Transforming Drinking Water in the Puget Sound Region: Cascade Water Alliance's Regional Blending Study

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Confluence Engineering Group

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American Water Works Association
Pacific Northwest Section

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Topics



Source: Cascade Photo Gallery

- Regional Blending Study Overview
- Approach, Limitations & Data
- Water Quality Comparison
  - Finished Water, Transmission, and Distribution System
- Water Quality Modeling (Chemistry, not hydraulic)
  - Water Quality Indices, Blending, Solubility & Scale Stability
- Risk Assessment Findings and Recommendations
  - Regulatory & Public Health, Aesthetics, Infrastructure

Acknowledgements & Gratitude:

Coauthors & Reviewers:

Cascade Water Alliance: Cody Nelson, Colleen Petilla, Melina Thung

Confluence Engineering Group: Grace Crowe, Melinda Friedman, Virpi Salo-Zieman

Contributors:

Data & Information:

Cascade & Member Agencies, Seattle Public Utilities, Tacoma Water



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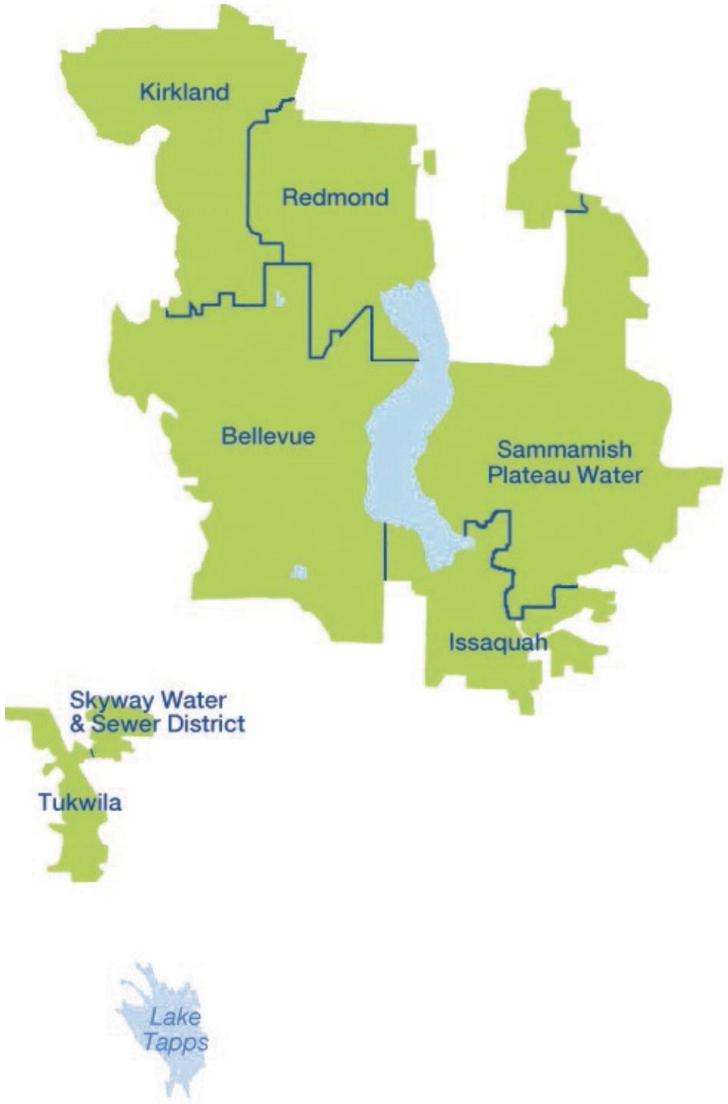
Regional Blending Study Overview


Mt. Baker 3286
Bellingham
Skagit
CASCADE RANGE
Okanogan
Kettle
Columbia
Abercro
Franklin
D. Roosevelt
Lake
Glacier Peak 3213
Lake Chelan
WASHINGTON
Everett
Skykomish
Hoh
Mt. Olympus
2429
Spokane
Banks Lake
Spokan
Seattle
Mt. Stuart 2870
Quinault
Bremerton
Lake Washington
Wenatchee
Crab Cr.
Moses Lake
Olympia
Tacoma
White
Yakima
Columbia
COLUMBIA
PLATEAU
Chehalis
Potholes Reservoir
Mt. Rainier
4392
Aberdeen
Centralia
Palouse
Yakima
Cowlitz
Richland
Mount Adams

Cascade Water Alliance

Member	2023 Population
Bellevue	162,200
Issaquah	29,000
Kirkland	49,200
Redmond	85,600
Sammamish Plateau Water	59,300
Skyway Sewer & Water District	12,500
Tukwila	7,500
Total	**405,300**

- Total Daily Demand 32-37 MGD
- Seattle Public Utilities (SPU) Primary Supply; declining block contract (beginning in 2040)



- Formed in 1999
- Is a joint municipal utility services authority (Ch 39.106 RCW)
- Focus on long-term water supply
- Purchased Lake Tapps 2009 for future supply
- Develop Lake Tapps as a new regional supply in the early 2060s (as needed)

Sources: Figures & Information: Cascade

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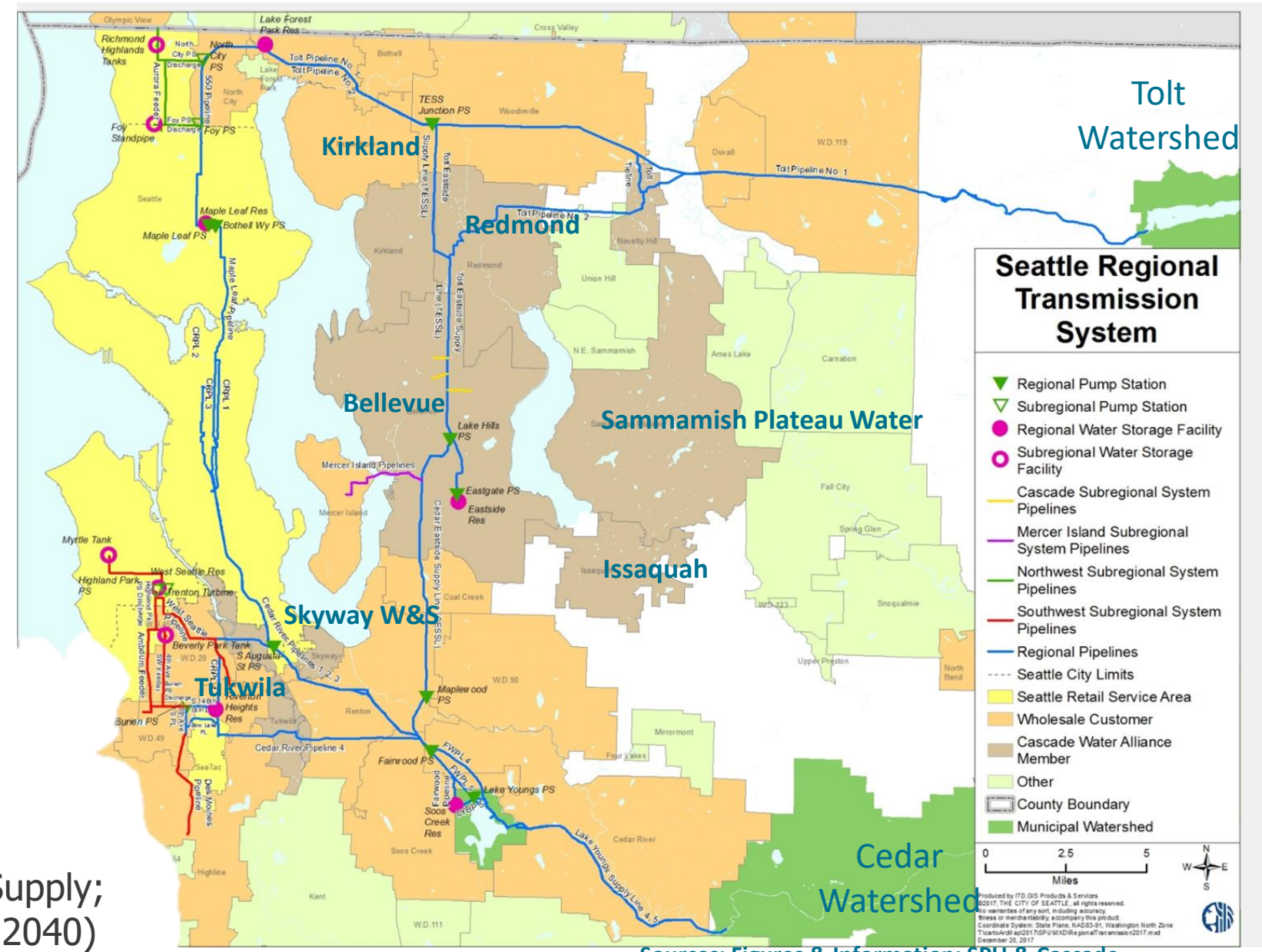
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Cascade Water Alliance

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Regional Surface Water Supplies, all with strong Watershed Control:

Tolt (2001): Preozonation, high rate granular media filtration, free chlorine, lime addition

Cedar (2004): Ozone, UV, chlorine, lime addition (unfiltered operating under federal Limited Alternative to Filtration)

Green (2015): Preozonation, high rate granular media filtration (2014), free chlorine, NaOH + CO_2



Sources: Figures & Information: TPU, SPU & Cascade

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Cascade Supply Program
Phase Map

Phase II - 2030-2053
Distribution

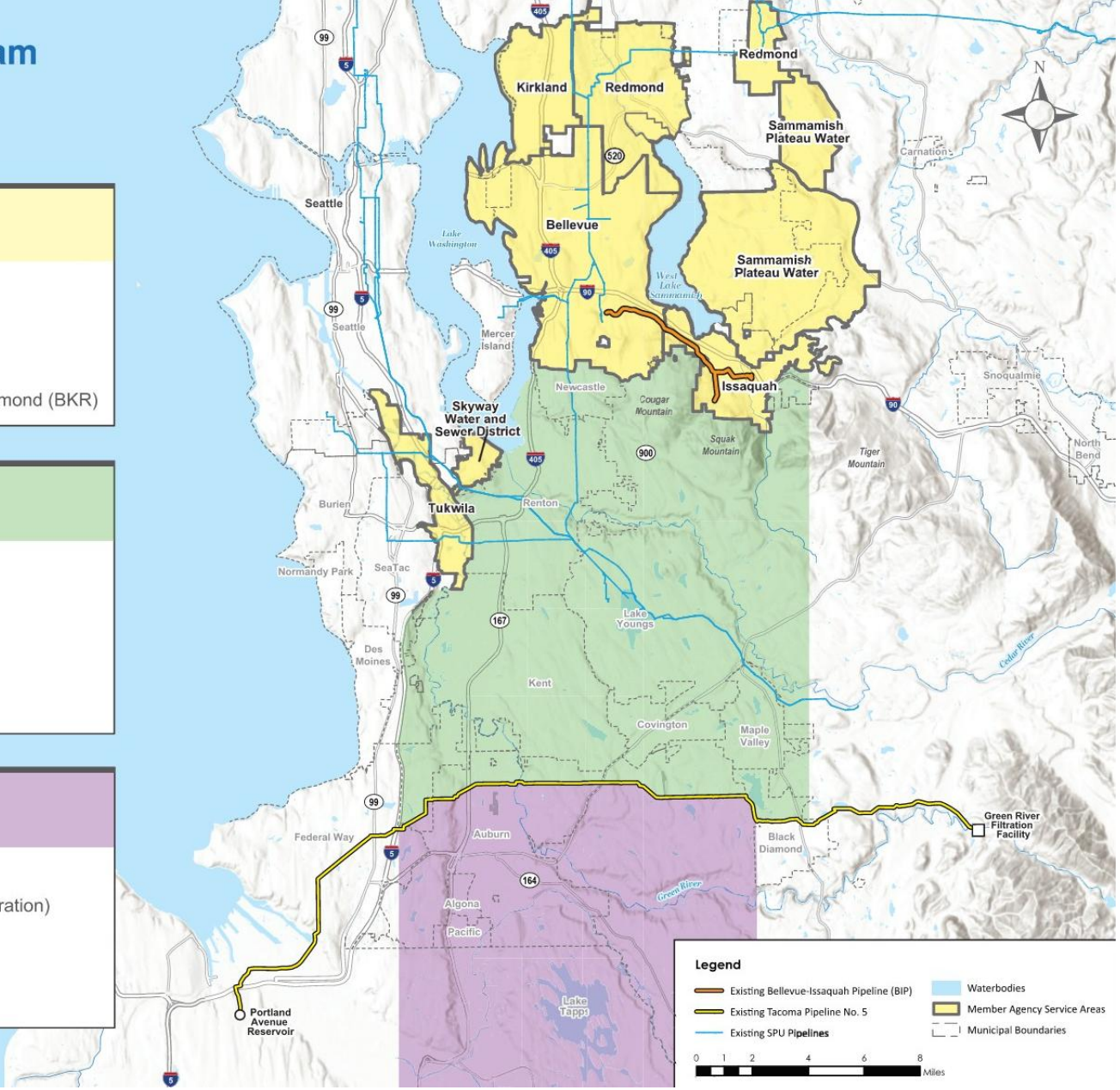
Member Distribution
- Potential additional storage tank
- Potential Bellevue-Issaquah Pipeline distribution improvements
- Potential Pump Station
- Potential Eastside distribution lines serving Bellevue/Kirkland/Redmond (BKR)

Phase I - 2026-2040
Transmission

Connect Tacoma and Cascade
- Tacoma-Cascade Transmission Line
- Cascade Storage Tank
- Cascade Re-chlorination Station
- Building facilities for SCADA and Operations
- Building facilities for Storage and Maintenance

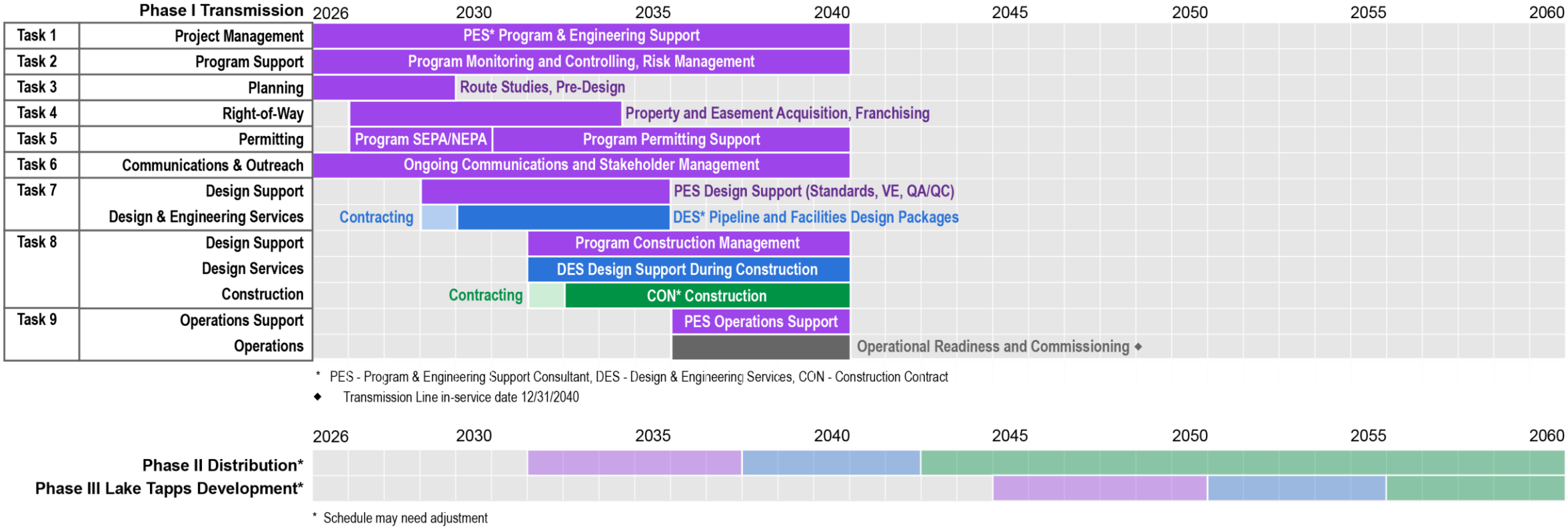
Phase III - 2043-2060
Water Supply Development

Treatment, Pumping and Transmission Pipeline
- Lake Tapps Reservoir Water Treatment Plant (water intake and filtration)
- Lake Tapps Transmission Line
- Potential appurtenant facilities
- Phased capacity buildout



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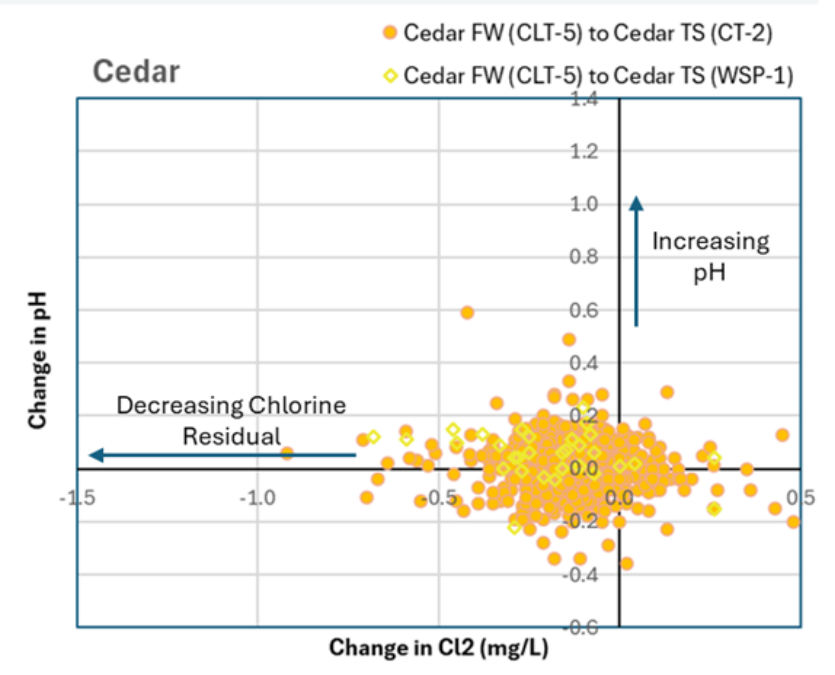
Program Next Steps

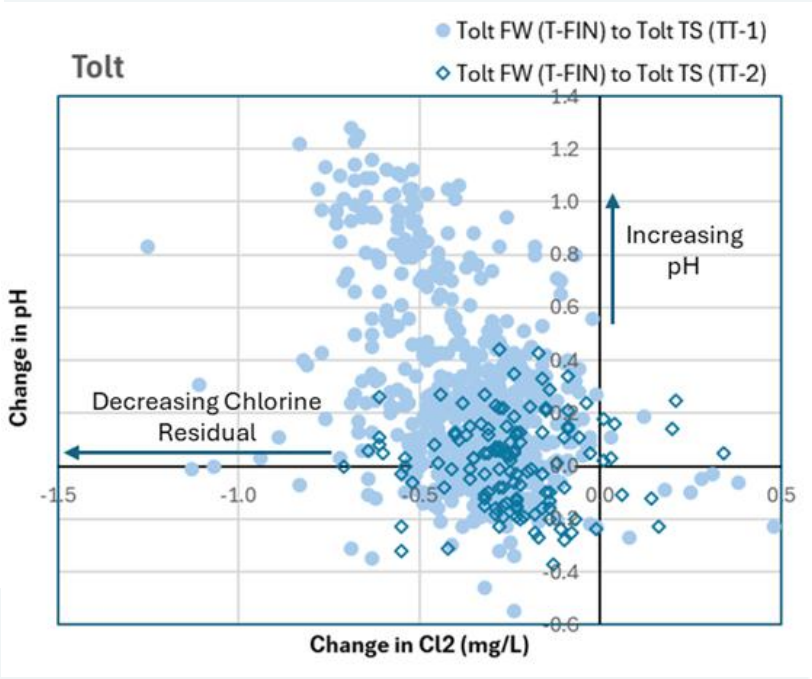


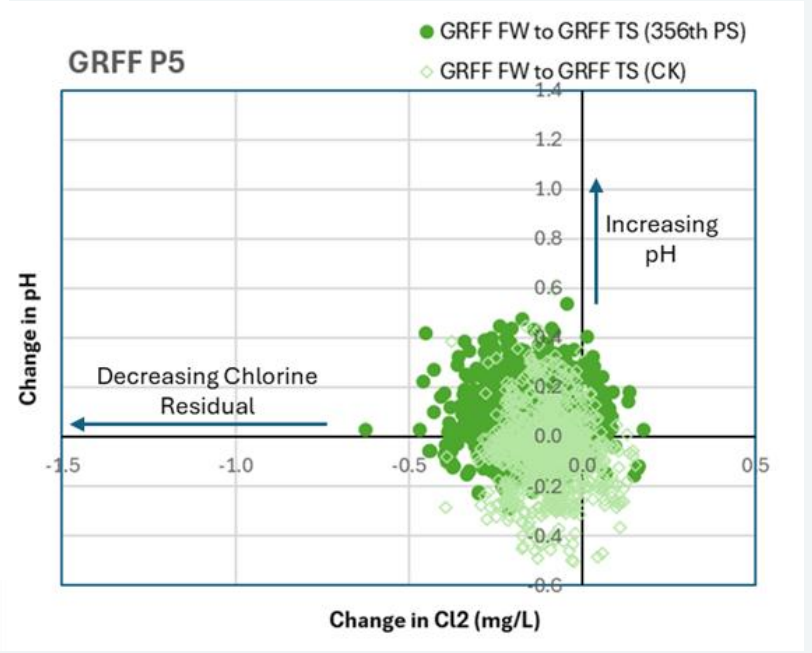
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Approach, Limitations & Data

Blending and Compatibility Study

Objectives

- Evaluate compatibility of Tacoma Water's Green River Filtration Facility (GRFF) supply with existing supplies from Seattle Public Utilities' (SPU) Cedar River and Tolt River water treatment plants.

Outcome

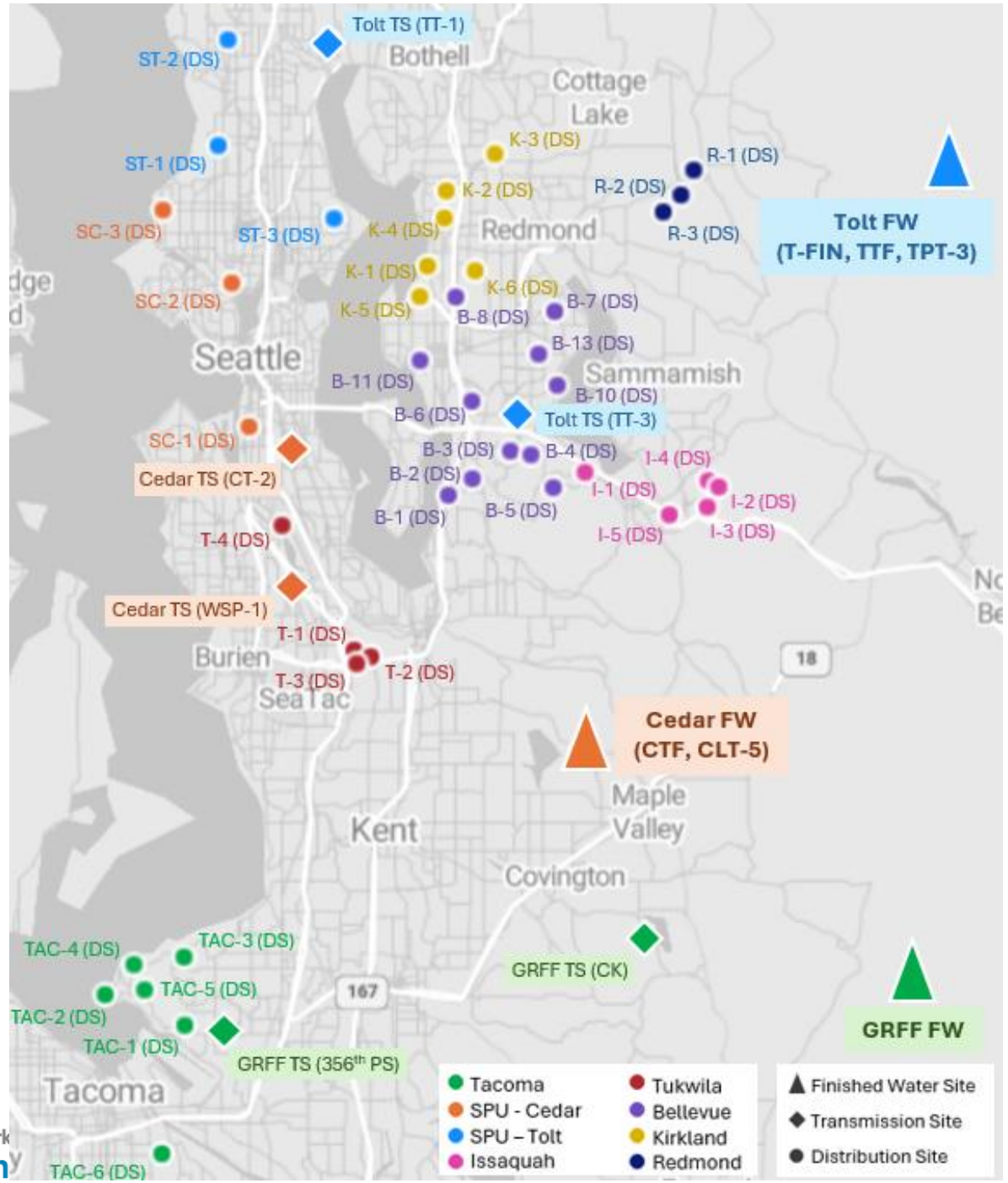
- Identification of water quality compatibility risks and potential mitigation strategies

Limitations

- Desk-Top Study based on existing data & theoretical modeling
- Data not "paired" (frequency, dates, analytical methods)
- Hydraulic impacts of supply introduction not considered

Water Quality Data

- Evaluate water quality at:
  - Finished Water (FW)
  - Transmission System Sites (TS)
  - Distribution System Sites (DS)
- Data from SPU, Tacoma, and member agencies
- Data analysis approach – time series, seasonal assessment, overall statistics – to:
  - Compare supplies against each other
  - See if and where parameters are changing during transmission
  - Establish inputs to water quality modeling
- Did not involve new, paired data collection



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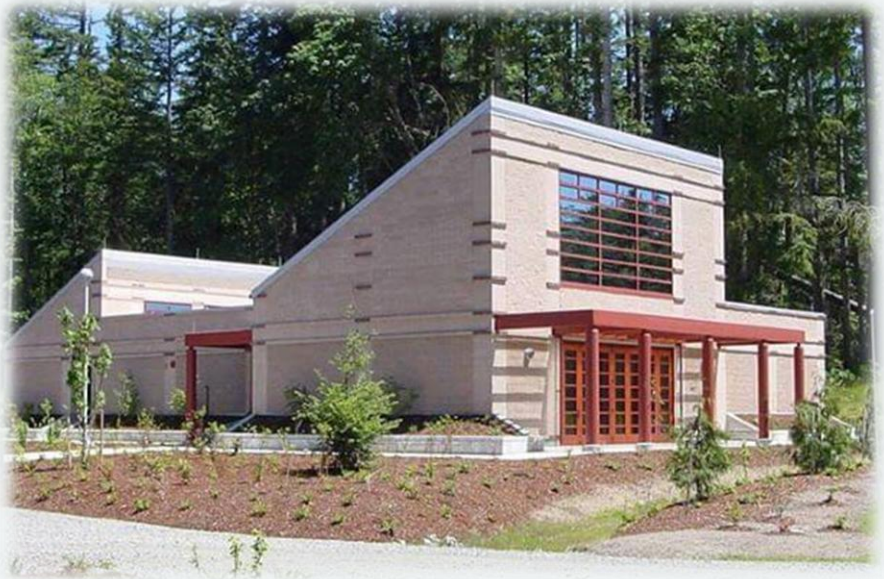
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Tolt Treatment Facilities



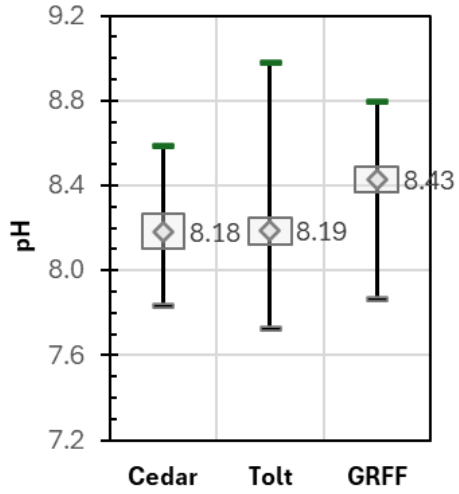
Green River Filtration Facility

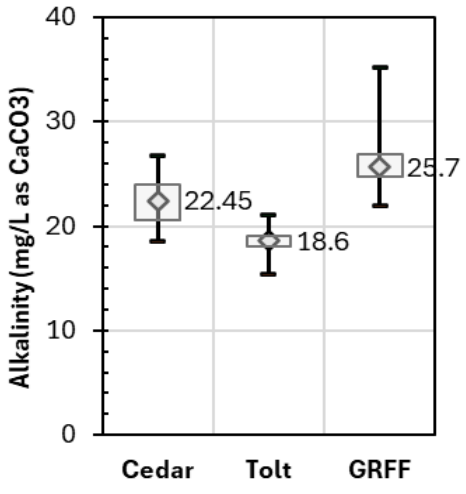


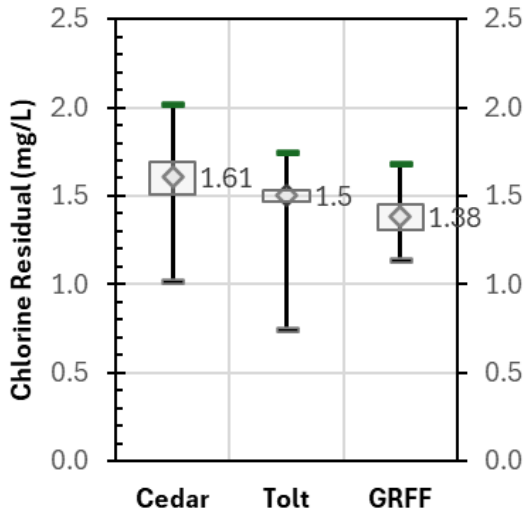
Cedar Treatment Facilities

Finished Water Quality Assessment

Finished Water Quality

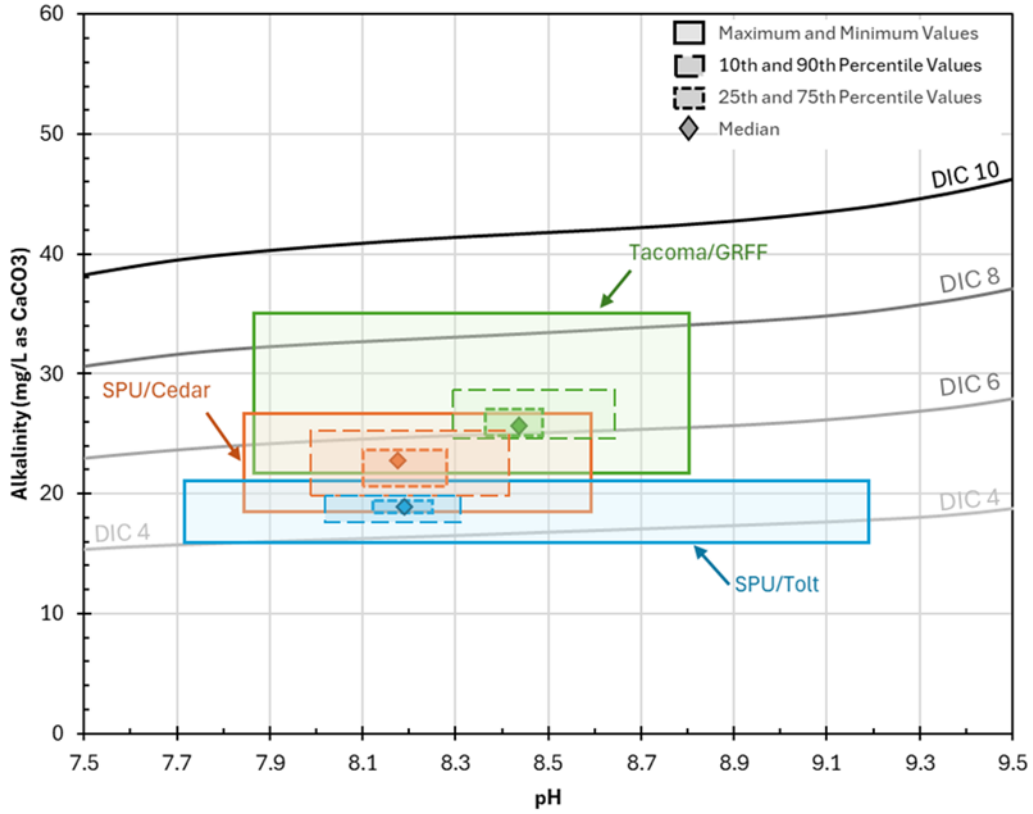






Dissolved Inorganic Carbon (DIC) Ranges:

- Cedar FW 4.5-6.5 mg/L as C
- Tolt FW 4-5 mg/L as C
- GRFF FW 5-8 mg/L as C



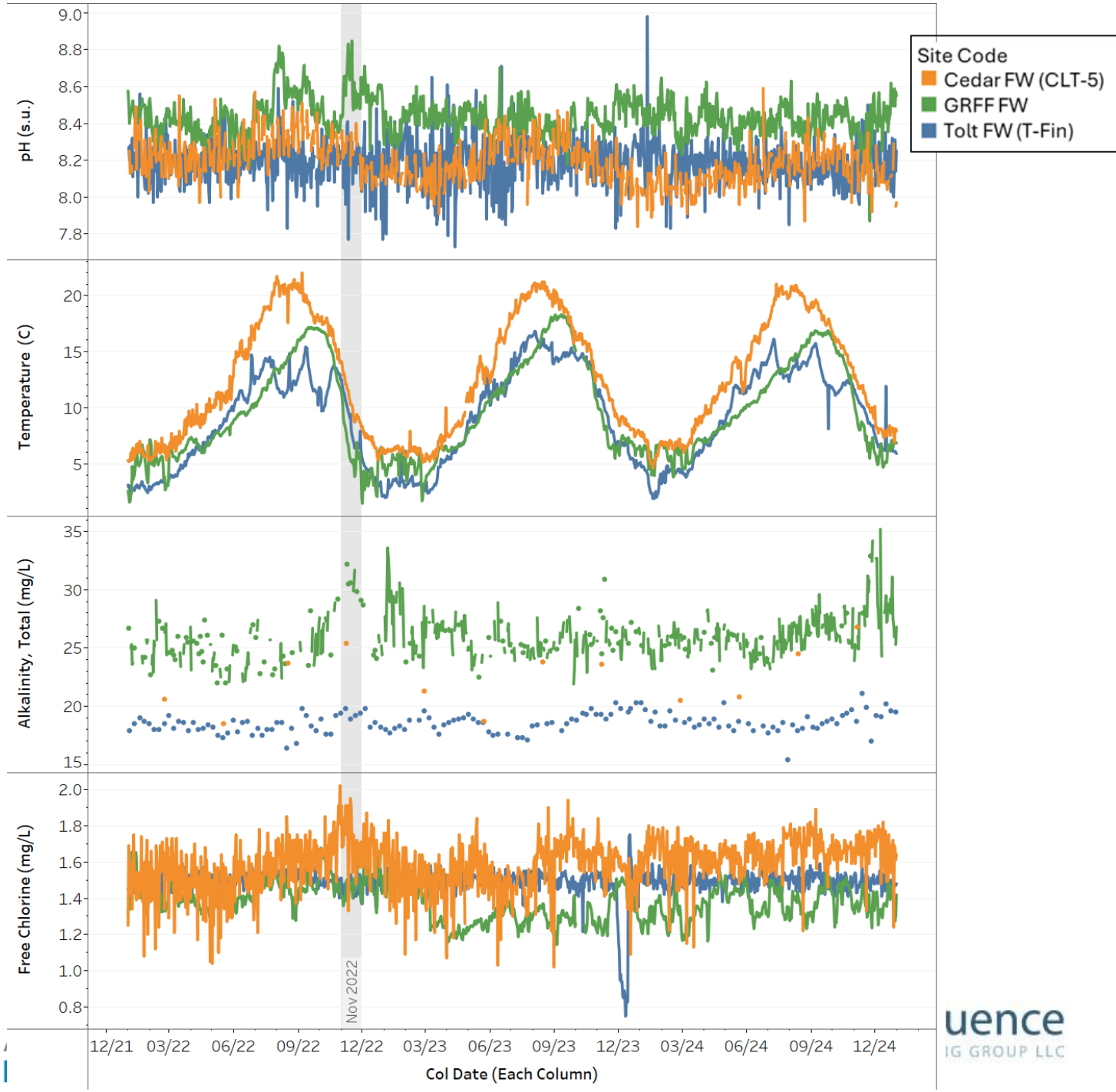
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Seasonal Finished Water Quality Comparison

- Cedar has seasonal pH profile, but generally falls between Tolt and GRFF
- Cedar water is warmer and temp peaks earliest
- GRFF has highest alkalinity. Cedar alkalinity falls between GRFF and Tolt and appears to have summer lows and fall/winter highs
- November 2022 (grey bar) – largest difference in pH and Alkalinity between sources.
- GRFF has a lower chlorine residual. Tolt falls between Cedar and GRFF



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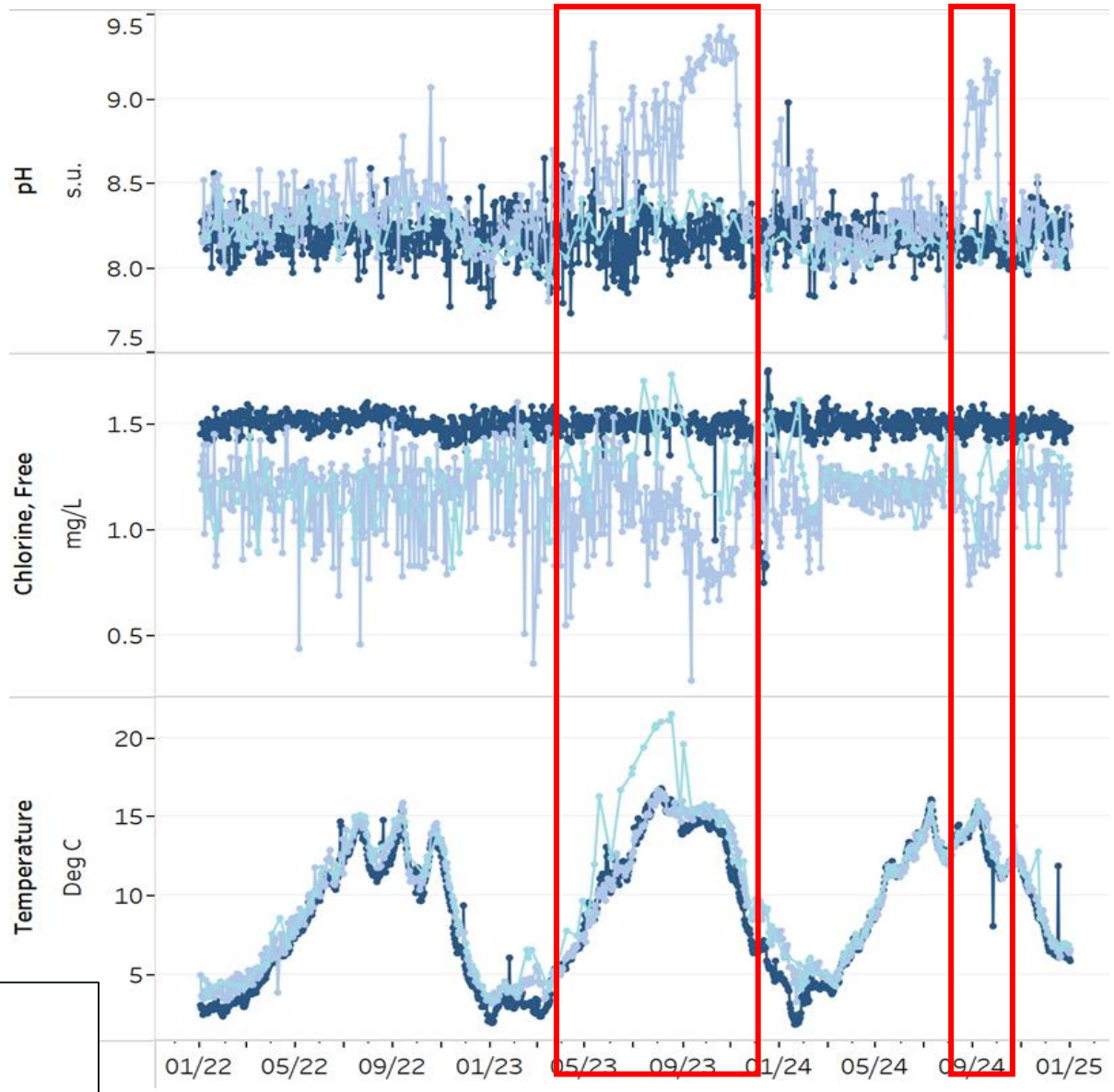
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Transmission System Impacts

Tolt Transmission System Impact on Water Quality

- Tolt Pipeline 1 (Tolt TS (TT-1))
  - pH increase & Cl2 decrease episode related to supply balancing operations that brought more Cedar water north
    - Reduced flows & increased water age in the Tolt Pipeline
  - Consideration for Cascade when designing for the new infrastructure
- Tolt East Supply Line (Tolt TS (TT-3))
  - No large swings



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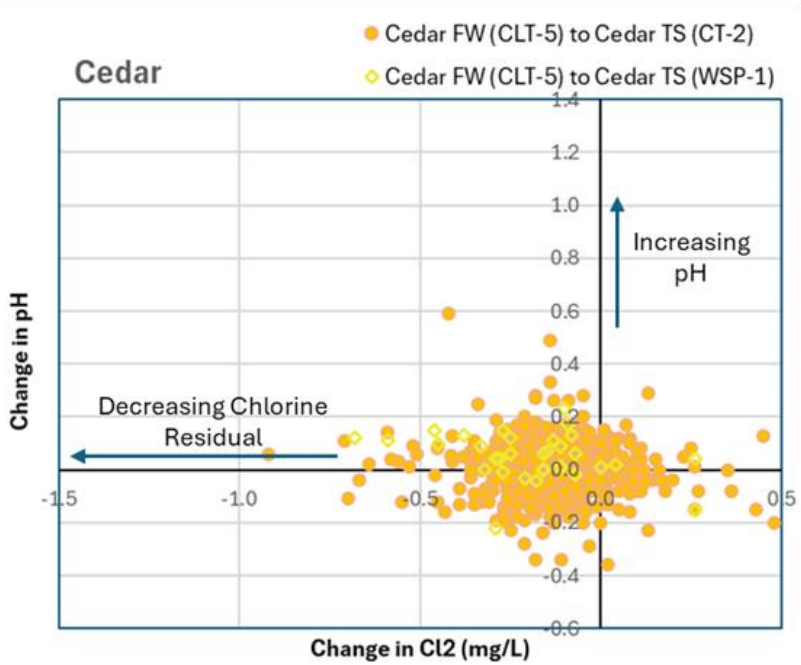
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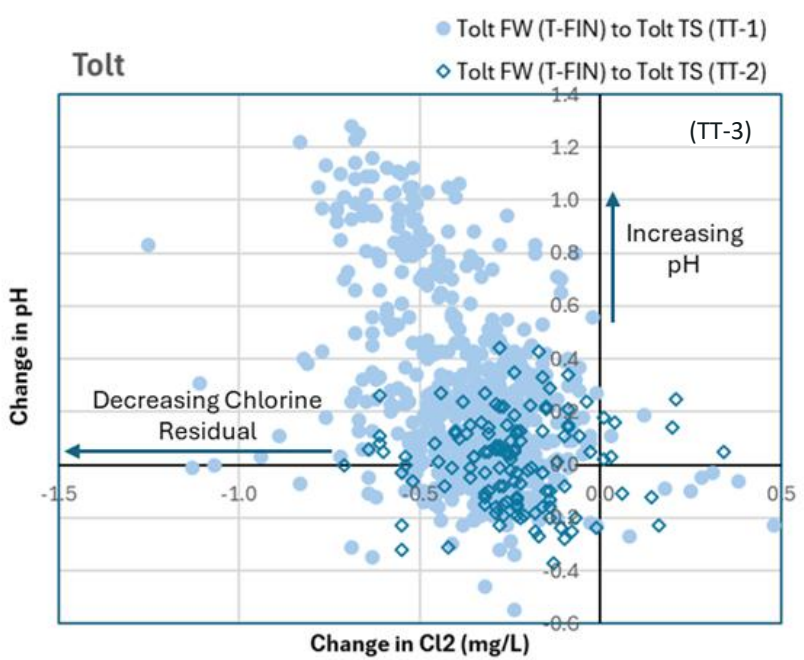
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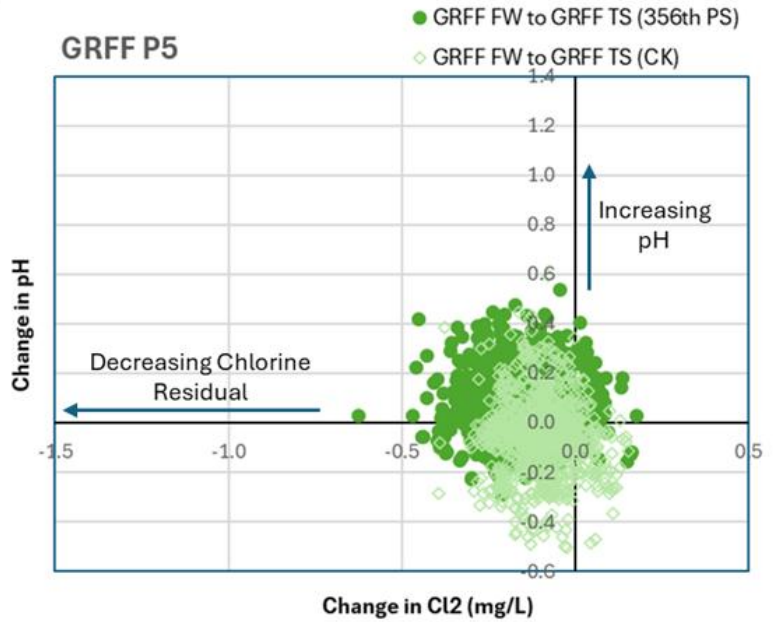
Transmission System Impacts on Water Quality

(Changes to pH and Chlorine residual)

- Cedar – generally stable
- Tolt – most variable (operational drivers)
- GRFF slightly more chlorine stable, in between observed changes for Cedar TS and Tolt TS (TT-3) for pH
- Aside from stagnation issue, no noticeable differences related to the main materials
  - SPU – Concrete, or cement mortar lined steel (steady pH and Ca levels in Cedar)
  - Tacoma – Polyurethane lined steel







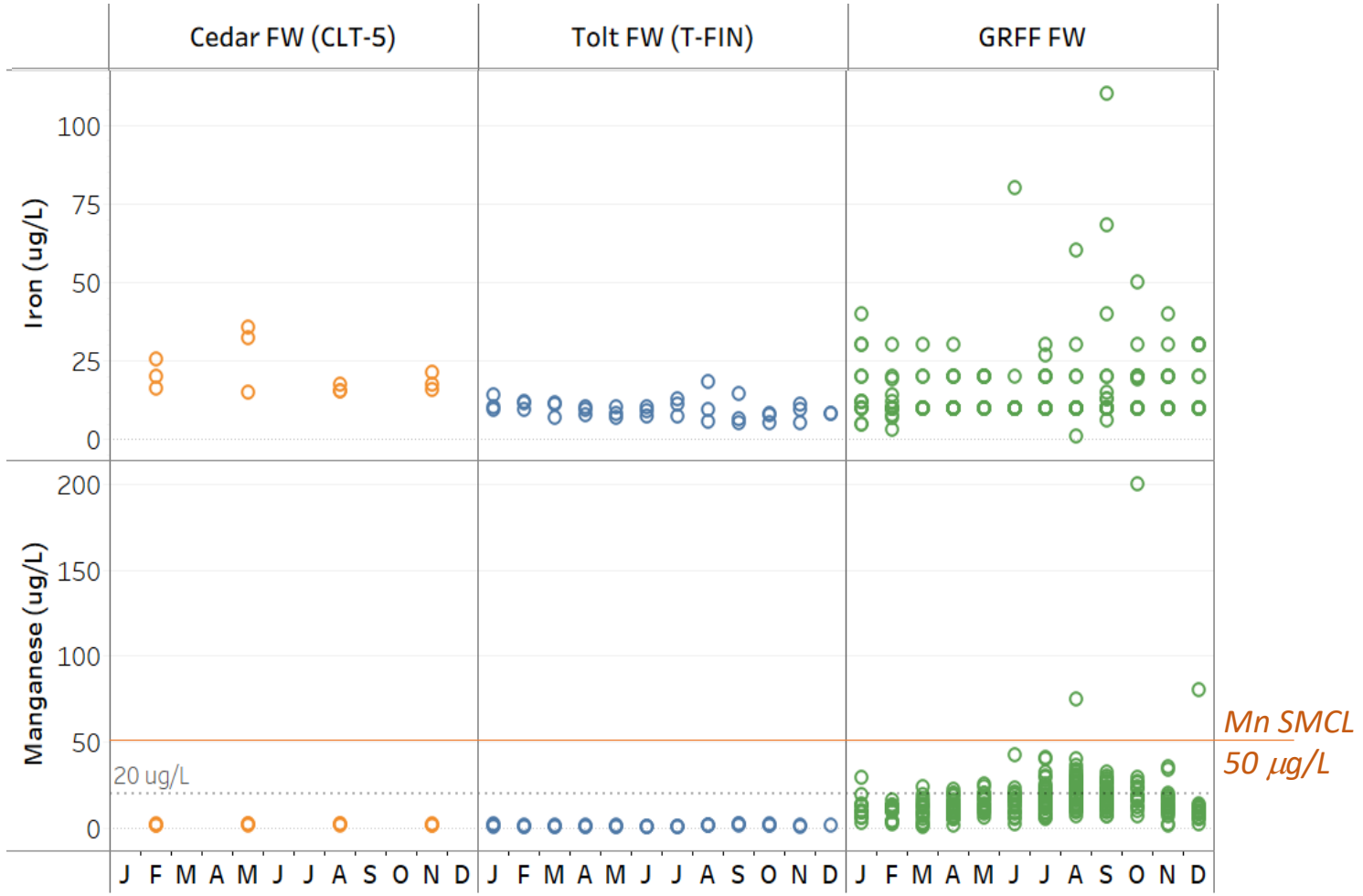
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Iron, Manganese - Finished Water

- Fe, Mn – Higher in GRFF
  - Least frequent monitoring at Cedar
  - Most frequent monitoring at GRFF
- Fe - All supplies below secondary MCL (SMCL) of 300 μg/L
- Mn - GRFF exceeded SMCL of 50 μg/L for manganese on a few occasions, seasonally exceeded industry recommended limit of 20 μg/L



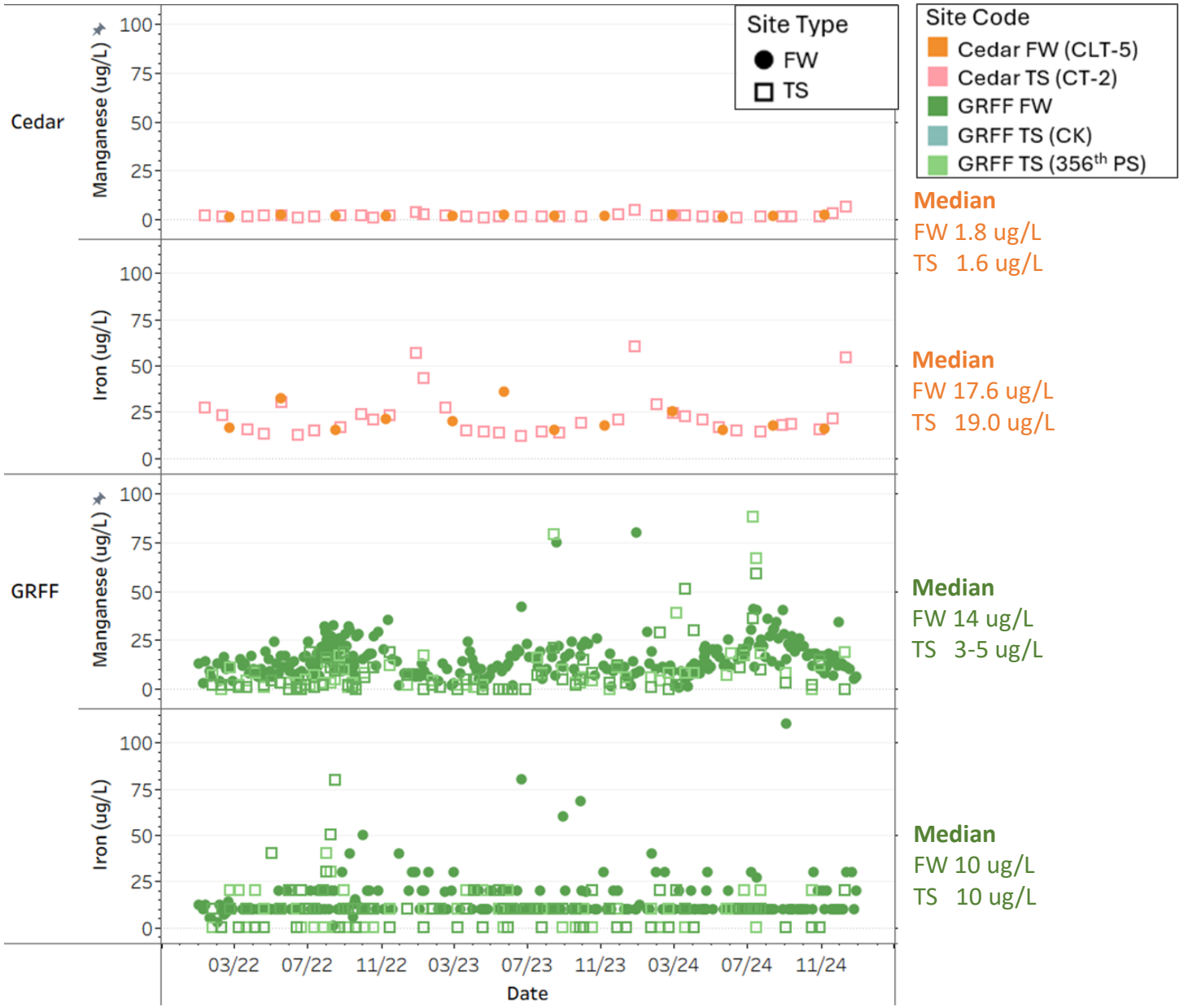
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Iron, Manganese - Transmission Sites

- No data from Tolt
- Significantly more data from GRFF
- Cedar iron
  - Medians higher than GRFF
  - Seasonal releases from transmission – magnitude is similar to GRFF
- GRFF manganese
  - Source loading & accumulation in Pipeline 5
  - Occasional releases from transmission pipeline



Median
FW 1.8 ug/L
TS 1.6 ug/L

Median
FW 17.6 ug/L
TS 19.0 ug/L

Median
FW 14 ug/L
TS 3-5 ug/L

Median
FW 10 ug/L
TS 10 ug/L

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Water Age in Transmission Estimates

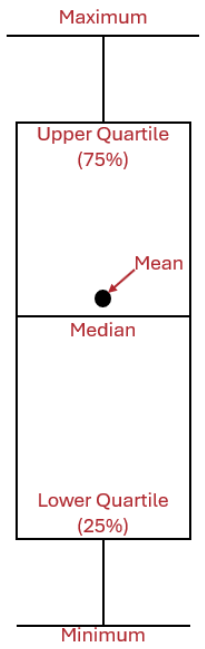
- Data Sources:
  - SPU EPANET hydraulic model
  - Tacoma operational data (P5 flows and chlorine)
  - SPU & regional operational data (chlorine residuals)
- Water Age
  - 6-30 hours in transmission on average
  - Future Cascade - Tacoma point of connection: 6-12 hours

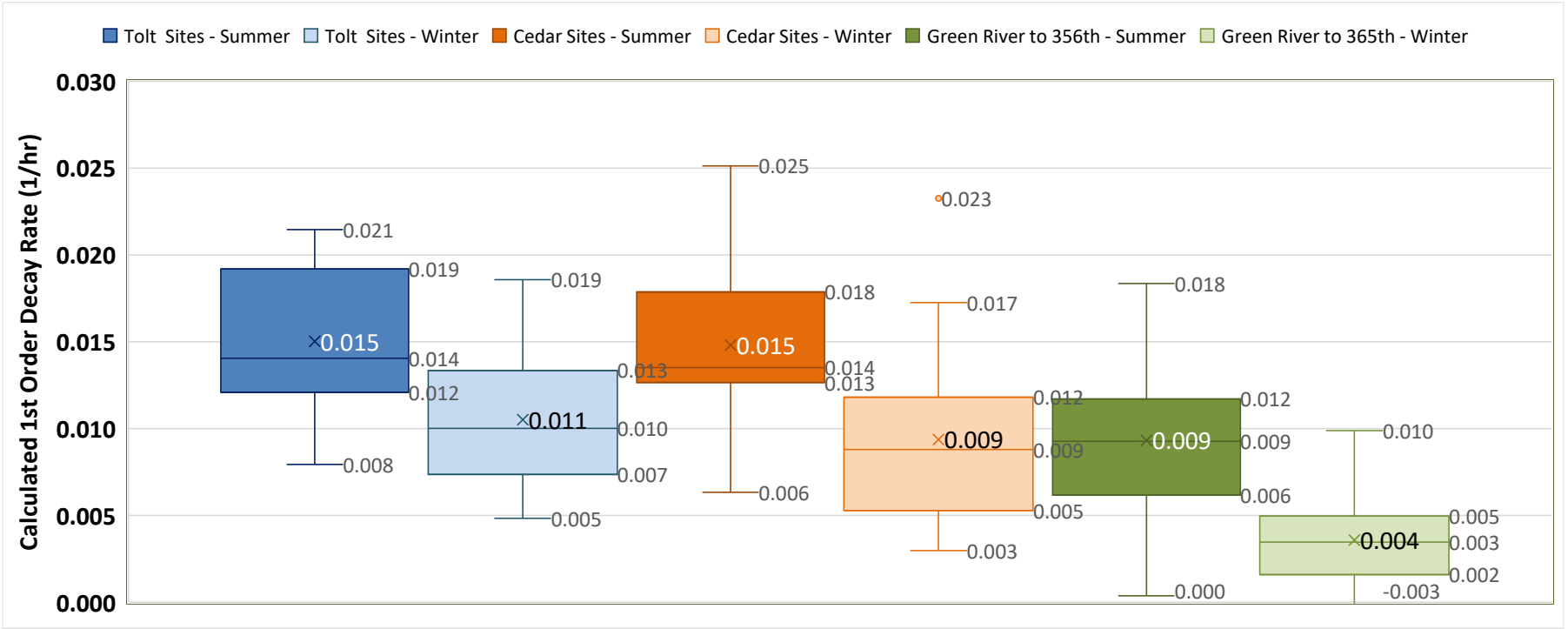
Pipelines	Portion	Appr. Distance	Average Day (Winter) Tolt Avg. Flow: 45 MGD Cedar Avg. Flow: 82 MGD GRFF Avg.Flow (P5): 23 MGD	Peak Day (Summer) Tolt Avg. Flow: 74 MGD Cedar Avg. Flow: 146 MGD GRFF Avg. Flow (P5): 44 MGD
			Water Age (Hours)	Water age (Hours)
Tolt Supply Lines	Tolt FW (T-FIN) to Tolt TS (TT-1) TTF to TT-1 (Lake Forest Res.)	25 miles	Average 24.5	Average 16
	Tolt FW (T-FIN) to Tolt TS (TT-3) TTF to TT-3 (Eastside Res.)	20 miles	Average 17	Average 15
Cedar Supply Lines	Cedar FW to Cedar TS (CT-2) (Beacon Hill Res.)	12 miles	Average 15	Average 7.4
	Cedar FW to Cedar TS (WSP-1) (to W. Sea Res.)	12 miles	Average 15	Average 8
	Cedar FW to Mercer Island Tanks	15 miles	Average 23	Average 11
GRFF Pipeline 5	GRFF FW to GRFF TS (CK) (1st Covington Turnout)	11 miles	Average 12	Average 6
	GRFF FW to GRFF TS (356th PS) (NE Tacoma)	27 miles	Average 31	Average 16

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Chlorine Decay Rates





- Winter (colder) better than summer, as expected
- Tacoma Green River decay rates lower, with overlap in the data
- 46 – 74 hours for chlorine residuals dosed at approximately 1.5 mg/L to decay to 0.75 mg/L (½ life) based on summer average values

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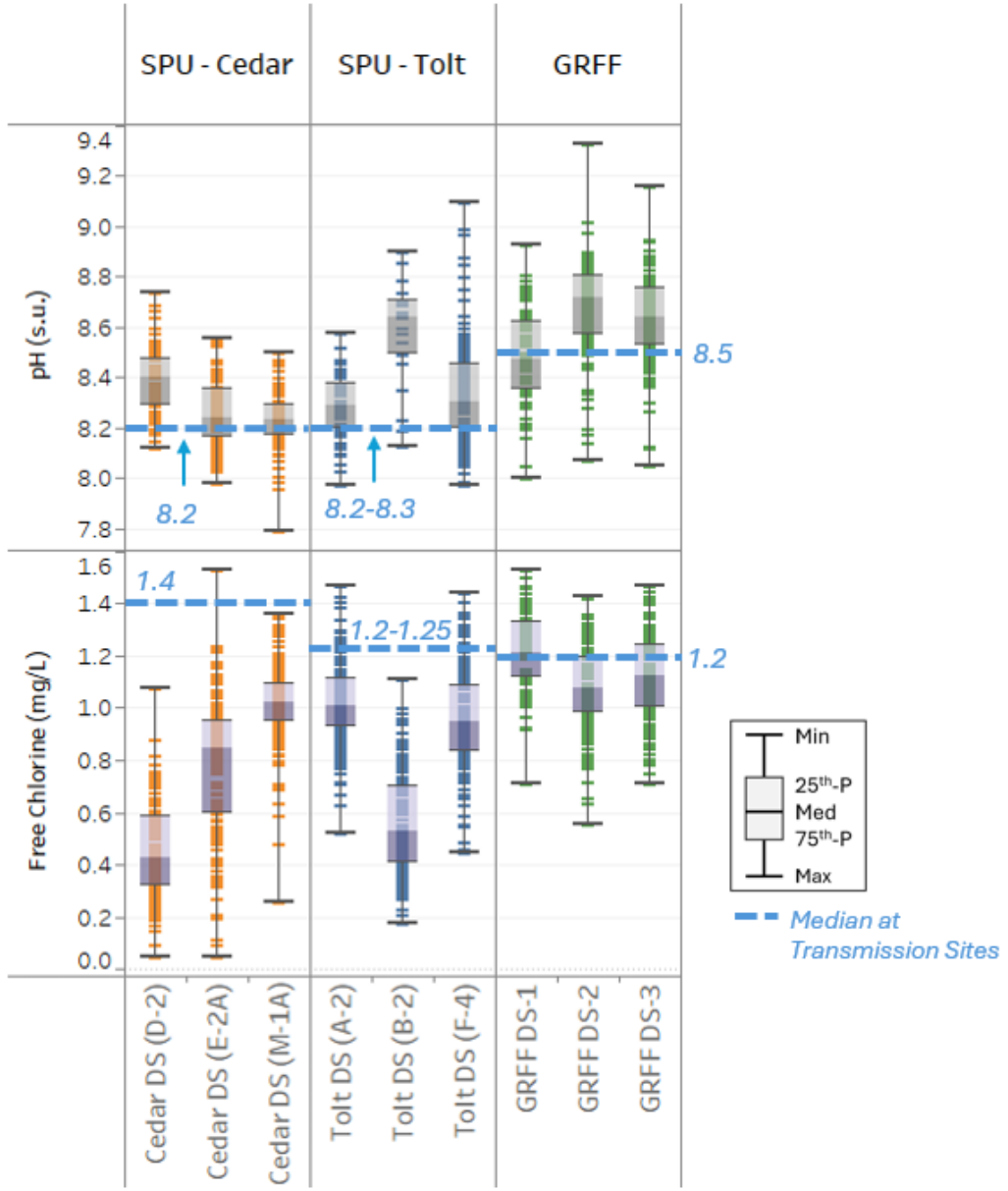
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Distribution System Water Quality Assessment

Distribution System pH and Chlorine Residual

- pH and chlorine residual within similar ranges at the Distribution System (DS) sites
- pH most stable at sites receiving Cedar water
- pH in GRFF DS sites about 0.2-0.4 higher than SPU sites
- Chlorine residuals more stable and experience less of a decrease at GRFF sites
- Cedar DS (D-2) lowest median Cl_2 and low residuals especially in summer

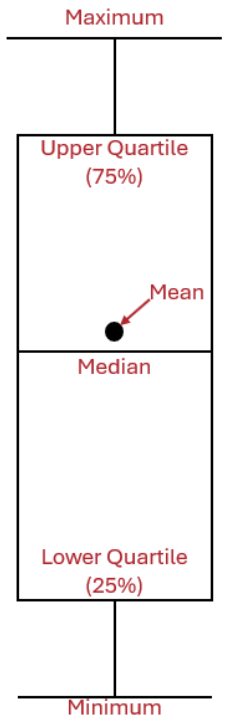


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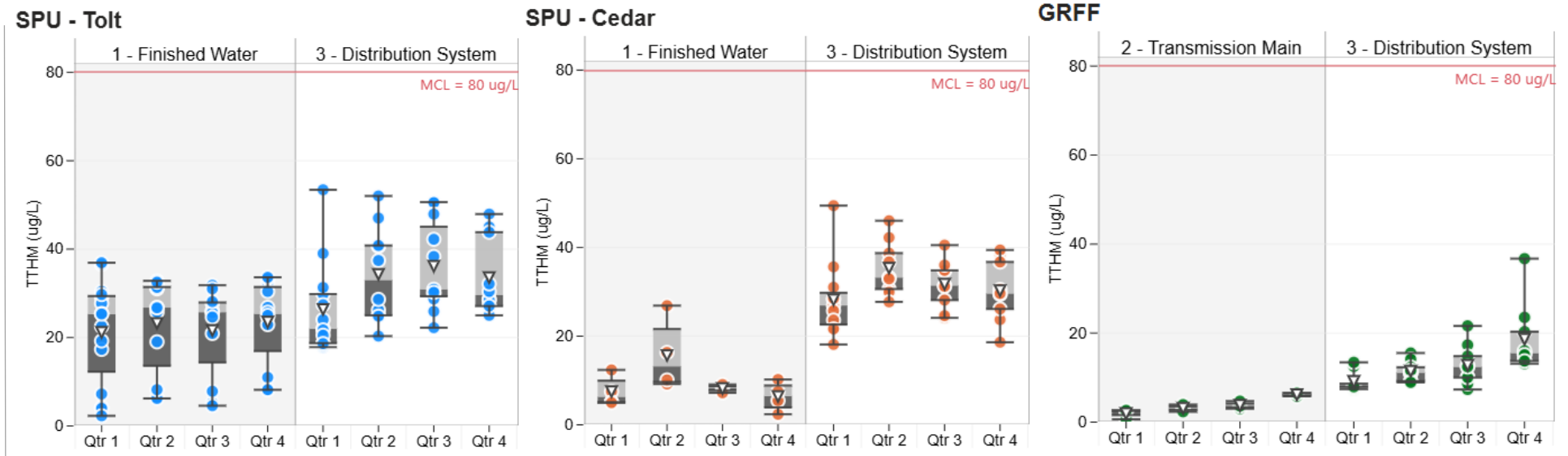
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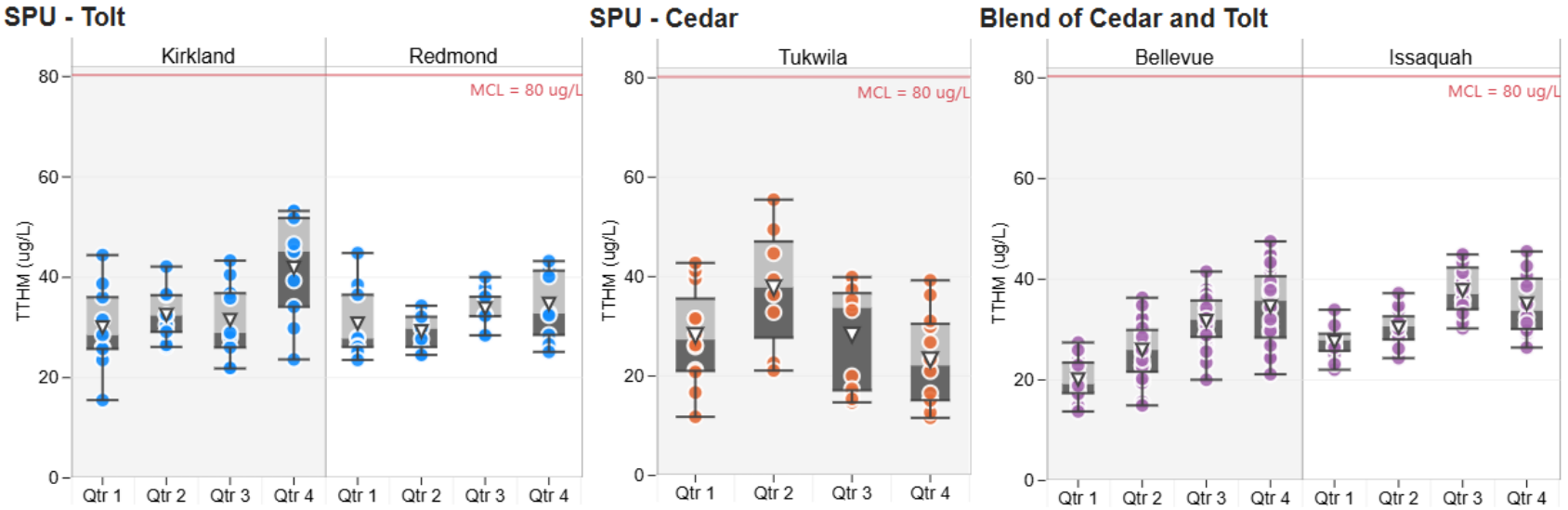
DBP – Total Trihalomethanes (TTHM)



Source Owner Samples (GRFF/SPU)



Cascade Member Samples

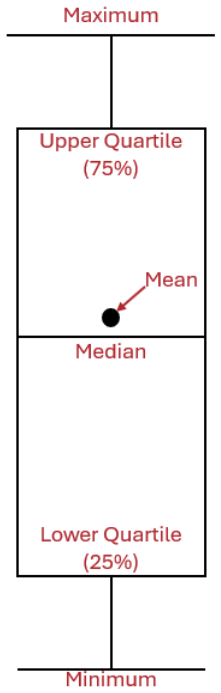


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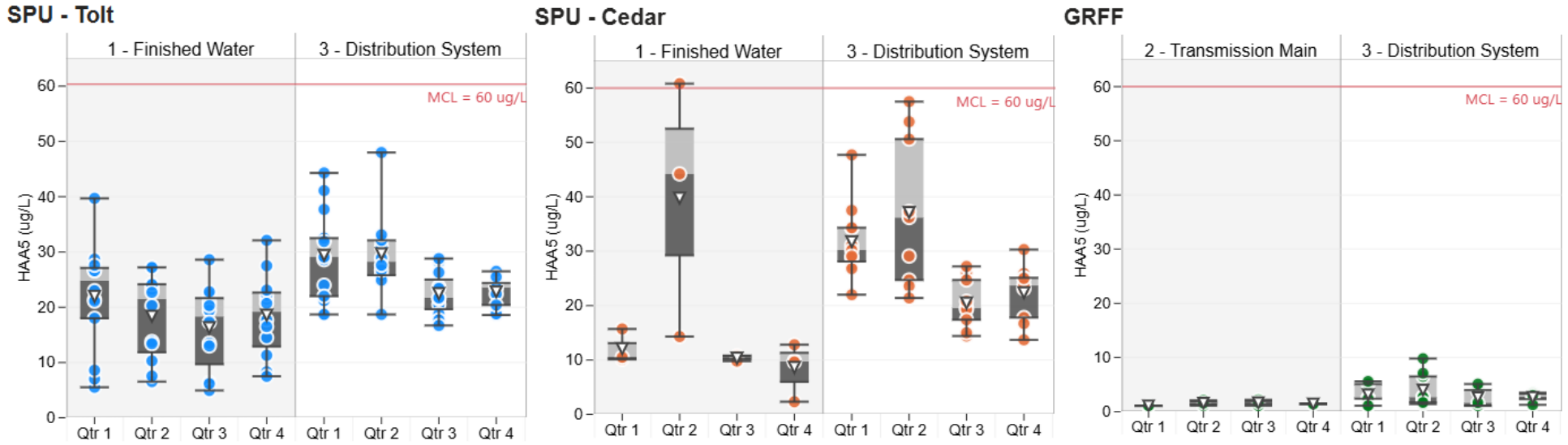
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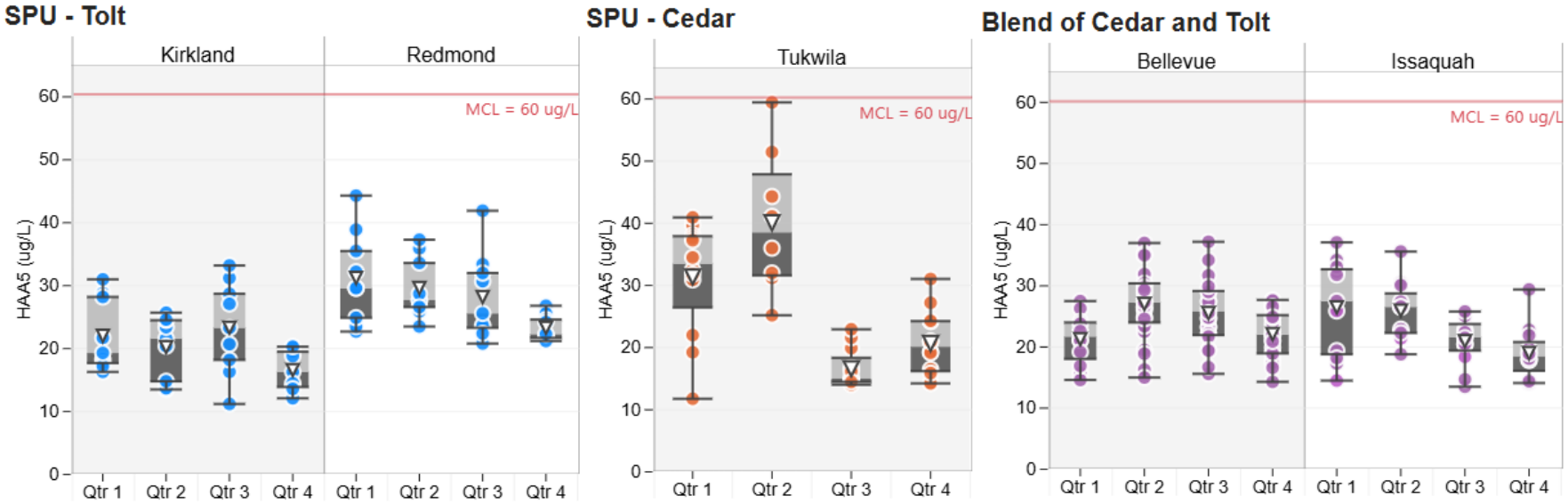
DBP – Haloacetic Acids-5 (HAA5)



Source Owner Samples (GRFF/SPU)



Cascade Member Samples



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DBP – Unregulated DBPs (HAA9 & Chlorate)

HAA5 and HAA9 Comparative Levels Across Source and Distribution Systems (UCMR 3&4)

Parameter	Unit	Average Result Including Both Source and Distribution System Samples		
		SPU Cedar	SPU Tolt	GRFF
HAA5	µg/L	23.0	27.6	5.3
HAA9	µg/L	24.1	29.5	5.9
Ratio HAA5/HAA9	%	95%	94%	89%
Chlorate (median/max)	µg/L	<20 - 61		55 - 220*

*Range of finished water only (UCMR3).



Water Quality Modeling

Water Quality Modeling

Water!Pro (Schott Software)

- Purposes:
  - Blended water quality
  - Water quality indices
  - Metal solubility & scale stability
- Selected Modeling Inputs/ Water Quality Conditions:
  - Median finished WQ data plus median November 2022 data
  - Additional ranges shown in table
- Completed for:
  - pH, alkalinity, DIC, buffer intensity, calcium carbonate precipitation potential (CCPP), Langelier saturation index (LSI), Pb & Cu solubility, chlorate levels, Mn levels

Parameters	Unit	2022-2024 (Median)			November 2022	
		Cedar FW (CLT-5)	Tolt FW (T-FIN)	GRFF FW	Tolt FW (T-FIN)	GRFF FW
TDS	mg/L	44	35	55	35	55
pH	s.u.	8.18	8.19	8.43	8.20	8.58
Total Alkalinity	mg/L as $CaCO_3$	22.5	18.6	25.7	19.3	31
Water Temperature	Deg C	11.8	9.6	8.2	8.6	5.8
Calcium	mg/L	8.5	9	4.7		
Magnesium	mg/L	1.1	0.4	0.8		
Sodium	mg/L	2.4	1.0	9.7		
Chloride	mg/L	3.5	2.7	3.1		
Sulfate	mg/L	1.9	1.6	3.4		
Silica	mg/L as SiO_2	8.9	5.2	13.9		
Additional Ranges Applied in Solubility Modeling						
10^{th} -90^{th} percentile pH range at Transmission Sites	s.u.	8.05 - 8.41	8.11-8.97 (TT-1) 8.04-8.35 (TT-3)	8.20 - 8.68		
DIC range	mg/L as C	4.5 - 6.5	4 - 5	5 - 8		
Temperature range	Deg C	6 - 21	4 - 15	5 - 17		
Additional Parameters Included in Blending Analysis						
Chlorate Median	µg/L	20	20	120		
Chlorate Max	µg/L	20	20	220		
Manganese Median	µg/L	1.75	0.94	14		
Manganese 90th percentile	µg/L	-	-	27		

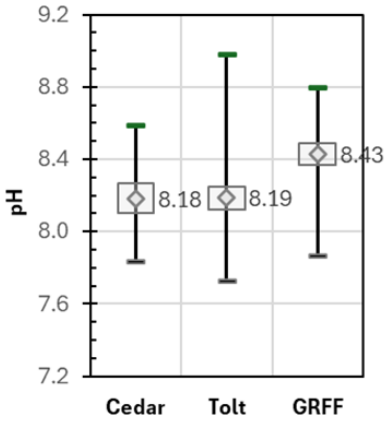
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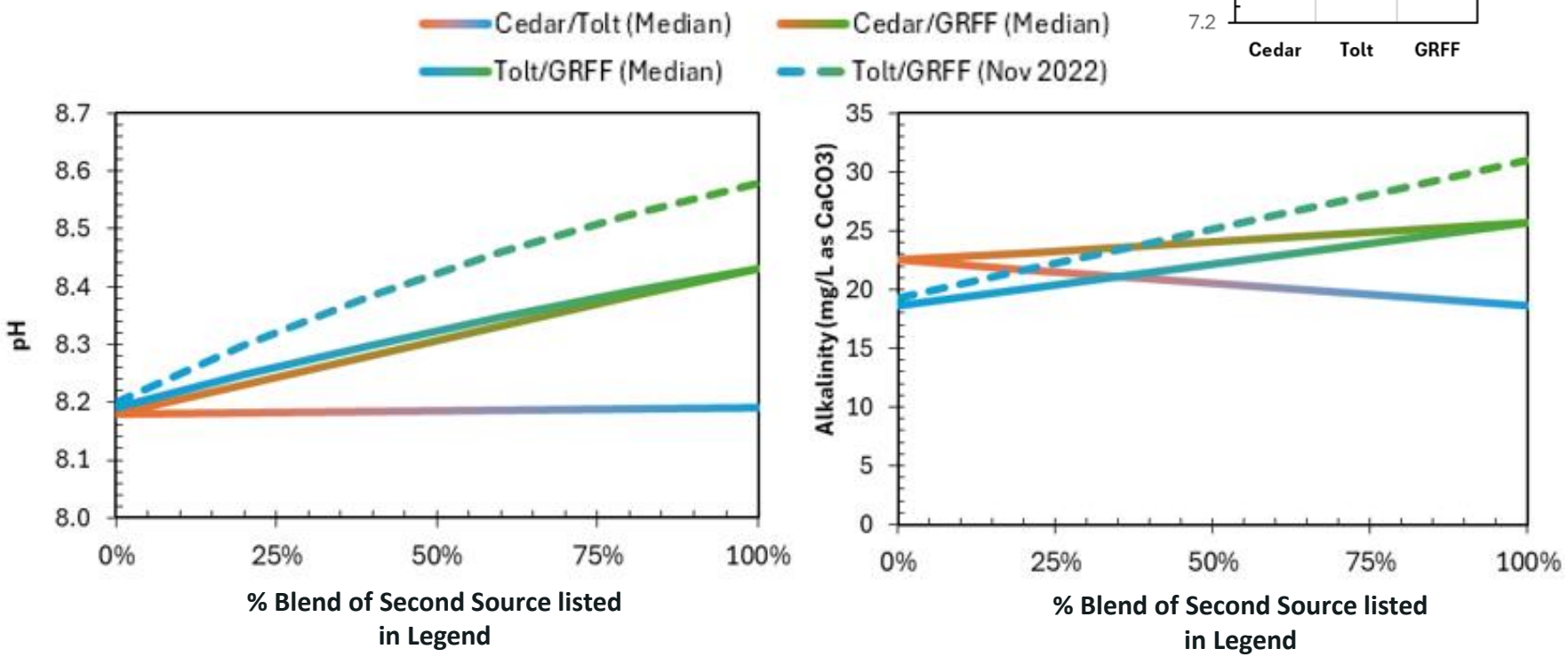
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Blending Impacts on pH and Alkalinity

- Graphs show % blend of second source
- With GRFF water, pH, alkalinity, buffer intensity, and DIC will increase, which generally benefits corrosion control and scale stability in the distribution system
- Magnitude of change when alternating already occurs within each individual source

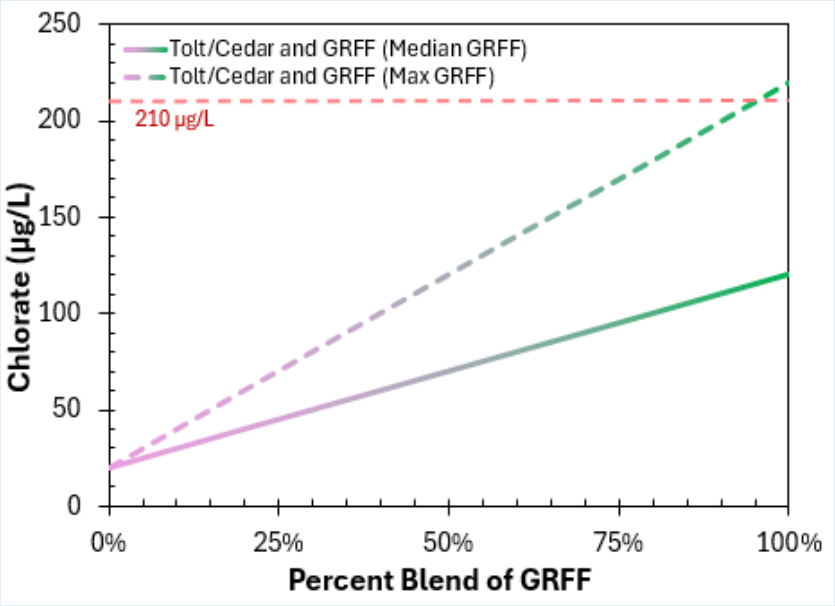




Blending Impacts on Chlorate, Manganese

Chlorate

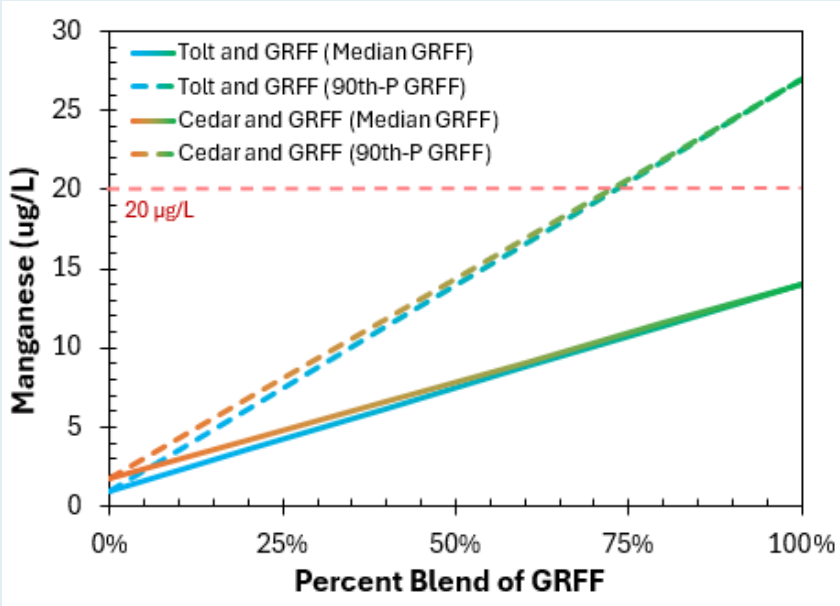
- Blended both median and max GRFF with Tolt/Cedar at MRL of 20 µg/L – Most Conservative
  - Health Reference Level (HRL) of 210 µg/L exceeded at 95% GRFF blend single max detected level



Max GRFF levels present theoretical risk, but unlikely represent long-term operating conditions

Manganese

- Blended 90th percentile and median concentrations in GRFF with median at Tolt/Cedar
- Recommended POE limit of 20 µg/L exceeded at ~75% GRFF blend levels during the high manganese times (summer)



90th % Mn levels present a risk assuming no Mn drops out during transmission which we know occurs in P5

Water Quality Indices

- No significant differences between the supplies
- No new risks identified

Corrosion Related Indices

- Larson-Skold Ratio (LR)
- Chloride Sulfate Mass Ratio (CSMR)

Similar results; No new risk

Scaling and Dissolution Indices

- Langelier Saturation Index (LSI)
- Calcium Carbonate Precipitation Potential (CCPP)
- Ryznar Index (RI)
- Aggressive Index (AI)
- Wollastonite Saturation Index (WSI)

All supplies undersaturated & similar results; No new risk

pH Stability Index

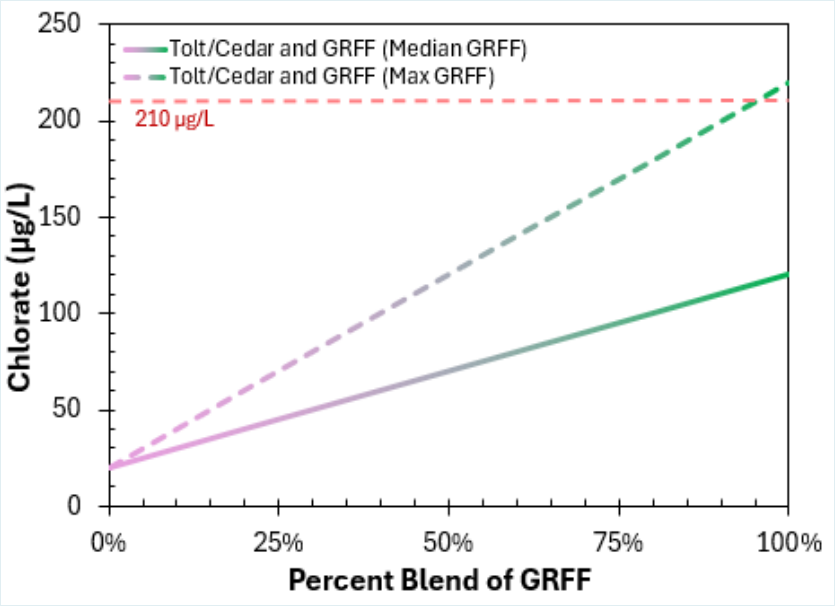
- Buffer Intensity (BI)

GRFF slightly higher

Blending Impacts on Chlorate, Manganese

Chlorate

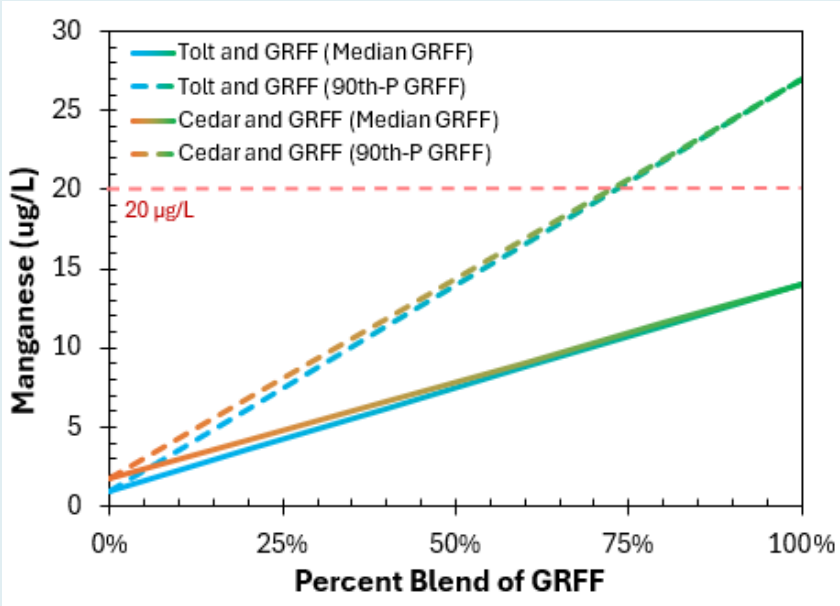
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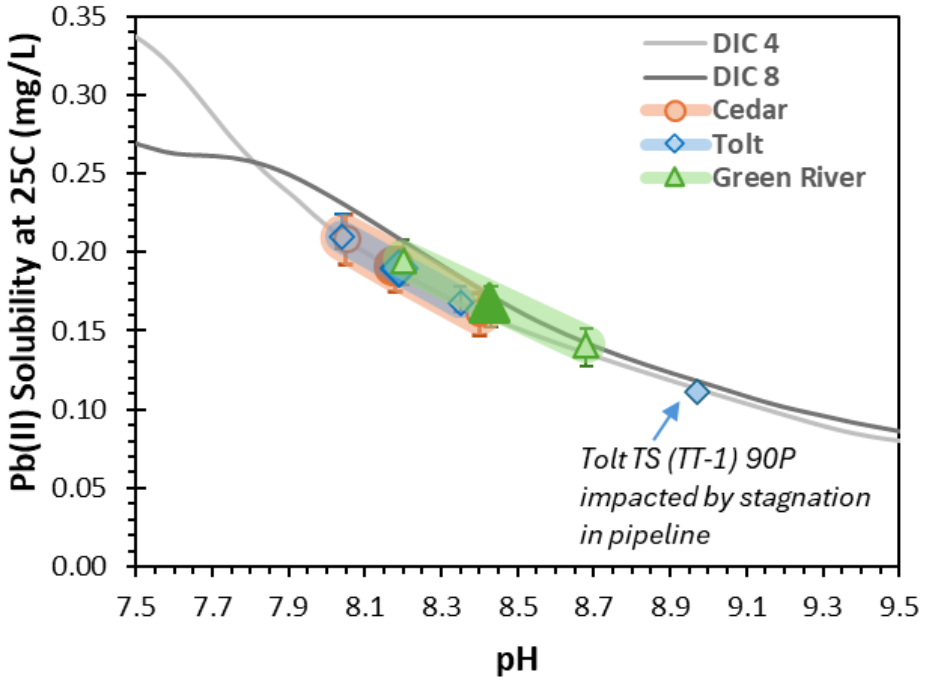
90th % Mn levels present a risk assuming no Mn drops out during transmission which we know occurs in P5

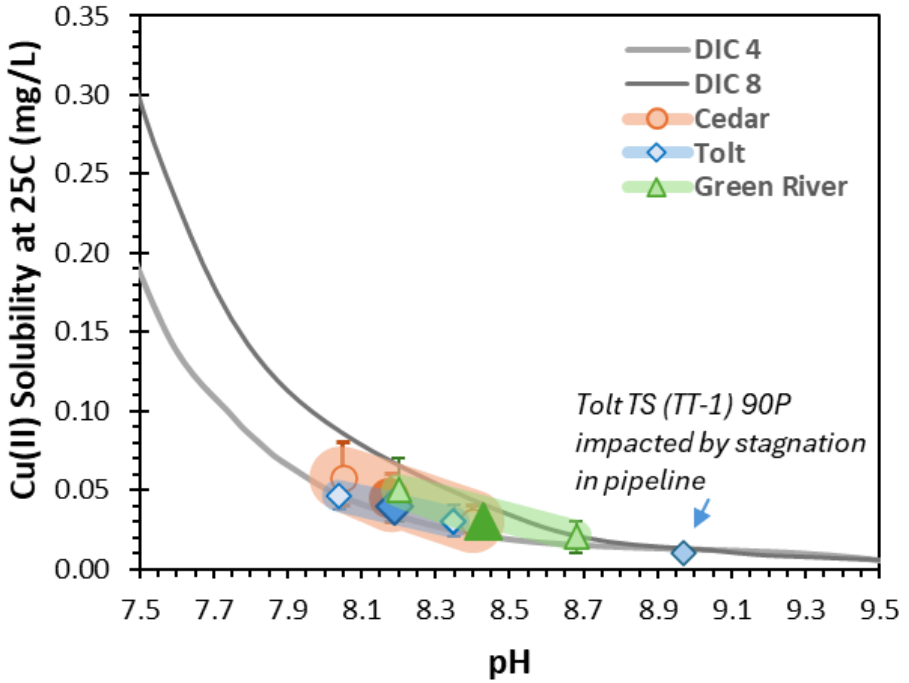
Lead and Copper Solubility

Table 14 SPU and Tacoma LCR Tap Sample Results (2022)

System	# Samples	90th percentile (mg/L)	
		Lead	Copper
SPU	50	0.0028	0.12
Tacoma	53	ND (<0.0010)	ND (<0.0200)

- Median Water Quality – larger, darker symbols
- 10th-90th Percentile Transmission Site pH – lighter symbols & shaded areas



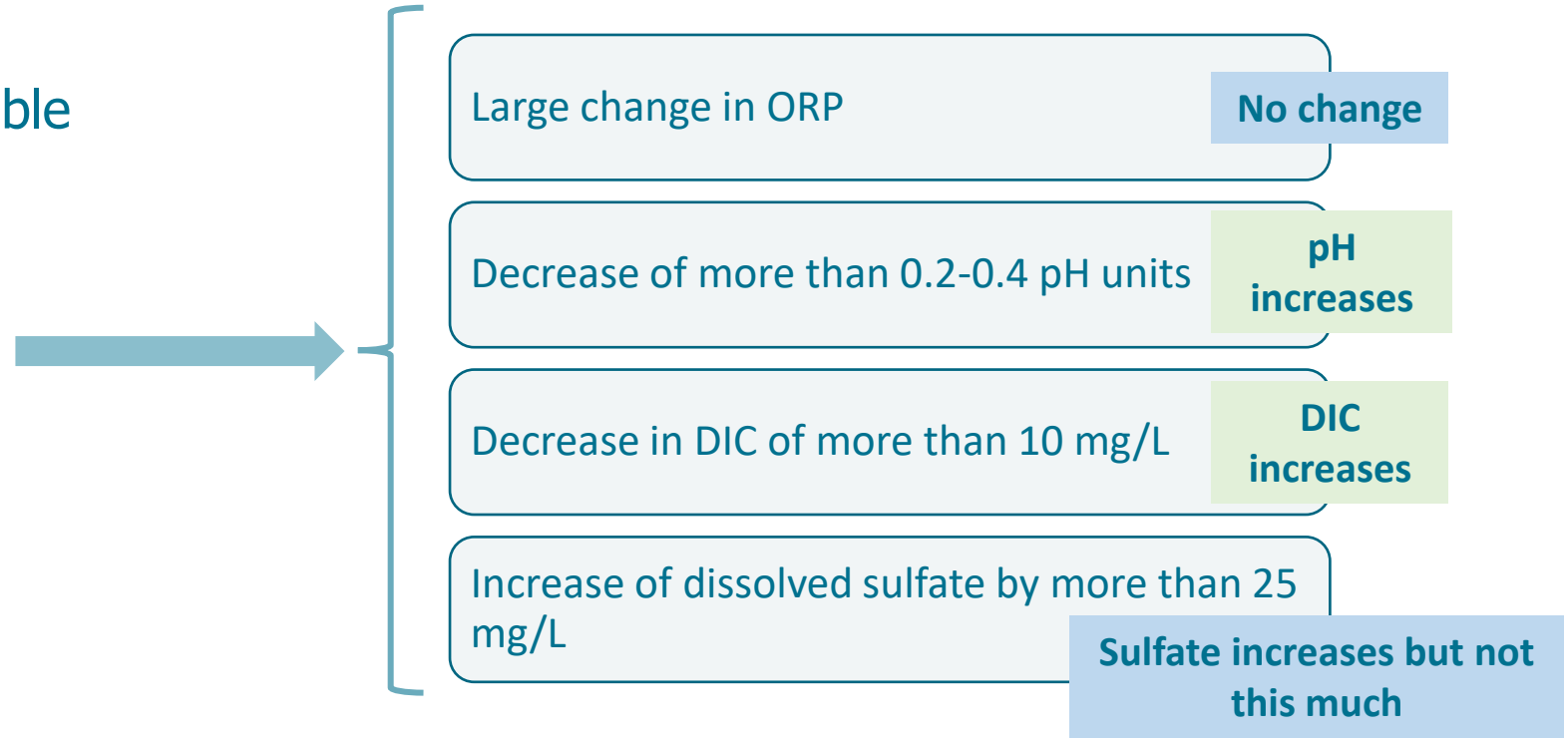


GRFF slightly lower lead and copper solubility due to higher pH but the overall ranges overlap. Dominant scale types also overlap between the supplies.

Iron Corrosion and Red Water Risk Factors

Variable ORP or significant decrease in ORP	**No change**
Significant change in DIC or decreasing DIC when previously in high DIC conditions	**Improved/ Lower Risk**
Low alkalinity and low buffer intensity	**Improved/ Lower Risk**
Change in pH	**No change**
Increased sulfate	**No change**
Sulfate reducing bacteria activity	**No change**
Increased chloride	**No change**
High Larson Ratio	**No change**
Change in NOM levels	**No change**
Temperature	**No change**

- Manganese more soluble than iron
- Higher loading from GRFF
- No risk factors for increased chemistry-based manganese releases are present





Qualitative Risk Assessment

Regulatory Compliance and Public Health

Considerations for Blending with GRFF Water

- For nearly all parameters, a potential positive impact or no change is expected
- Chlorate (currently unregulated) is only potential regulatory compliance parameter for which risk may increase (limited data set)

Water Quality Factor	Anticipated Impact and Risk Rating for Introducing GRFF Water (+ Potential positive impact;	No change or similar; − Potential negative impact)	
	Current Supply Cedar		Current Supply Tolt	
D/DBP Rule Indicators				
TTHM Formation	Lower formation	+	Lower formation	+
HAA5 Formation	Lower formation	+	Lower formation	+
Chlorine Residual Level (MRDL)	No change		No change	
DBP Precursors (TOC)	Decrease	+	No change	
Bromate Formation	No change		No change	
Chlorate (potential future regulation)	Increase	−	Increase	−
HAA9 (potential future regulation)	Lower formation	+	Lower formation	+
Lead and Copper Rule Compliance Indicators/Corrosion Control				
Lead Solubility	Slight decrease	+	Slight decrease	+
Lead Scale Stability	No change		No change	
Copper Solubility	Slight decrease	+	Slight decrease	+
Copper Scale Stability	No change		No change	
Galvanic Corrosion	No change		No change	
pH, Alkalinity Stability	Slightly improved	+	Slightly improved	+
LCR Tap Sample Results (2022 data)	Slightly improved	+	Slightly improved	+
Disinfectant Residual Stability (Surface Water Treatment Rule)				
Chlorine Demand and Decay	Slightly improved	+	Slightly improved	+

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Aesthetic Acceptance Considerations for Blending with GRFF Water

- Factors that could increase the risk of aesthetic issues:
  - GRFF Mn loading however, chemistry-based release risks are similar across. systems (slightly lower for GRFF water)

Water Quality Factor	Anticipated Impact and Risk Rating for Introducing GRFF Water (+) Potential positive impact (I) No change or similar (−) Potential negative impact			
	Current Supply Cedar		Current Supply Tolt	
Discolored Water (Accumulation/Release) Indicators				
Fe Loading	No change	I	No change	I
Fe scale stability, red water	No change	I	No change	I
Mn Loading	Increase	−	Increase	−
Mn scale stability, black water	No change	I	No change	I
Turbidity	Likely decreased	+	No change	I
Scaling (white precipitates) Indicators				
Calcium-based (LSI and CCPP)	No change	I	No change	I
Silicates (WSI)	No change	I	No change	I
Taste & Odor				
Chlorine	No change	I	No change	I

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Infrastructure Considerations for Blending with GRFF Water

- No factors identified that could increase the risk to infrastructure corrosion
- Increased inorganics accumulation risk with GRFF

Water Quality Factor	Anticipated Impact and Risk Rating for Introducing GRFF Water (+) Potential positive impact (I) No change or similar (−) Potential negative impact			
	Current Supply Cedar		Current Supply Tolt	
Corrosion of Pipe Linings				
Asbestos Cement (Aggressivity Index)	No change	(I)	No change	(I)
Steel Corrosion (Ryznar Index)	No change	(I)	No change	(I)
Concrete, cement-mortar lined mains (Langelier Saturation Index, Wollastonite index)	No change	(I)	No change	(I)
Accumulation/Fouling				
Inorganics Accumulation	Potential Increase	(−)	Potential Increase	(−)
Biofilm/Organics Accumulation	No change	(I)	No change	(I)

Risk Assessment Conclusions

- Water quality risks of introducing GRFF water into the SPU system were identified and evaluated
- Of the 28 water quality risk factors evaluated in this report:

15 = no change in risk predicted	10 = predicted improvement or reduced risk	3 = possible increased risk

Risk Mitigation Strategies

Chlorate

- Further characterize existing risk (occurrence and levels in all member systems)
  - Monitor all supply entry points, chlorine booster facilities, and sites around the distribution systems on a regular schedule
- Implement best management practices (BMPs) for hypochlorite storage if needed
- Consider/incorporate BMPs into the planning and design of future facilities

Manganese (Discolored Water and Accumulation in Pipelines)

- Revisit options to reduce loading and remove legacy deposits fromTacoma's Regional Supply Pipeline (Pipeline 5)
- Consider and integrate the need for transmission system monitoring, maintenance, and cleaning in the design of the future facilities
- Follow future regulatory development around manganese

Additional Recommendations



Topics Not Included in this Phase of Work

- Compatibility with the Cascade Member Agency groundwater supplies
  - Determined to be unnecessary where already blending with SPU supplies
- Levels of accumulation present in any of the systems
- Source water taste and odor
  - Risk for algal toxins and taste & odor compounds
- Customer complaint data
  - Frequency, magnitude, geographic coverage of discolored water and/or taste and odor complaints
- Watershed/source water stability risks
- Hydraulic impacts of introducing new supply



Questions?

Source: https://bakerpedia.com/processes/water-blending-systems/

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