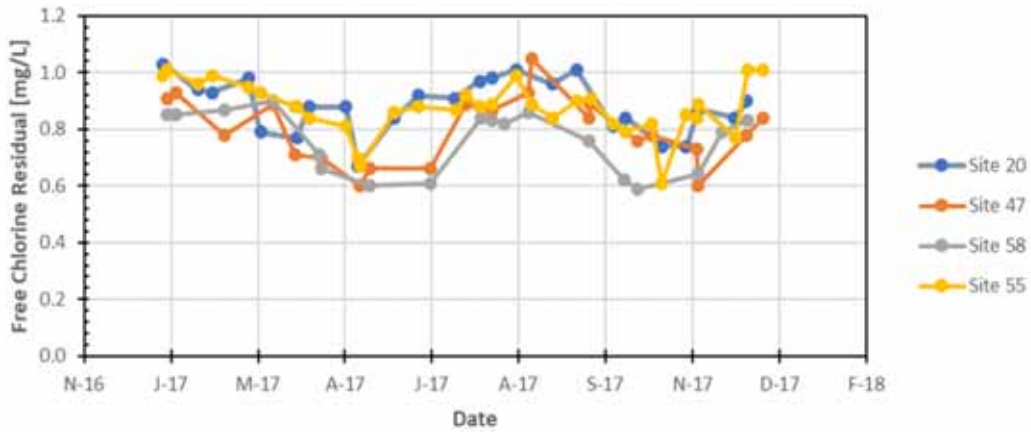


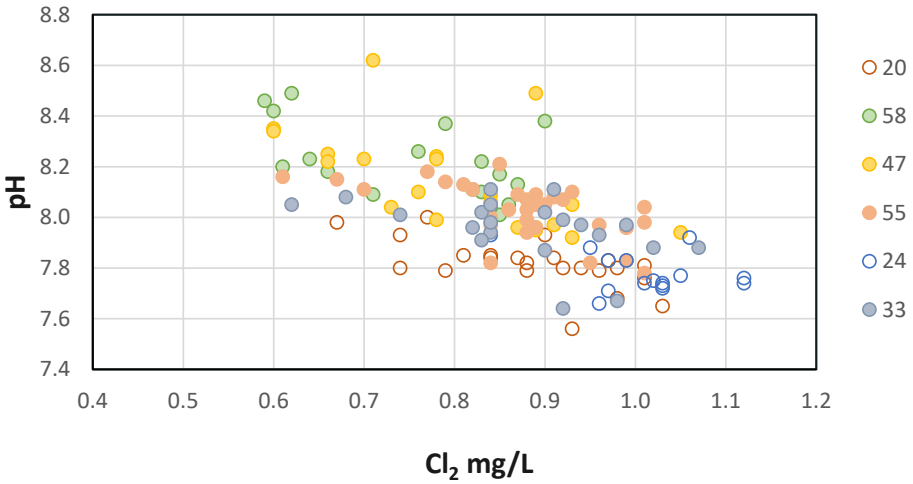




Chemistry Stability - Hillsboro







- 20 – 47 – 58 – 55 order of distance from the STL to north
- 24 – 33 from NTL to south
- pH tended to increase and chlorine residual decrease as water aged and moved farther from the TLs.

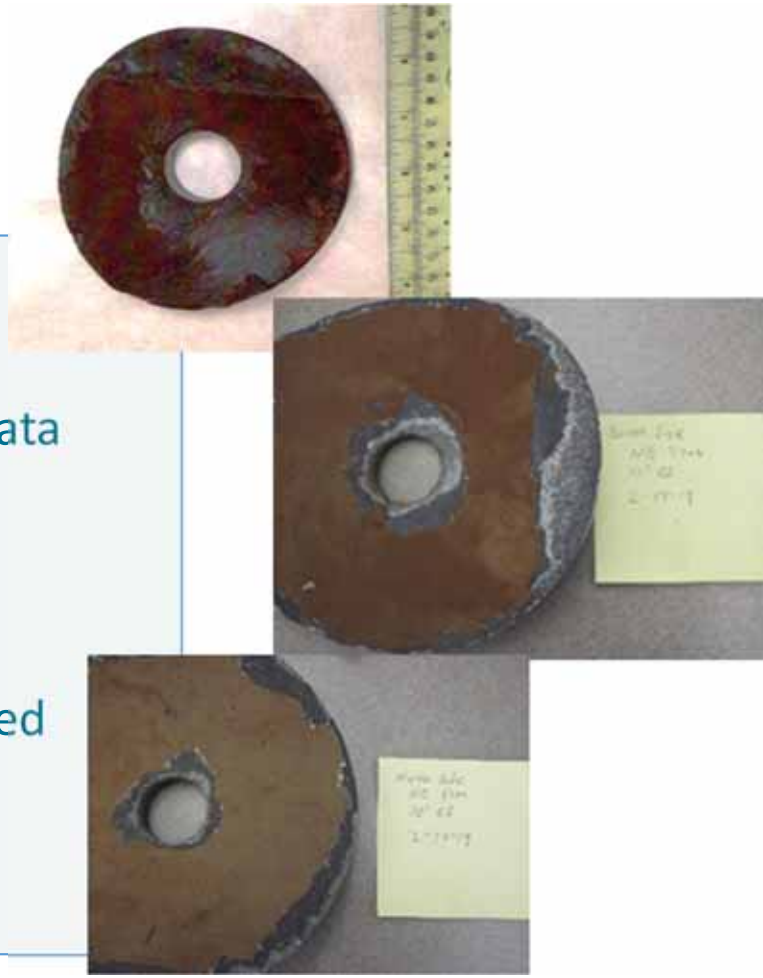
LCR – Hillsboro

- Optimal Water Quality Parameter (OWQP) set as minimum pH of 7.2 throughout the distribution system (operate pH > 7.6)
- No known lead service lines or goosenecks
- Very low lead and copper results
- Forming Pb(IV)?

Year	Number of Samples	Lead (mg/L)		Copper (mg/L)	
		90th Percentile	Max result	90th Percentile	Max result
2009	47	0.002	0.004	0.060	0.150
2012	39	0.003	0.043	0.095	0.132
2015	35	0.0025	0.005	0.110	0.212
2018	34	0.001	0.003	0.073	0.095

Pipe Coupons – Hillsboro

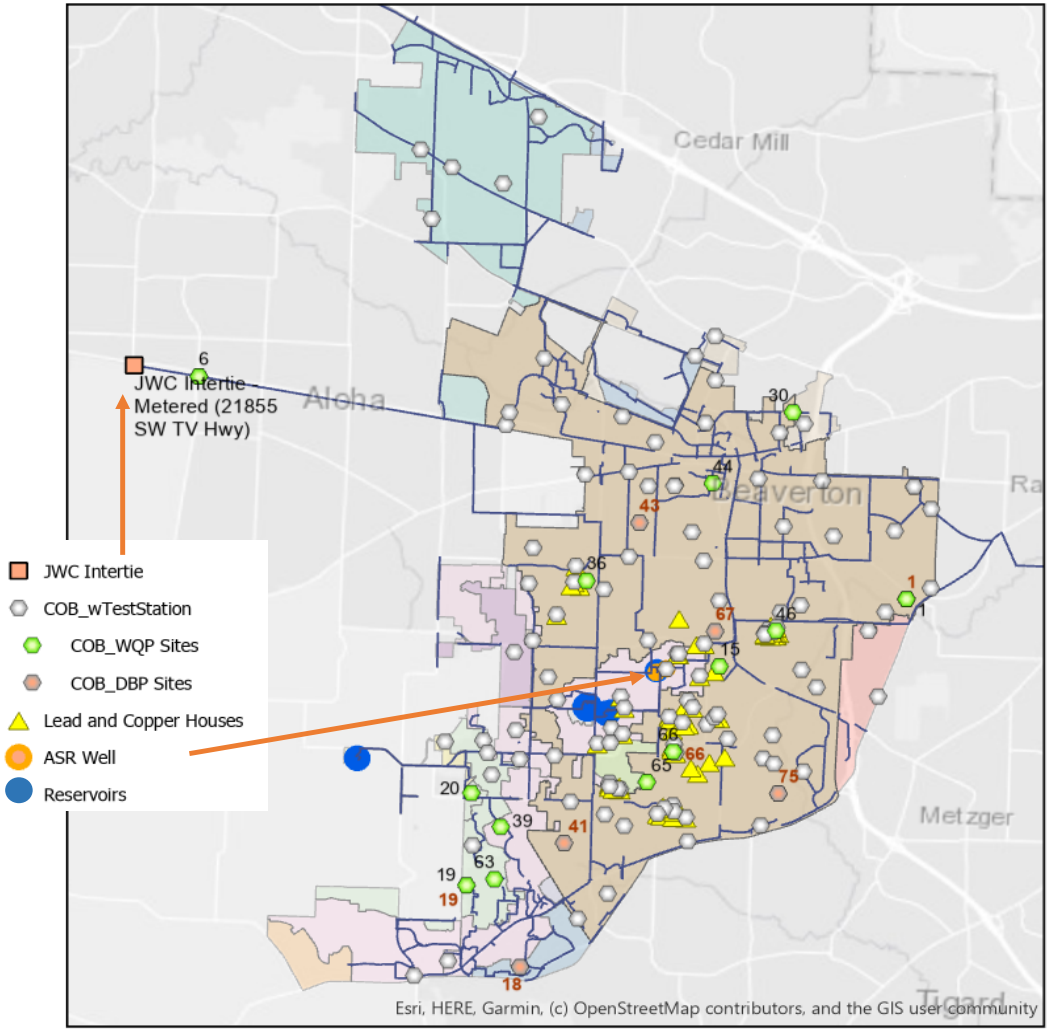
- 3 coupons with adequate mass for dry weight analyses
- Very little mass on the inner walls of the pipes
- Samples with adequate mass were compared with the data available in WRF 3118[1]
  - Mn < 10th percentile at NE 34th, but > 90th percentile at Jackson & 7th
  - Fe < 10th percentile at all locations
  - Arsenic and lead levels less than but approaching median levels
- Two coupons with insufficient mass for dry weight showed presence of sulfur and iron bacteria



[1] WRF 3118 (*Assessment of Inorganics Accumulation in Drinking Water System Scales and Sediments*, Friedman and Hill et al., Water Research Foundation, 2010)

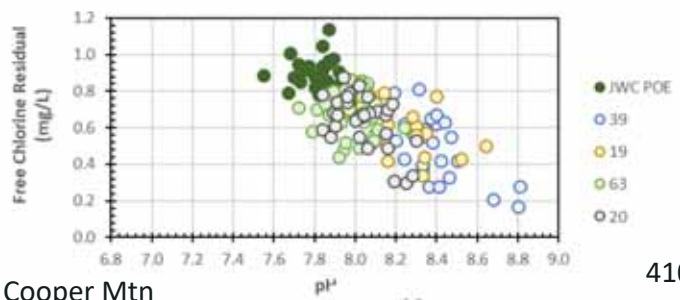
Beaverton

- 80 TCR monitoring sites
- Booster chlorination at JWC intertie, Sexton and Cooper Mtn reservoirs
- Ductile iron and cement-lined cast iron mains; no UCI
- Tier 1 homes are copper pipe with lead solder
- WQP monitoring completed at 13 sample sites (green dots)
  - JWC POE (master meter, site #6)
  - All in DI mains with sizes 6”-10” (except one site that is near both DI and CI mains)
  - Installation dates from 1973 to 2014
  - Four sites near Tier 1 homes
  - Three sites within the zone of influence of the City’s ASR wells
  - Four sites in area served by Cooper Mtn reservoir



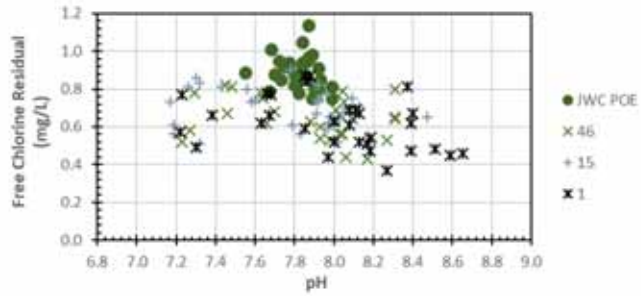
Beaverton

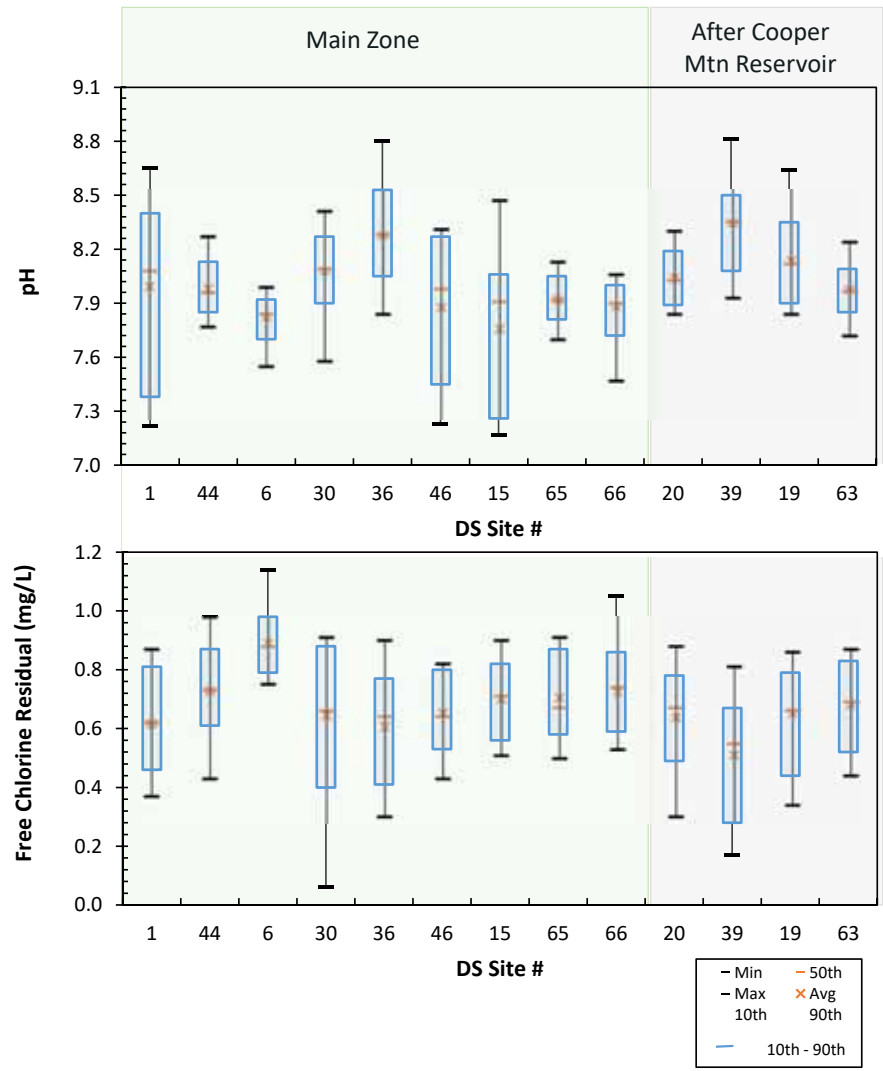
- Stable bulk water chemistry
- Strong chlorine residuals and highly oxidizing conditions
- "Met" Partnership for Safe Water Optimization Criteria in 2017 for chlorine residuals
- Variability in water quality related to ASR use
  - CCT at ASR will reduce copper corrosion and improve computability of the existing supplies
- Increasing pH with decreasing chlorine residual in Cooper Mountain area (likely water age)



Cooper Mtn

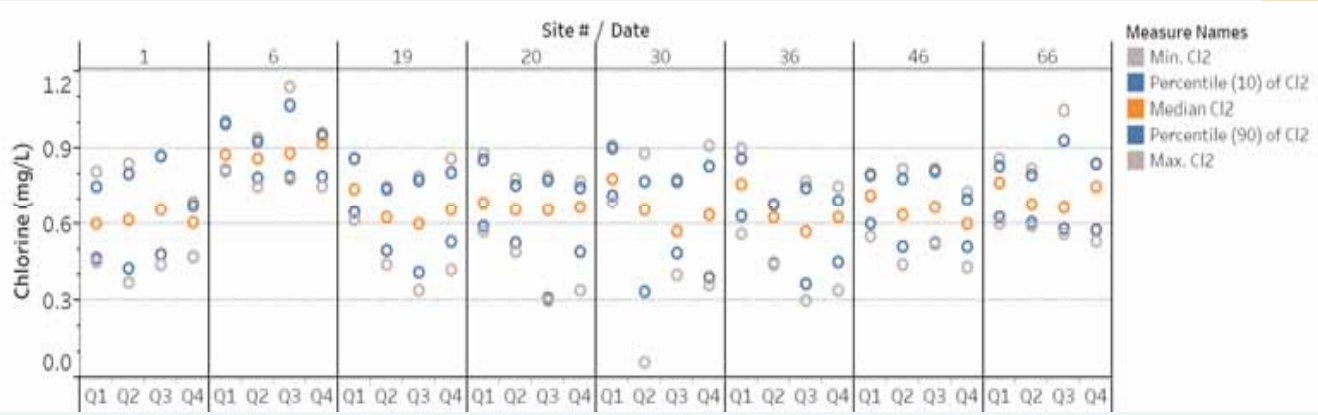
410 Zone- ASR Impacted

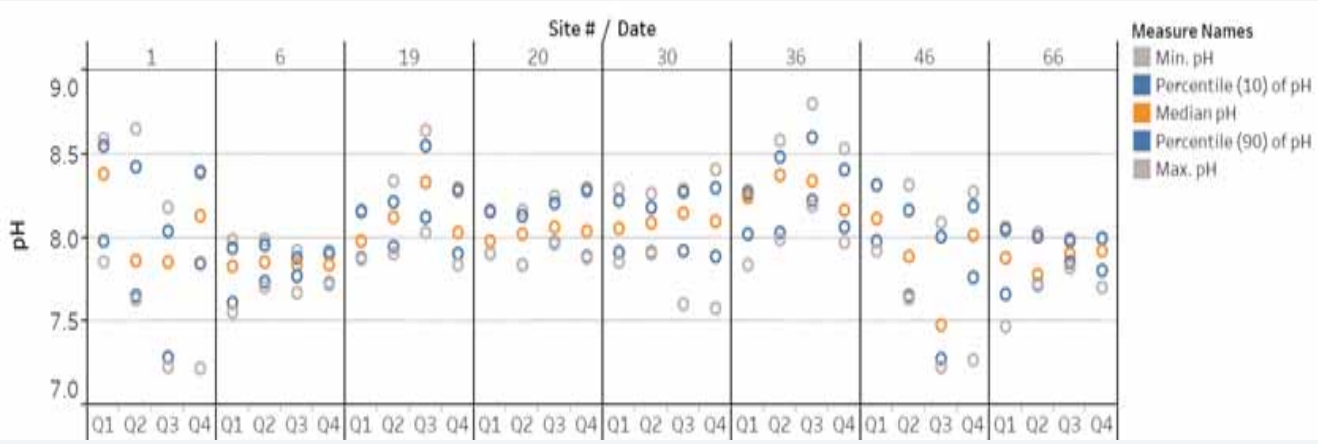




Seasonal Water Quality - Beaverton

- Some seasonal variations
- ASR impact appear throughout the year (sites 1 & 46)





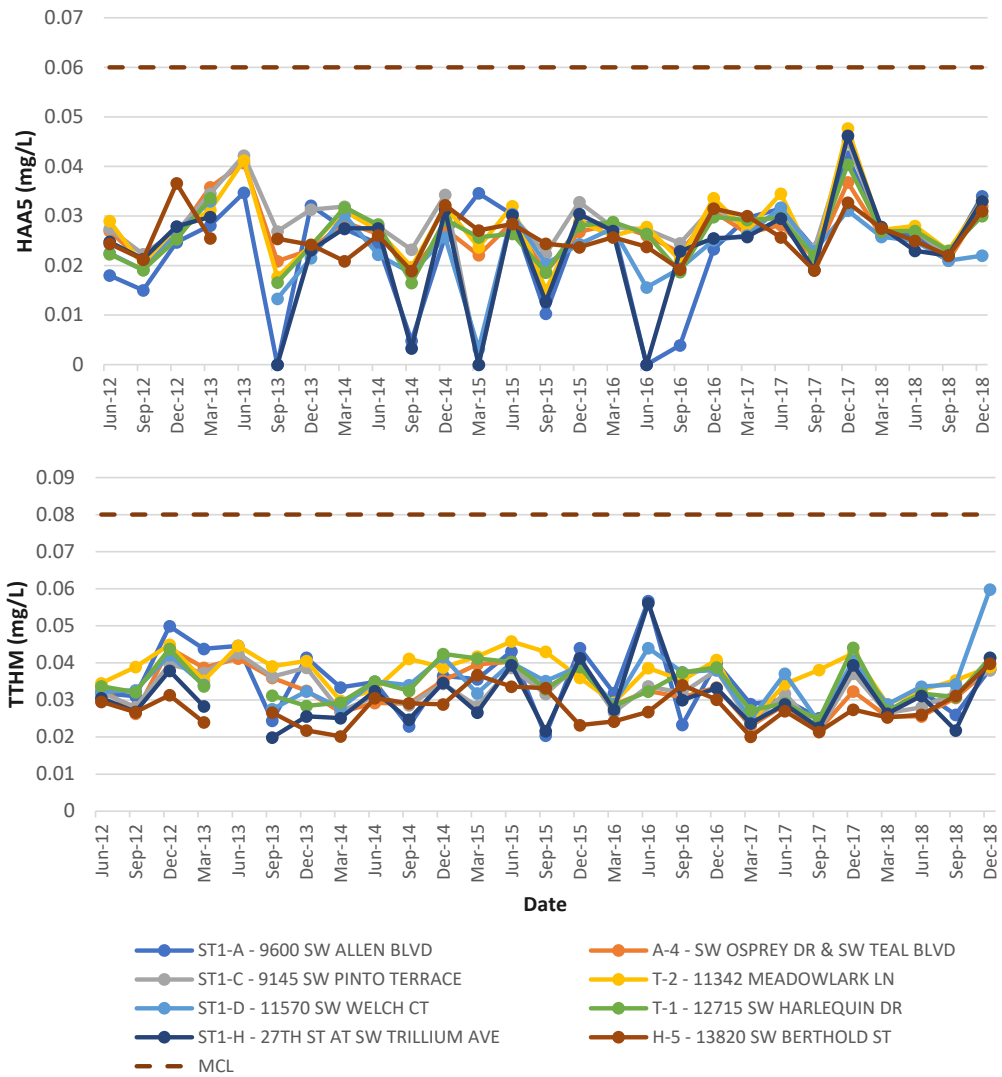
LCR – Beaverton

- Optimal Water Quality Parameter (OWQP) set as minimum pH of 7.2 throughout the distribution system No known lead service lines or goosenecks
- Very low lead and copper results
- ASRs can be used for groundwater withdrawal and the native groundwater has lower pH
- pH adjustment planned for CCT at ASRs
  - increases the compatibility
  - improves corrosion control
- Potentially forming Pb(IV)?

Sampling Event	Number of Samples	Lead (mg/L)		Copper (mg/L)	
		90th Percentile	Max Result	90th Percentile	Max Result
2004	30	-	-	0.240	0.260
2007	30	0.005	0.007	0.270	0.500
2010	34	0.003	0.006	0.090	0.150
2013	30	0.007	0.010	0.252	0.437
2016	30	ND	0.007	0.171	0.247

DBPs - Beaverton

- Generally, less than half the MCLs
- Highest results typically in December
- Similar levels of DBPs around the system

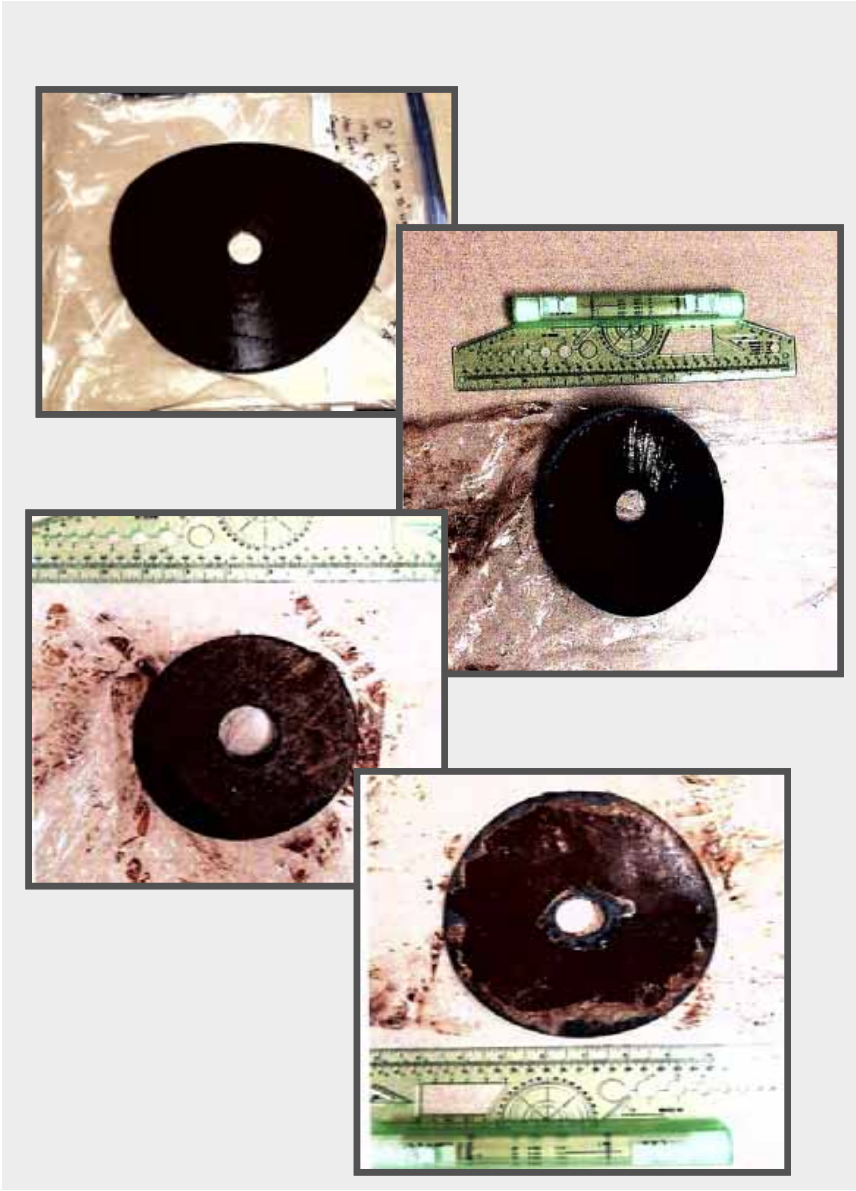


Infrastructure - Beaverton

- UDF-program
  - May not be conducting strict UDF
  - Some signs of Fe/Mn accumulation
  - UDF trial and swabbing tests may be recommended
- Several new capital projects prior to 2026
  - Routine distribution main replacements (~$1M/year)
  - A connection to the JWC NTL
  - Completion of additional ASR wells
  - Installation of Cooper Mountain Reservoir #2 and transmission lines
  - Addition of a booster pump station at the 219th St. master meter
  - Other pump station upgrades

Pipe Coupons – Beaverton

- 8 coupons with adequate mass for dry weight analyses
- Thin films on inner pipe walls
- Fe bacteria were present at levels 1×10^6 – 158×10^6 /g
- Samples with adequate mass were compared with the data available in WRF 3118[1]
  - Mn levels were higher than median level of 790 mg/kg
  - Canyon & 217th sample was higher in Mn than 90th percentile value of 7,000 mg/kg in the WRF study
  - Fe < 10th percentile at all locations except at Canyon & 217th Site
  - Arsenic and lead results were not measured



[1] WRF 3118 (*Assessment of Inorganics Accumulation in Drinking Water System Scales and Sediments*, Friedman and Hill et al., Water Research Foundation, 2010)

Qualitative Summary of Identified Risks

		TVWD				Hillsboro	Beaverton
		Metzger	West Hills	385 Zone	Cooper Mountain		
Water Quality	**Stability**						
	Chlorine	◊◊	●●●	●●●	●●●	*	*
	pH	◊◊	◊◊	◊◊	◊◊	*	*
	Alkalinity	◊◊	◊◊	◊◊	◊◊	*	*
	Water Quality Changes	*	●●●	●●●	●●●	*	◊◊
	Compatibility						
	Disinfectant Type	*	●●●	●●●	●●●	*	*
	Source Type	*	*	●●●	●●●	*	*
	Source Loading						
	Metals	*	*	*	*	*	◊◊
	Organics	◊◊	◊◊	◊◊	◊◊	*	*
	Nutrients	◊◊	*	*	*	*	*
Distribution Infrastructure	**Materials**						
	Scale Forming	●●●	◊◊	◊◊	◊◊	*	*
	Accumulation						
	Pipelines	? ◊◊	? ◊◊	? ◊◊	? ●●●	? ◊◊	◊◊?
	Reservoirs	?*	?*	?*	?*	?*	*

* = no significant issues associated with current conditions

◊◊ = moderate issues associated with current conditions

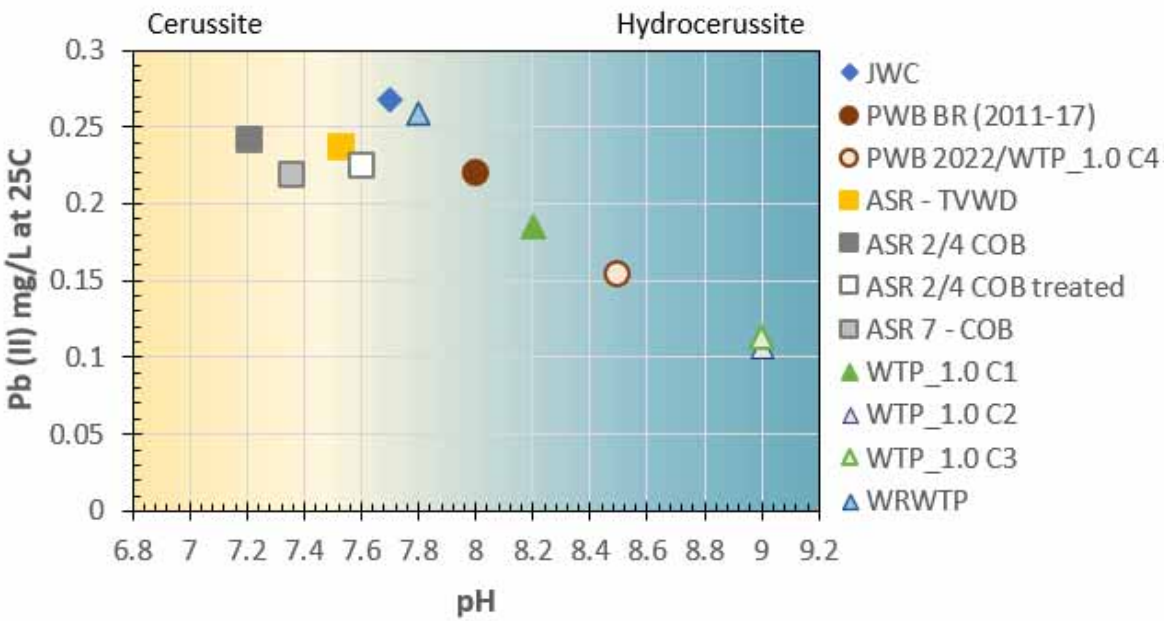
●●● = potentially significant issues associated with current conditions

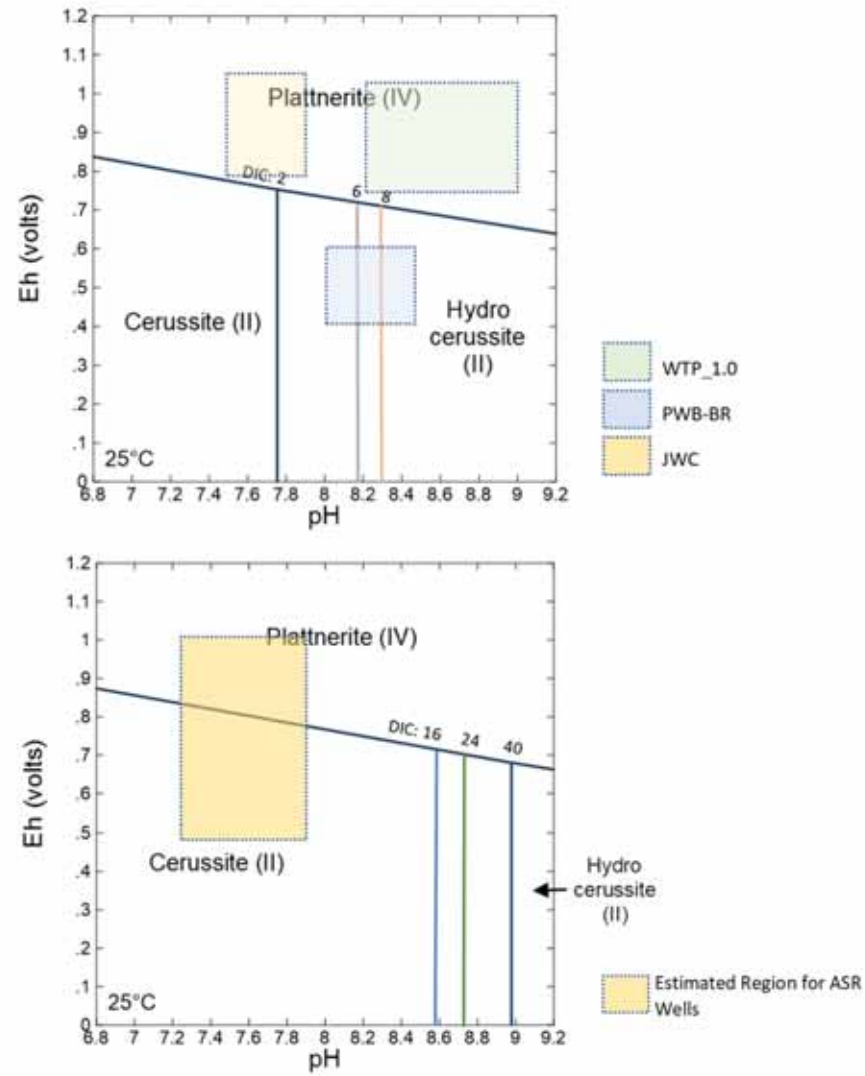
? = more data or information are needed to characterize conditions

Solubility and Scale Stability

Lead Results

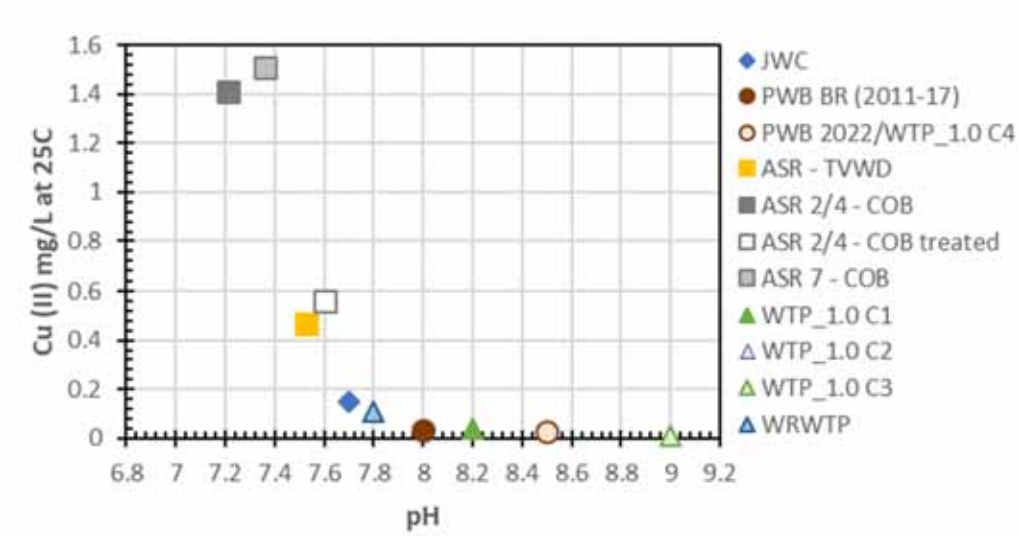
- pH, DIC, and ORP => Major differences in solubility and lead species between the supplies

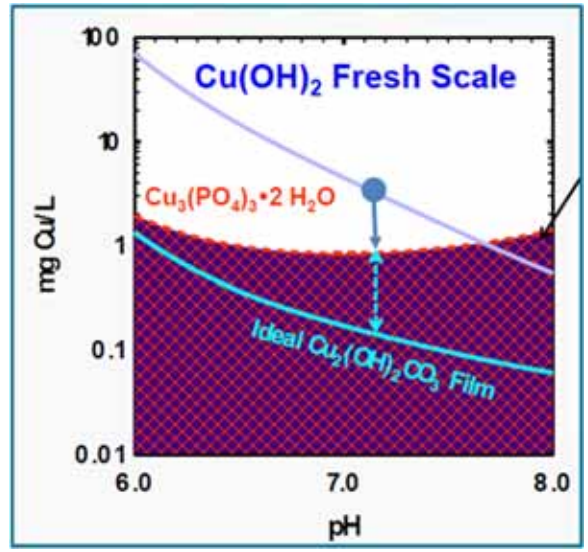




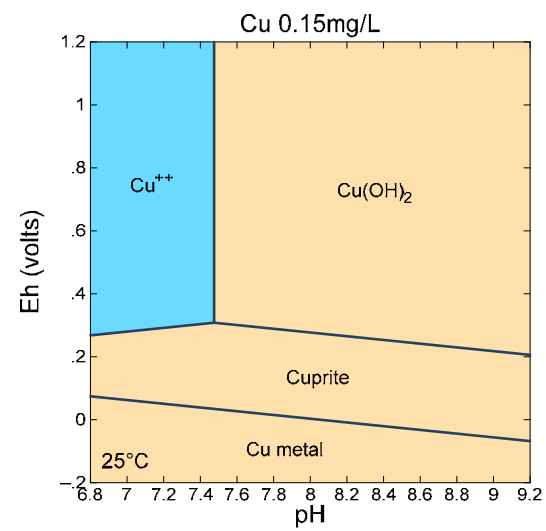
Copper Results

- Copper a concern only for untreated ASRs



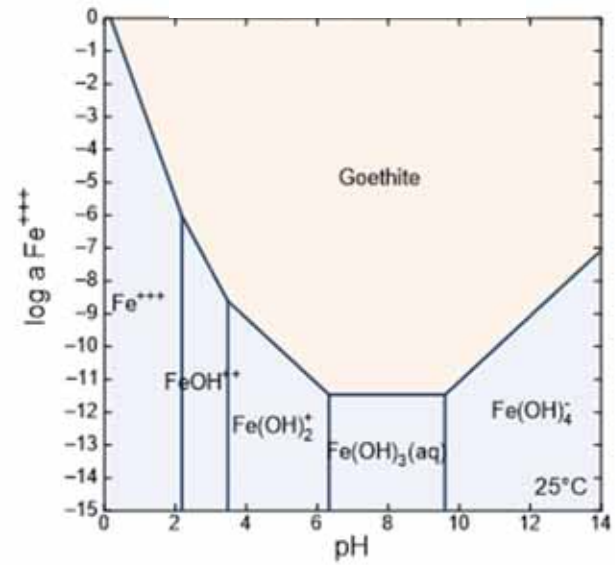


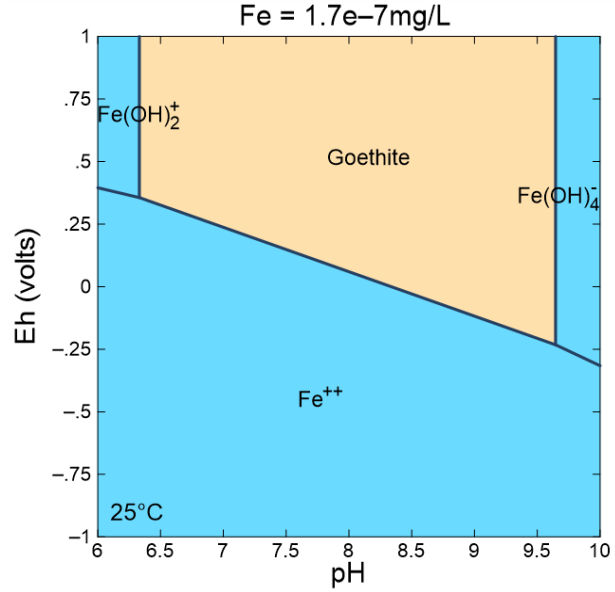
(Source: Schock and Lytle 2014)



Iron

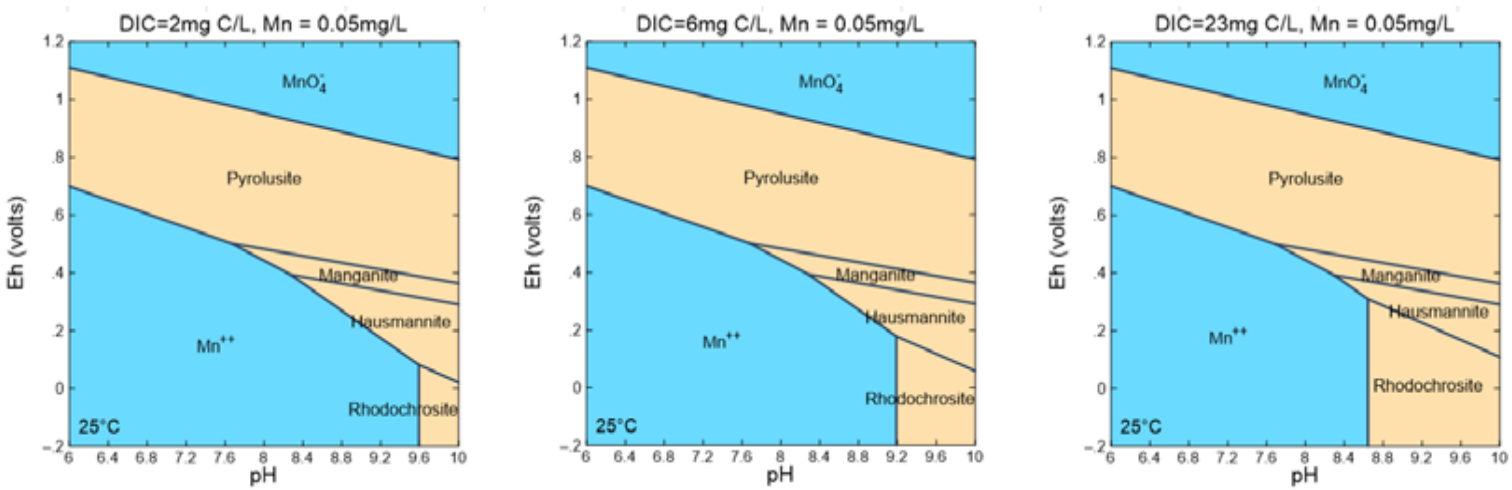
- Scales can be complex (Goethite only one of several potential species)
- Very low solubility under the supply conditions
- A significant drop in ORP could result in soluble iron release
  - Pipe surfaces
  - Tubercles of cast iron mains
  - Biofilm
  - Chlorine breakpoint reactions



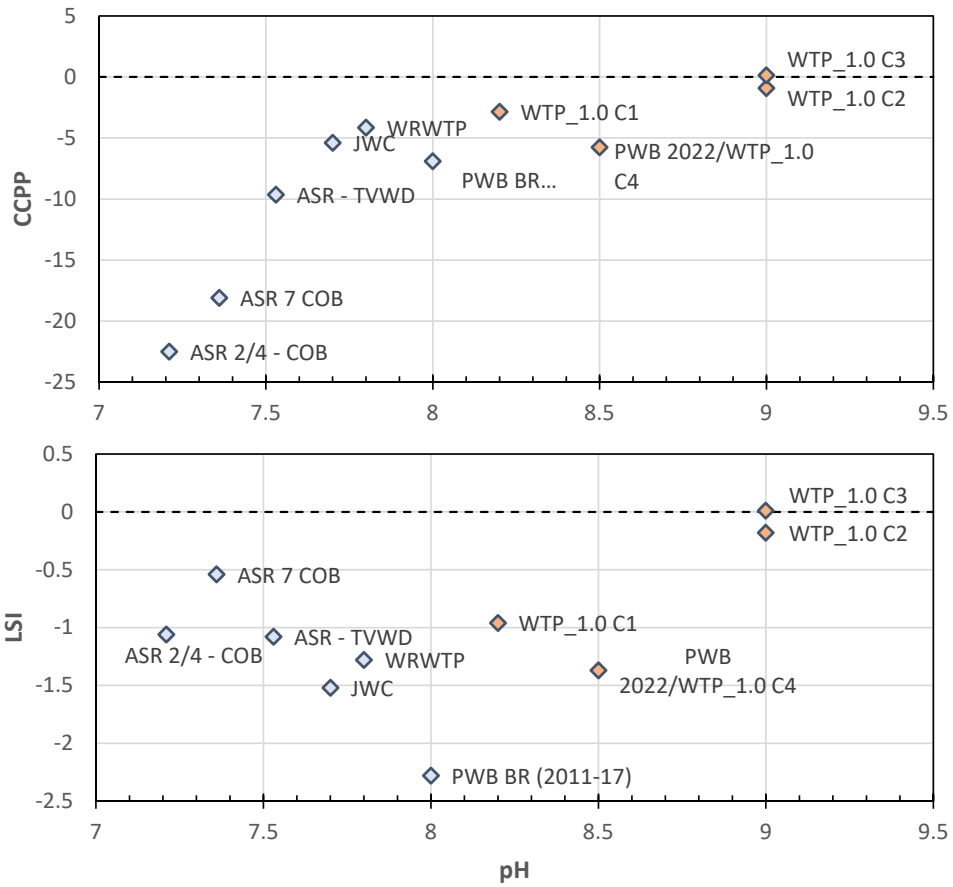


Manganese

- DIC affects the stability fields
- ORP drop can result in release event, discolored water when residual increases again
- Releases less likely with increased pH

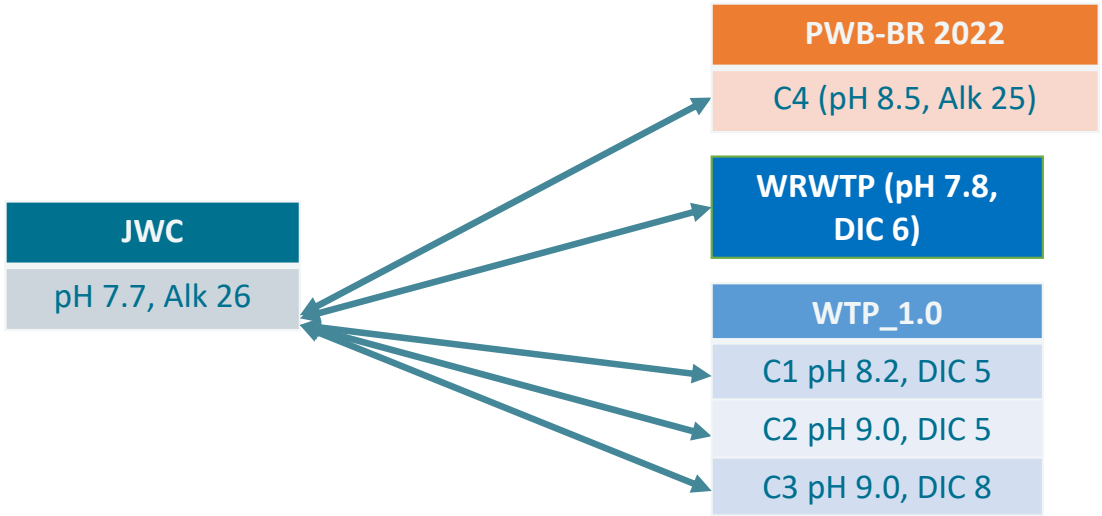


Supply Comparison for CCPP and LSI



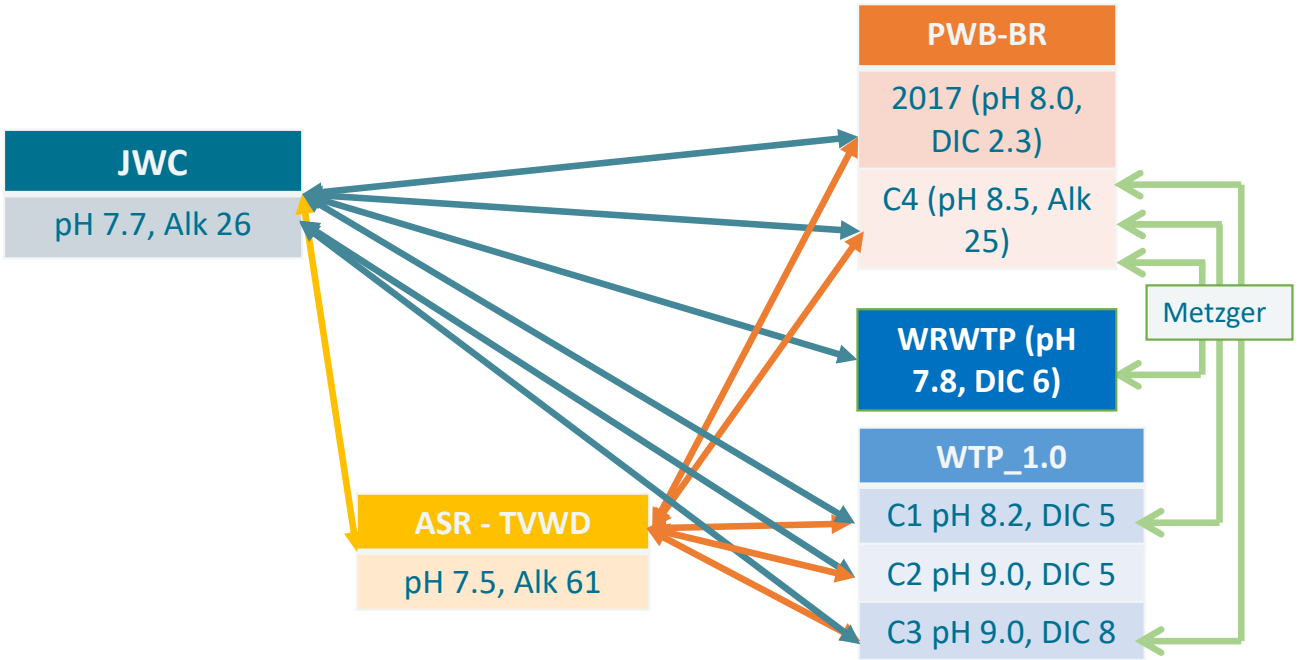
Blending Analyses

Hillsboro – Blending Scenarios



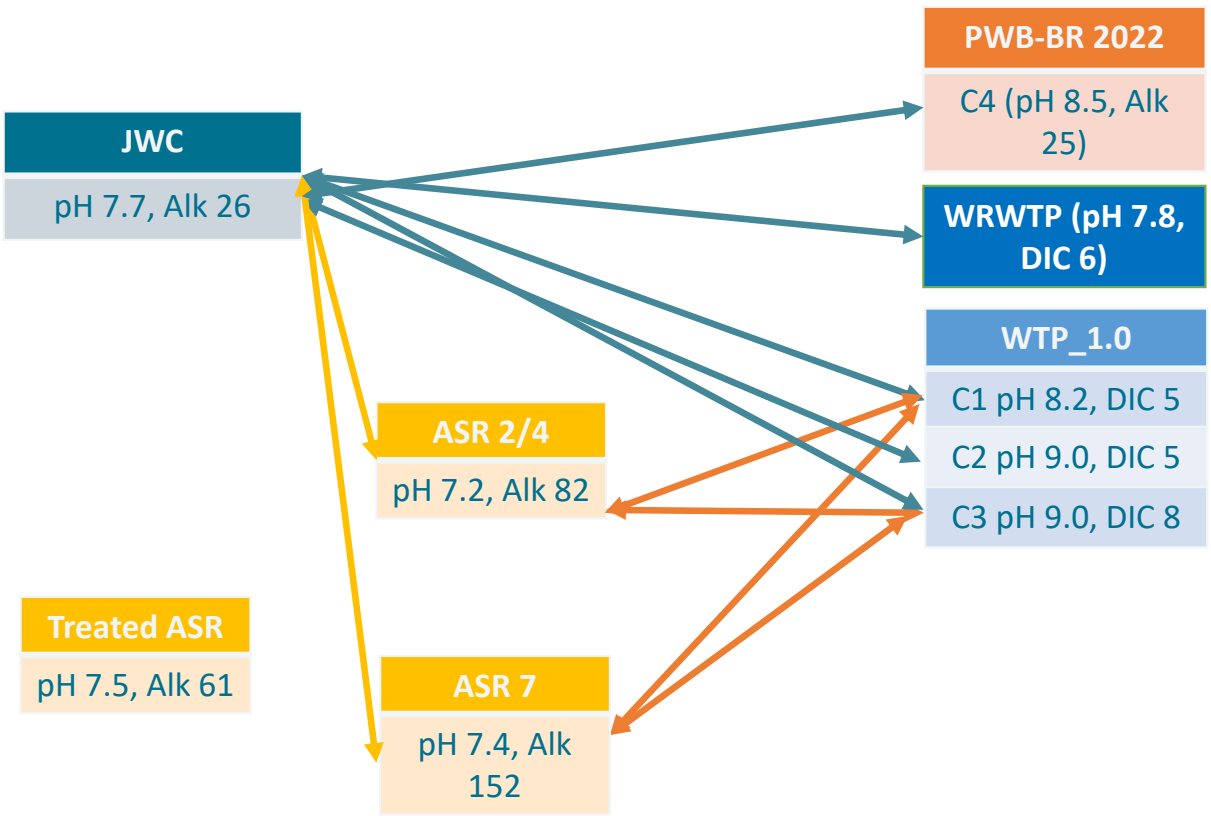
- JWC – Boundary Conditions:
  - pH, Alk – the most common conditions
  - other parameters to remain constant (Medians of the data)
- PWB 2022 represent the WTP_1.0 C4
- No other supplies

TVWD – Blending Scenarios



- JWC
  - pH, Alk – the most common paired conditions
  - Other parameters to remain constant
- ASR
  - Assume water quality remains the same as in the last four cycles
- PWB – BR
  - Used median water quality (2017)
- PWB – BR 2022
  - Used treatment goal which will be achieved gradually over time
  - Also represents WTP_1.0 C4
- WRWTP
  - Median water quality

Beaverton – Blending Scenarios



- JWC
  - pH, Alk – the most common conditions
  - other parameters to remain constant
- WRWTP
  - Median water quality
- PWB-BR 2022 represents WTP_1.0 C4
- ASR 2/4
  - Baseline groundwater – water quality for 2014-2017
- ASR 7
  - Native groundwater data
- Limited WTP_1.0 modeling to C1 and C3 with ASRs (C4 would be in between)
- Treated ASR represented by TVWD ASR

JWC vs WTP_1.0

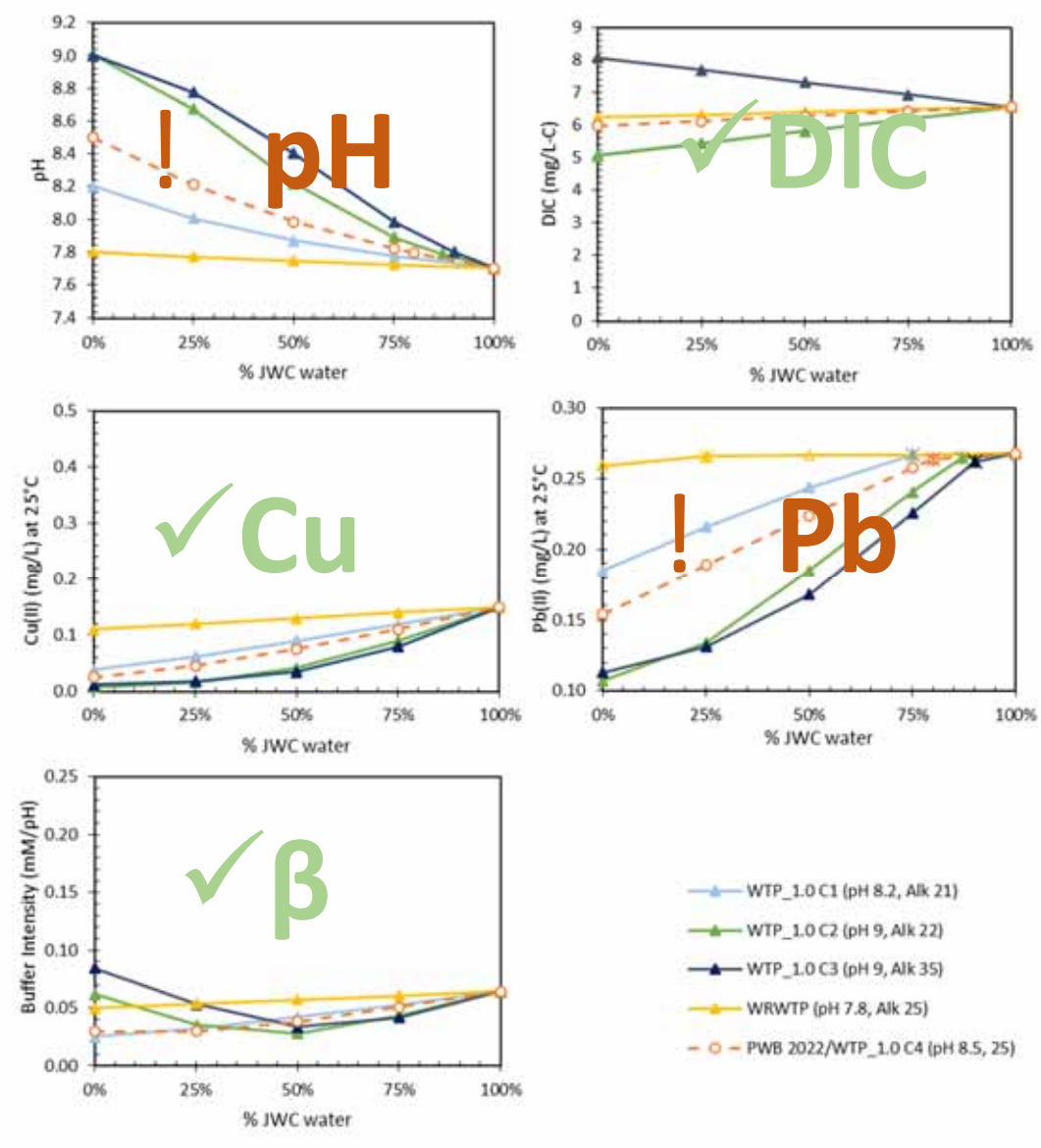
Legend

! indicates significant difference between scenarios or a concern

❖ Indicates a difference between the end points, but small difference between the blends

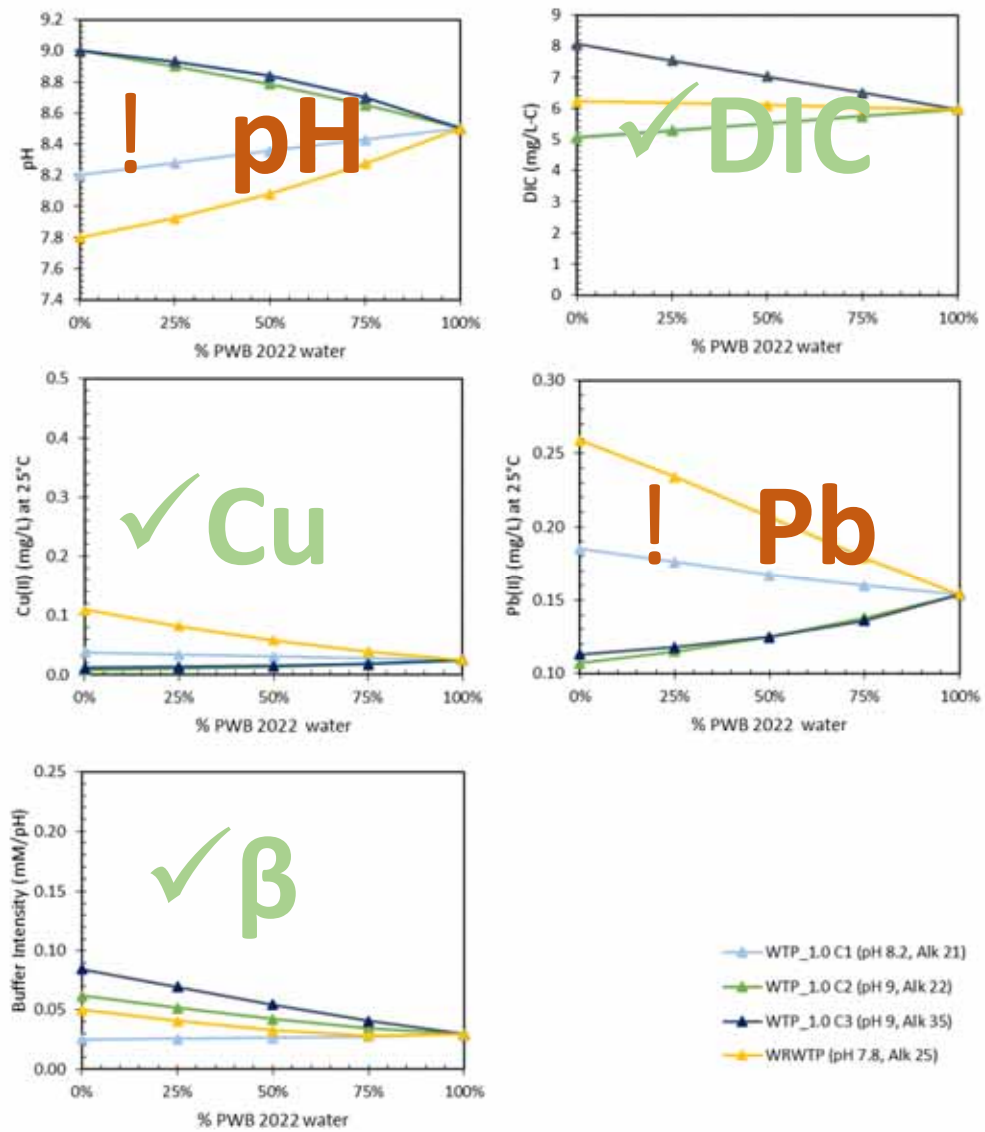
✓ Indicates negligible difference and no concern

- WTP_1.0 C2 and C3 (pH 9.0) very similar
- pH and Pb differences at all blend levels



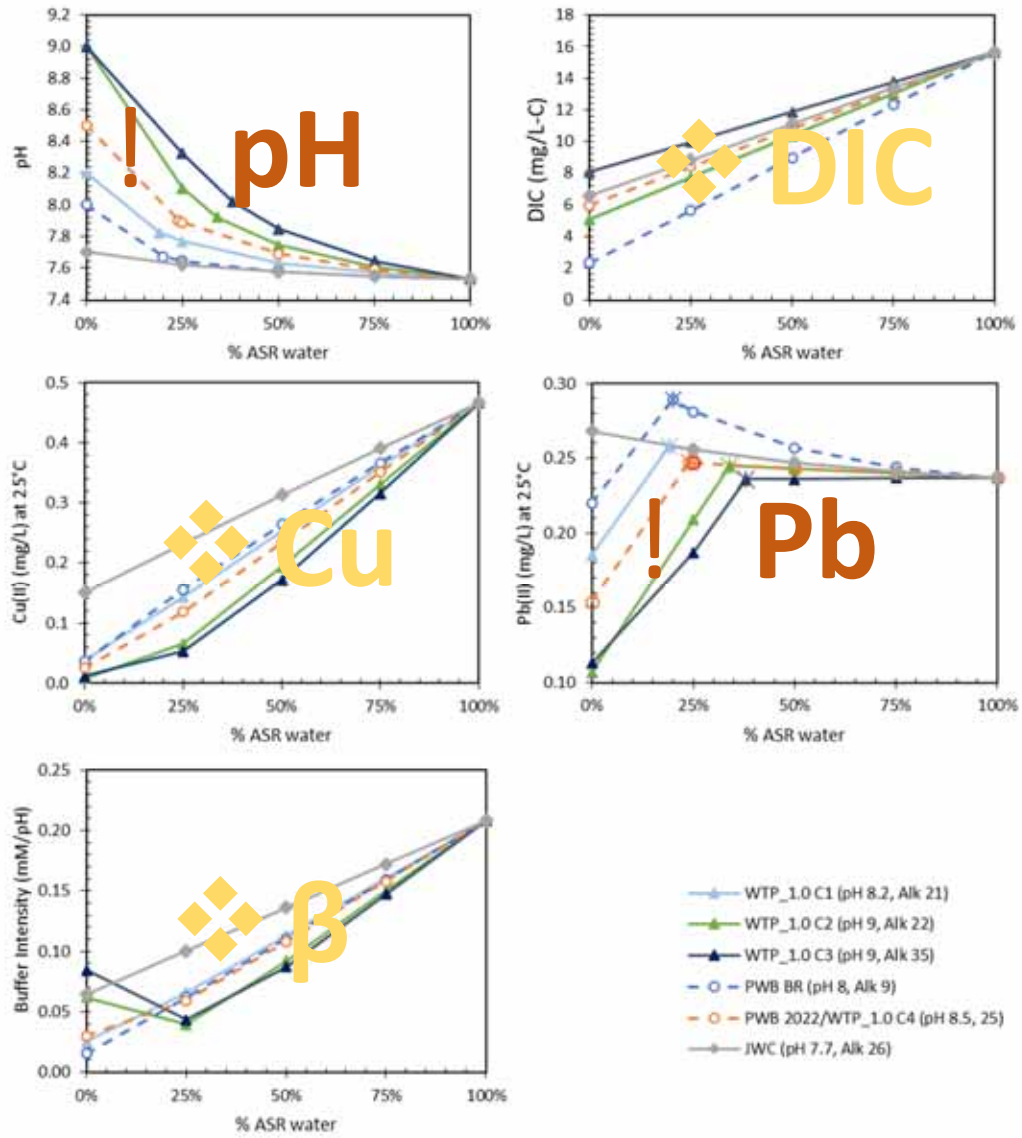
C4 - PWB-BR 2022 vs WTP_1.0 (Metzger Example)

- pH and Pb differences at all blend levels
- Lead could *increase* if choose WTP_1.0 C1 or WRWTP
- No difference between WTP_1.0 C2 and C3
- WTP_1.0 C4 = PWB-BR 2022



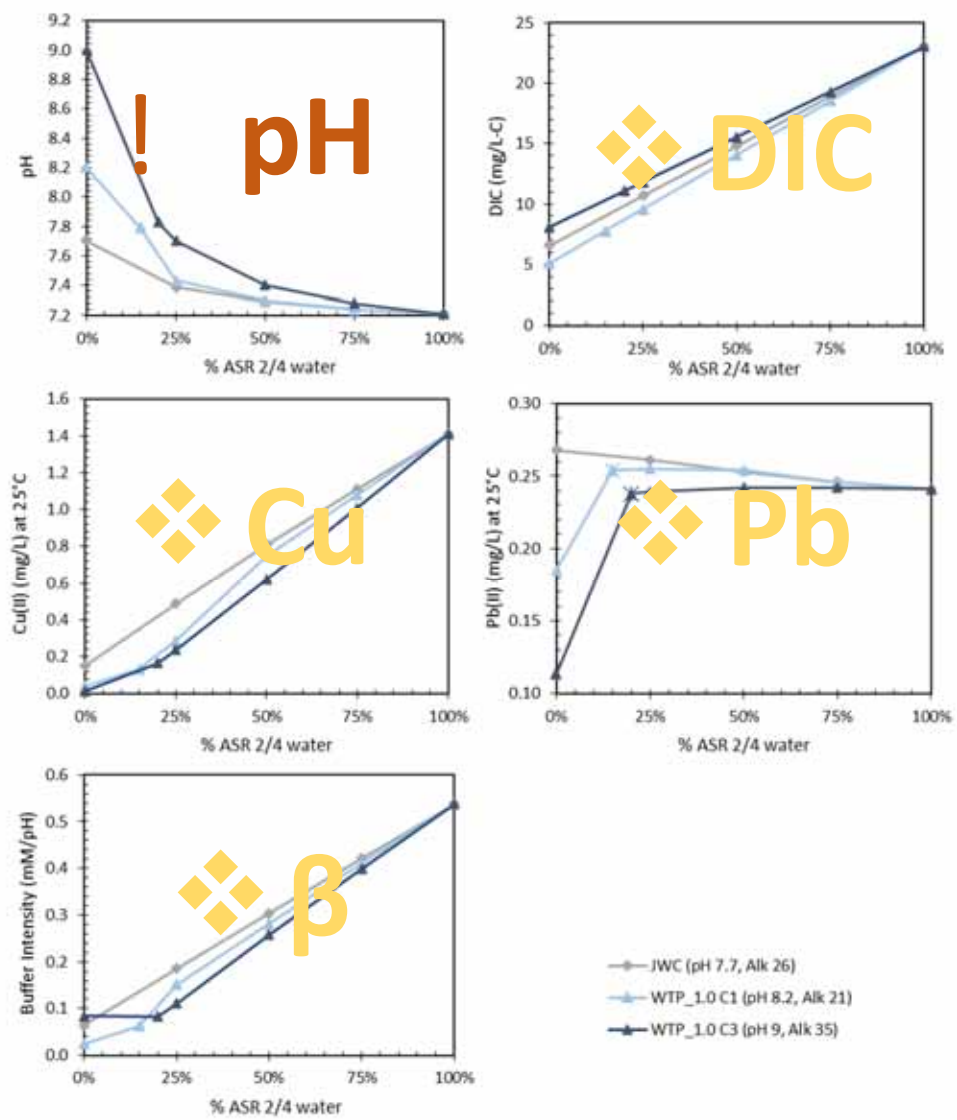
TVWD-ASR vs WTP_1.0

- Benefit of lower lead under WTP conditions tapers off quickly (~10-40%)
- Lead scale change at 25-50% blends
- ASR has higher DIC although no major differences between the blends.
- Copper solubility higher with ASR water quality; close to linear increase although the highest level << 1.3 mg/L
- Possible area in the system around 10-20% blending level that may experience higher lead solubility than if supplied by either source alone (C1)
- ASR provides increased buffer intensity, some differences between the blends



COB-ASR 2/4 vs WTP_1.0

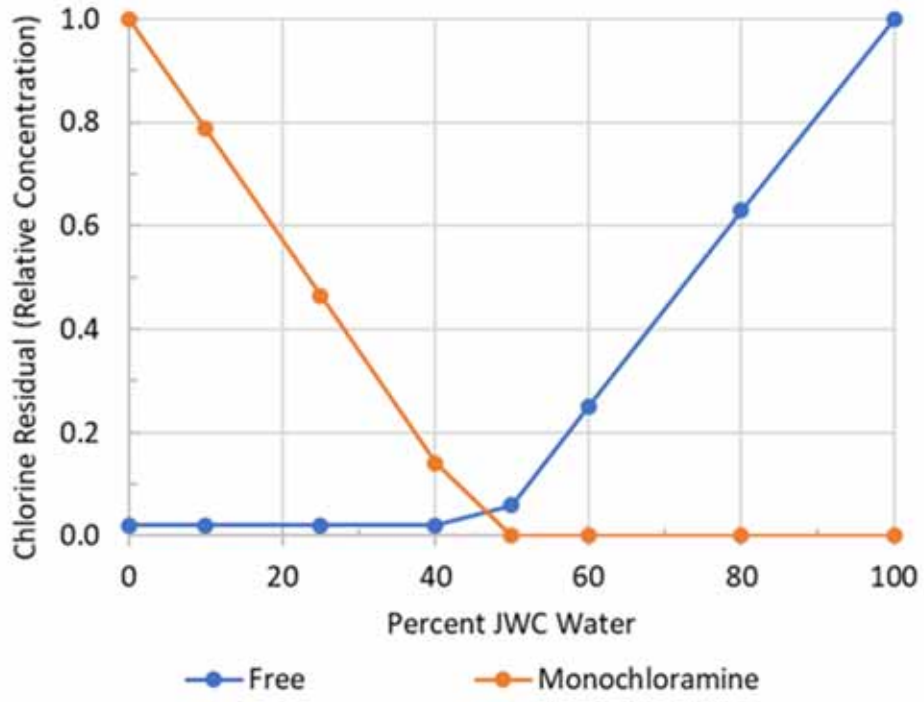
- Benefit of high pH under WTP conditions tapers off fast (~20%)
- ASR has much higher DIC; no difference between the blends
- Copper
  - solubility a concern under ASR water quality
  - close to linear increase in copper solubility with increasing blend levels
  - no difference between the blends
- Possibly area in the system around 10-20% blending level (only) at WTP C1 that may result in higher lead solubility than either source alone
- ASR provides increased buffer intensity; no difference between the blends



Desk-Top Free Chlorine/Chloramine Blending Breakpoint Curves

Assumptions:

- JWC Water at TVWD POE:
  - Free chlorine residual = 0.9 mg/L
  - Negligible ammonia
- PWB-BR Water at TVWD POE:
  - Monochloramine residual = 1.7 mg/L
  - 5:1 ratio
  - Free chlorine residual = 0.02 mg/L
  - Negligible free ammonia



- Essentially no chlorine at 40-50% blends
- Blends of less than 20% or more than 80% water with a free chlorine residual needed to maintain a significant total chlorine residual in the blend

Summary of Desk-Top Water Quality Analyses

Scale Stability

Lead species and stability significantly impacted by pH, DIC, ORP

Copper, iron, manganese should be OK over range of WTP_1.0 endpoints

Metals Solubility

Lead species and solubility significantly impacted by pH, ORP

Copper, iron, manganese should be OK over range of WTP_1.0 endpoints

Blending

Biggest Impact to pH, and therefore lead

Copper and indices impacted, but all improve over range of WTP_1.0 endpoints

Cement Linings

All WTP_1.0 endpoints should be less reactive compared to current JWC and PWB

Reactivity decreases as DIC and buffering intensity increase

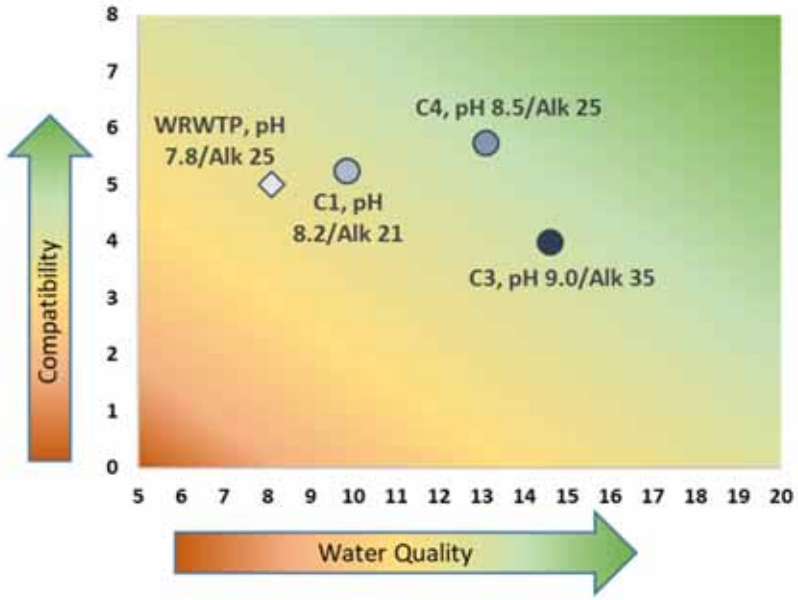
Evaluation Criteria – Qualitative and Semi-quantitative Approach

Public Health/Regulatory Compliance	• Pb(II) solubility • Pb(II) and Pb(IV) scale stability • DBP formation potential • Cu(II) solubility • CSMR	**Water Quality**
Aesthetics	• Fe(III) solubility • Mn(IV) solubility • Fe(III) stability indices	
Other Parameters Impacting Distribution System Water Quality	• Buffer Intensity (higher intensity = more stabilize pH) • CCPP and LSI Indices	
Compatibility with Other Supplies	• Overall impact when blended with the other supplies • Compatibility with ASR aquifer conditions	**Compatibility**

Recommended Initial Target

Recommended WTP_1.0 initial target:
pH 8.5/Alkalinity 25 mg/L $CaCO_3$ (WTP_1.0 C4, same as PWB 2022)

- Potential drawbacks
  - Increased formation of TTHMs
    - *Currently under evaluation*
  - Potential impacts on ASR aquifers
    - *Subsequent study by geochemists found no significant concerns*
  - Decreased compatibility with the existing JWC water that has higher theoretical Pb(II) solubility
    - *Confirm presence of Pb(IV)?*
  - Lower free chlorine disinfection efficiency at higher pH
  - Possible impacts to taste, odor, or feel of water
    - *Conducted analogous system review*
  - Buffer intensity
    - *Retain CO_2 at WTP_1.0*



General Framework

Modeled Parameters	Mechanism
Flow Direction – Reversals **Maximum Velocity** – Increases	Deposit Release Biofilm Sloughing
Water Age – Significant Changes – Elevated	Change in chlorine residual
Source Contribution – New Source – Seasonal Changes	Re-Equilibration Re-Acclimation

Potential WQ Impacts

Regulatory/Public Health

- Metals Excursions
- Bacterial Activity ↑
- Bacterial Regrowth
- Total Coliform +
- DBP Formation

Aesthetics/Other

- Colored Water
- Scale Destabilization
- Corrosion
- Taste and Odor
- Customer Perception