Investigating Manganese Accumulation, Release, and Mitigation in Tacoma Water's Large Diameter Transmission Main

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confluence
ENGINEERING GROUP LLC

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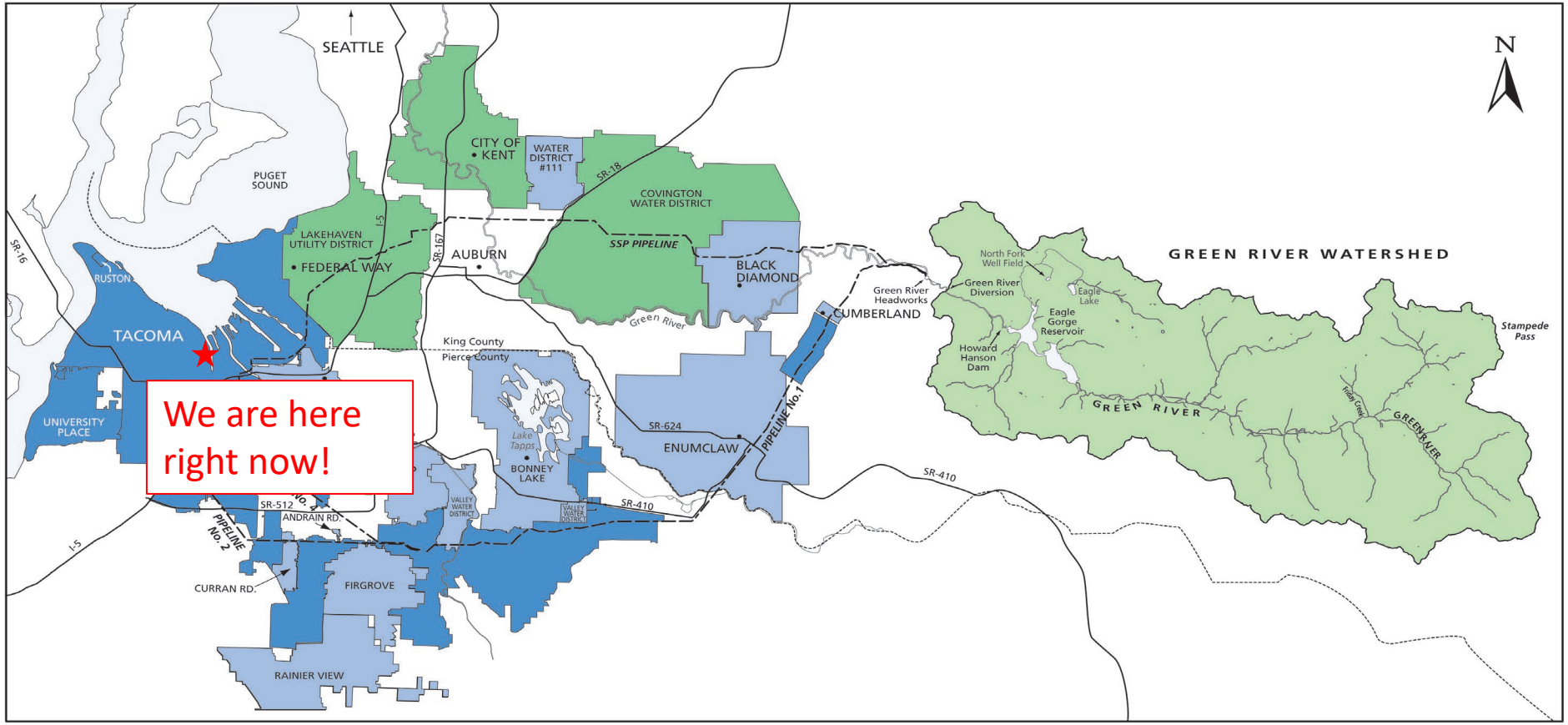
Acknowledgements

- Tacoma Water and Regional Water Supply Partners
  - Covington Water District
  - City of Kent
  - Lakehaven Utility District
- Others at Confluence Engineering Group
- Carollo Engineering

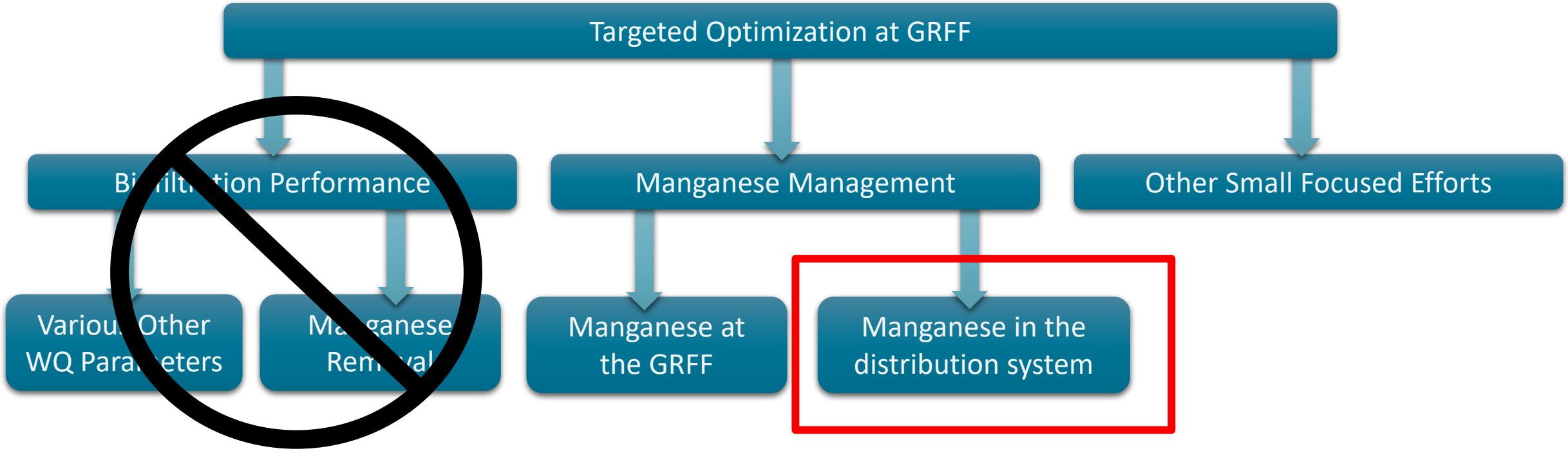
1 Background, Objectives, and Approach

Tacoma Water System Overview

- System serves approximately 320,000 people directly in the Puget Sound Region, plus Partner and wholesale connections.
- 231 square miles of protected watershed in Cascade foothills.
- Green River supply was unfiltered until the Green River Filtration Facility (GRFF) was completed in December 2014.
- P5 installed in 2002. Polyurethane coated welded steel. ~33 miles long.



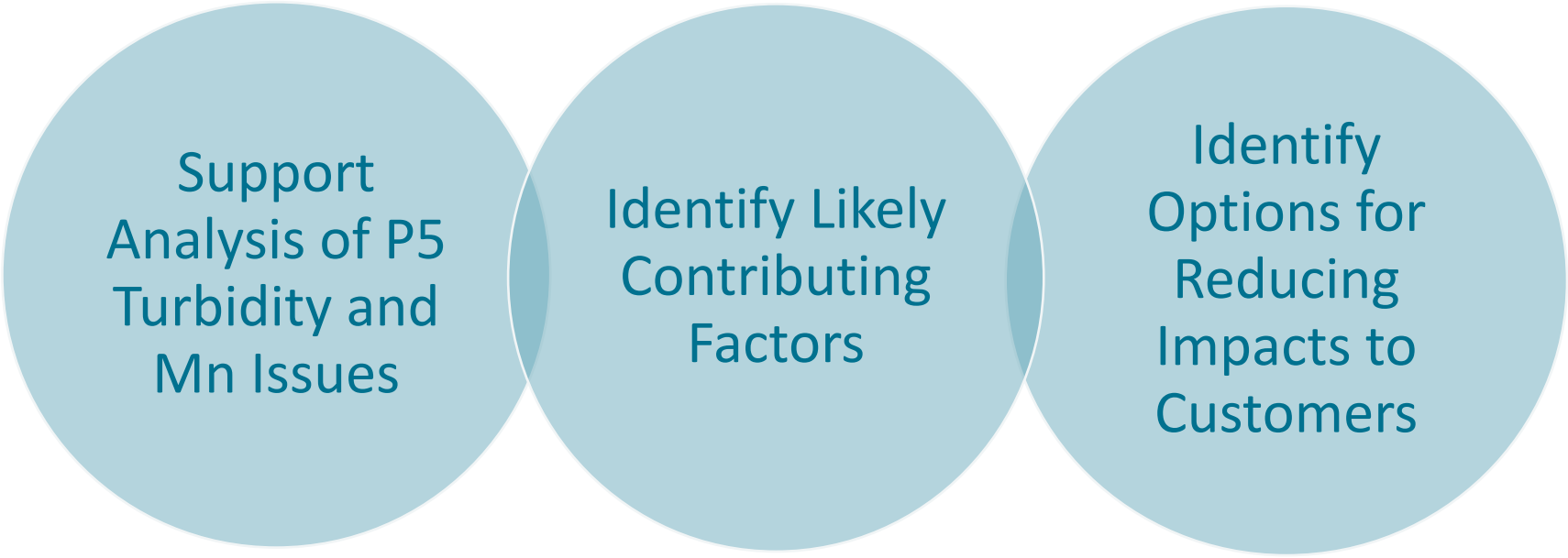
Overall Project

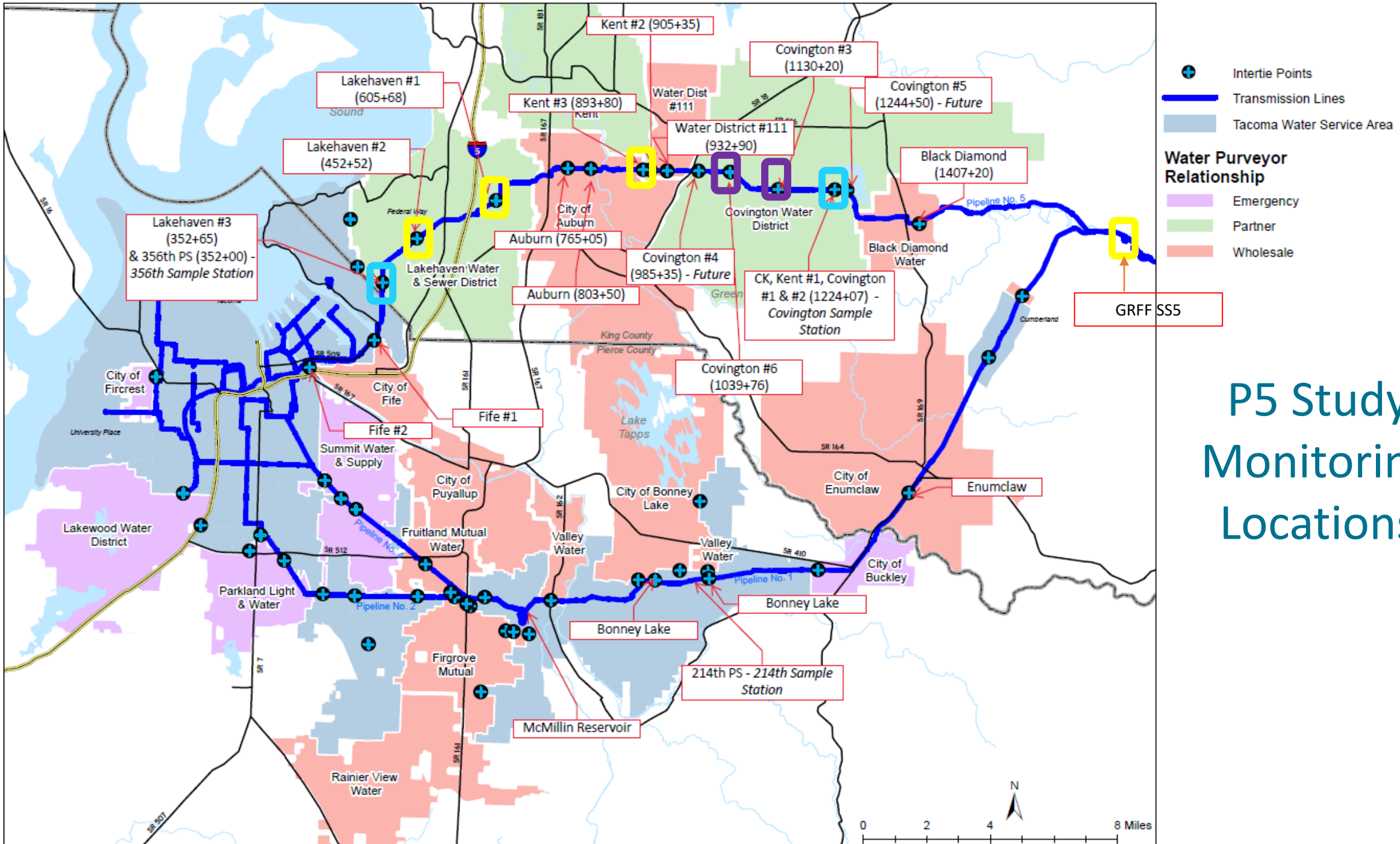


Not talking about this today!

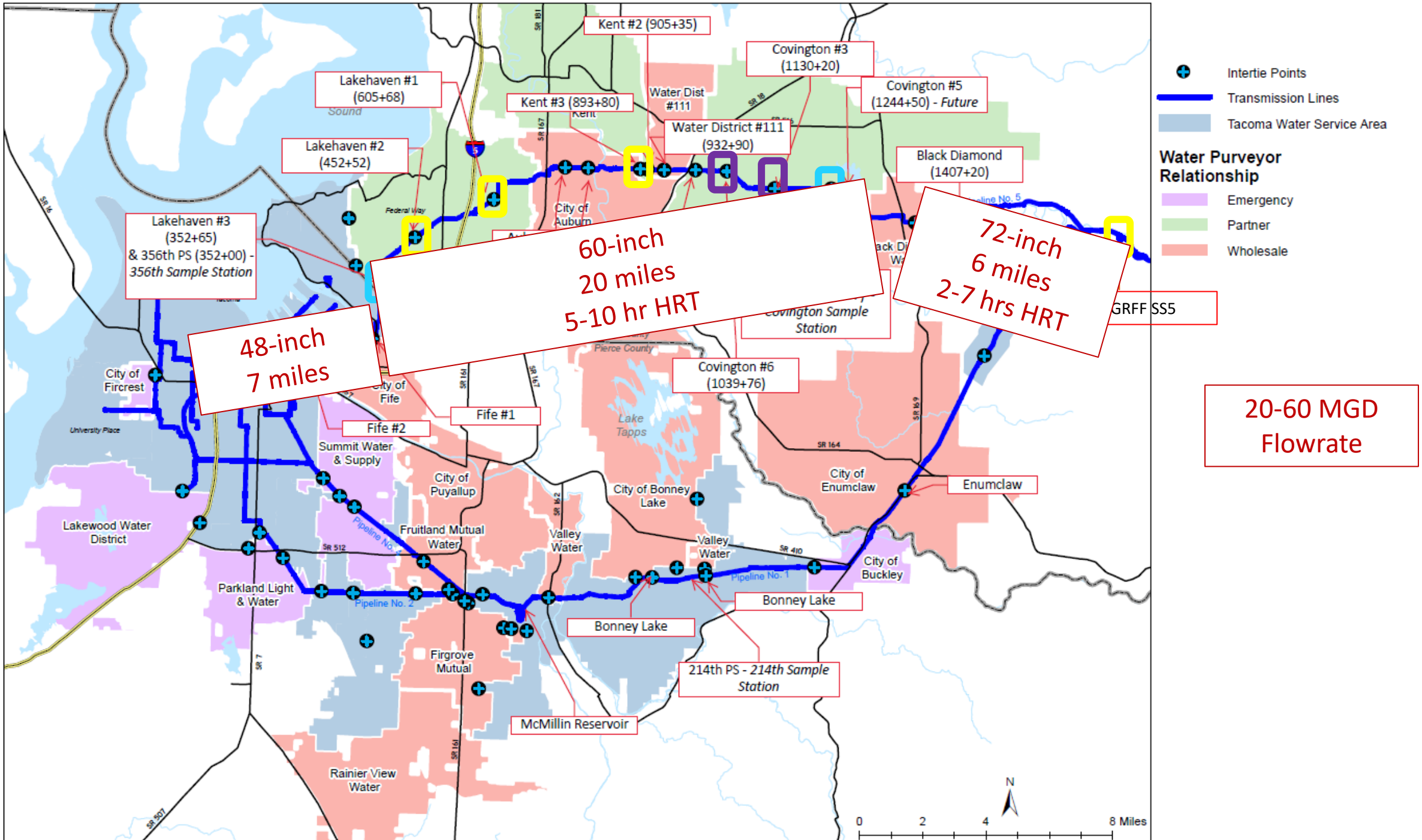
Overall Pipeline 5 (P5) Manganese Project Objectives

Assess sporadic discolored water issues and customer complaints in areas served from Tacoma Water Pipeline 5 (P5).





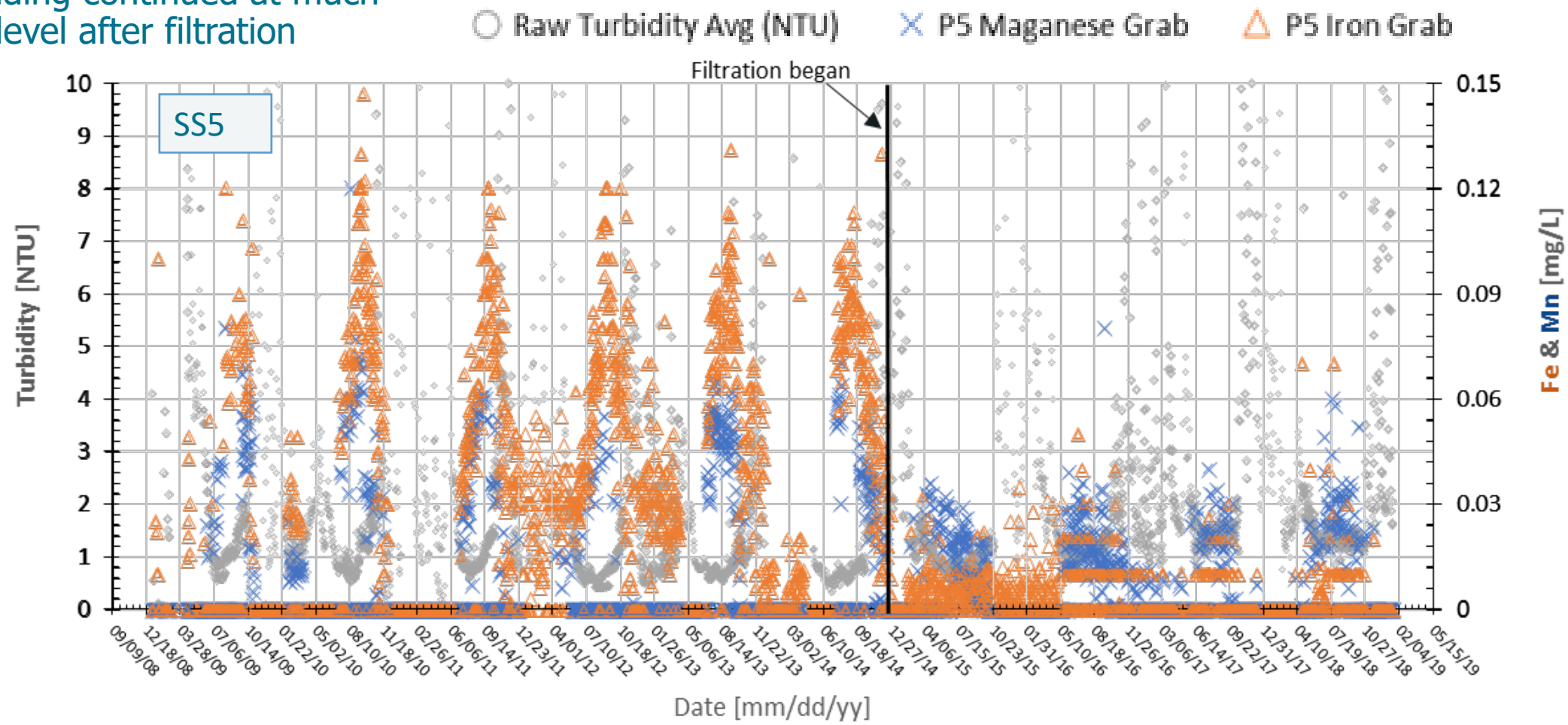
P5 Study Monitoring Locations


Kent #2 (905+35)
Covington #3 (1130+20)
Lakehaven #1 (605+68)
Kent #3 (893+80)
Water Dist #111
Covington #5 (1244+50) - Future
Water District #111 (932+90)
Lakehaven #2 (452+52)
Black Diamond (1407+20)
Lakehaven #3 (352+65) & 356th PS (352+00) - 356th Sample Station
60-inch
20 miles
5-10 hr HRT
72-inch
6 miles
2-7 hrs HRT
48-inch
7 miles
GRFF SS5
Covington Sample Station
Covington #6 (1039+76)
City of Fircrest
Fife #1
Fife #2
Summit Water & Supply
City of Puyallup
City of Bonney Lake
City of Enumclaw
Enumclaw
Lakewood Water District
Fruitland Mutual Water
Valley Water
City of Buckley
Parkland Light & Water
Bonney Lake
Firgrove Mutual
214th PS - 214th Sample Station
McMillin Reservoir
Rainier View Water
Intertie Points
Transmission Lines
Tacoma Water Service Area
Water Purveyor Relationship
Emergency
Partner
Wholesale
20-60 MGD Flowrate
N
0
2
4
8 Miles

Filtration Impact

- Prior to filtration, seasonal loading of both Fe and Mn
- Minimal Fe loading following filtration
- Mn loading continued at much lower level after filtration

- Did removal of Fe affect behavior of Mn?
  - More mobile
  - Less likely to settle out
  - Colloidal/Organically bound?



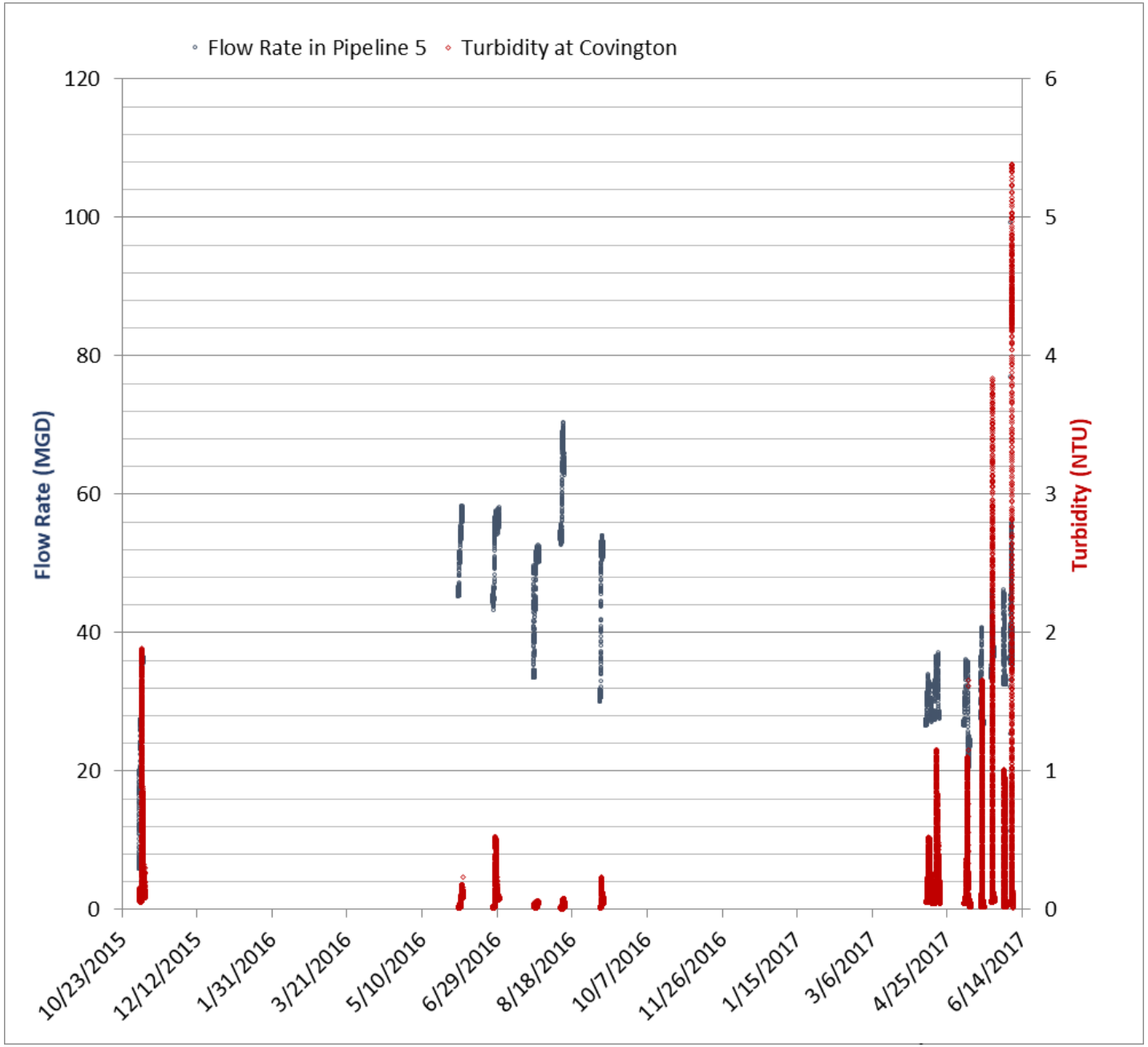
Mini-Flushes

Pre-Filtration

- Conducted routinely prior to filtration to "flow condition" the pipeline during lower flow, wet season
- 35 MGD for about 5 hours every other week
- Helped prevent sediment accumulation in 72" section, but created turbidity in the 5-10 NTU range

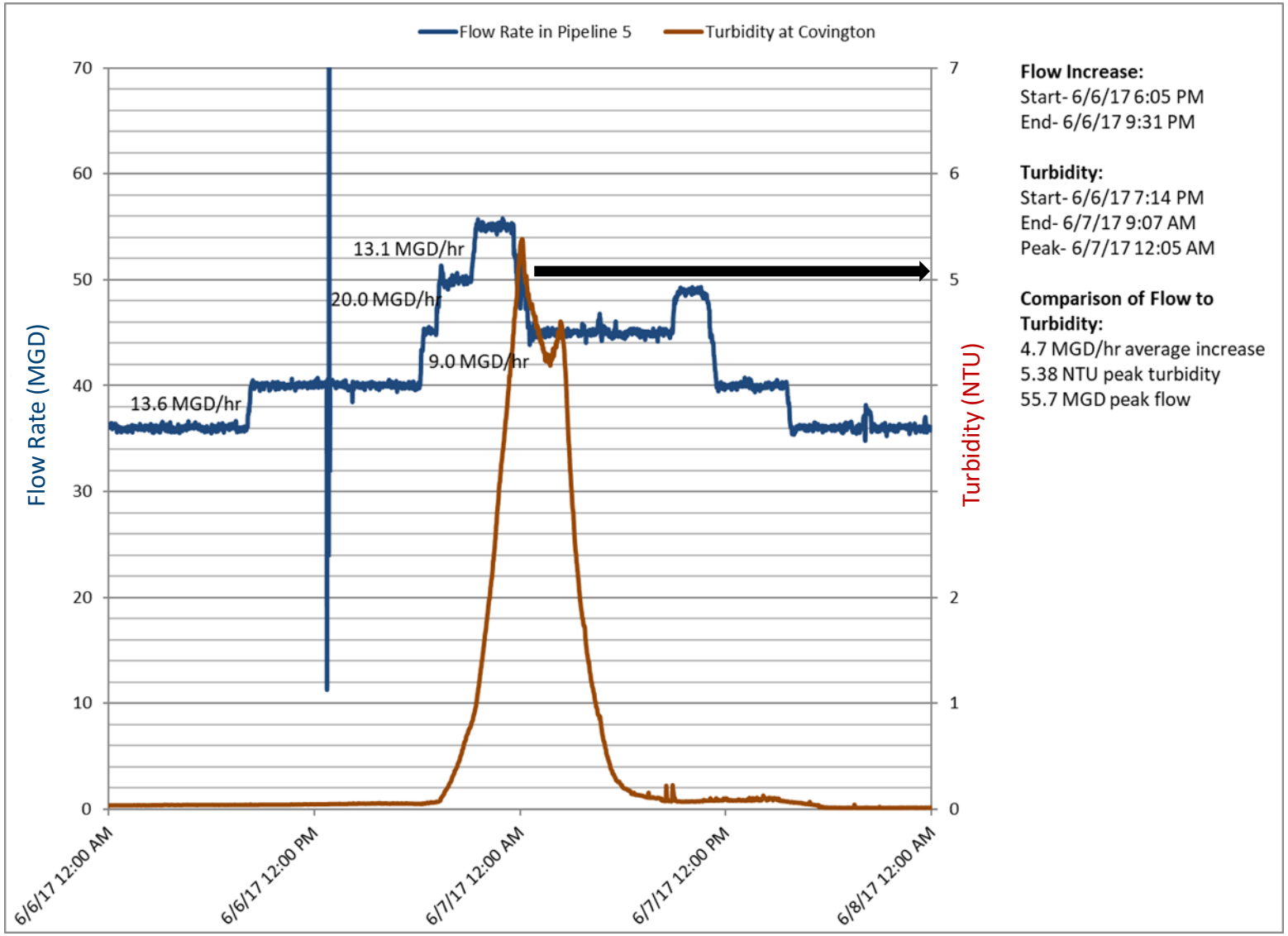
Post-Filtration

- Practice stopped after 2016 success, with hope that filtration made mini-flushes no longer necessary
- 2017, turbidity increased whenever P5 flow increased to meet demand
    - Did filtration (removal of iron) change behavior or Mn??)
- Conducted June 6-7, 2017 mini-flush



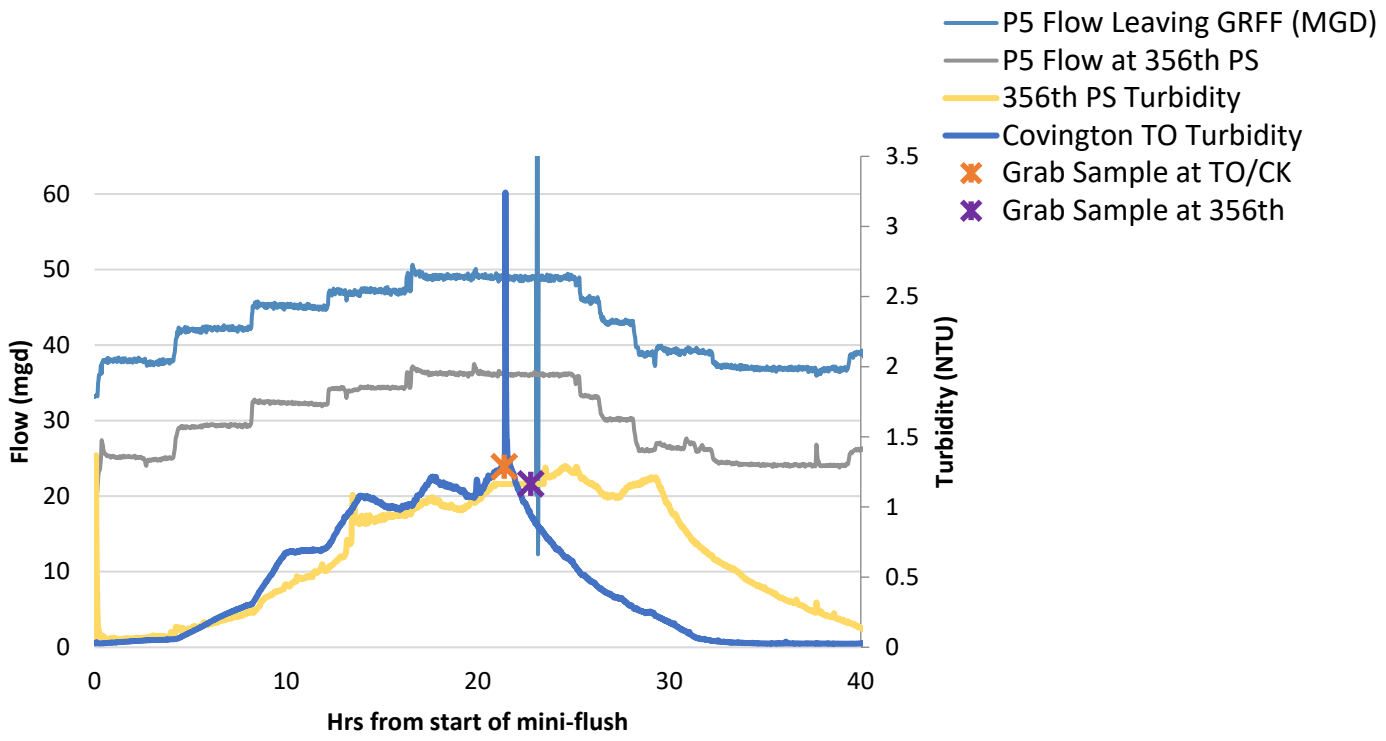
June 6-7, 2017 Mini-Flush Turbidity at CK and Water Quality at 356th St. PS

- Effective at mobilizing sediment but significant water quality impact at 356th St. Pump station:
  - Turb = 23 NTU vs. 5 NTU at Covington
  - Fe = 2.96 mg/L
  - Mn = 0.57 mg/L
  - Pb = 0.010 mg/L
  - TOC = 1.9
- Moving forward, made flow changes more slowly
- Added turbidimeter at 356th St. PS



June 2020 Mini-flush

- Flow 33 → 49 MGD over 16 hrs (1 MGD/hr)
- Controlled to 1 NTU at CK
- Mn in particulate form and similar concentration at CK and 356th
- Very low Fe
- Much higher Mn at Portland Ave
  - 48" main
  - Additional release
- Findings:
  - Mn originated upstream of CK
  - Plug flow behavior
  - Suggests other turbidity events of similar magnitude are also releasing significant Mn

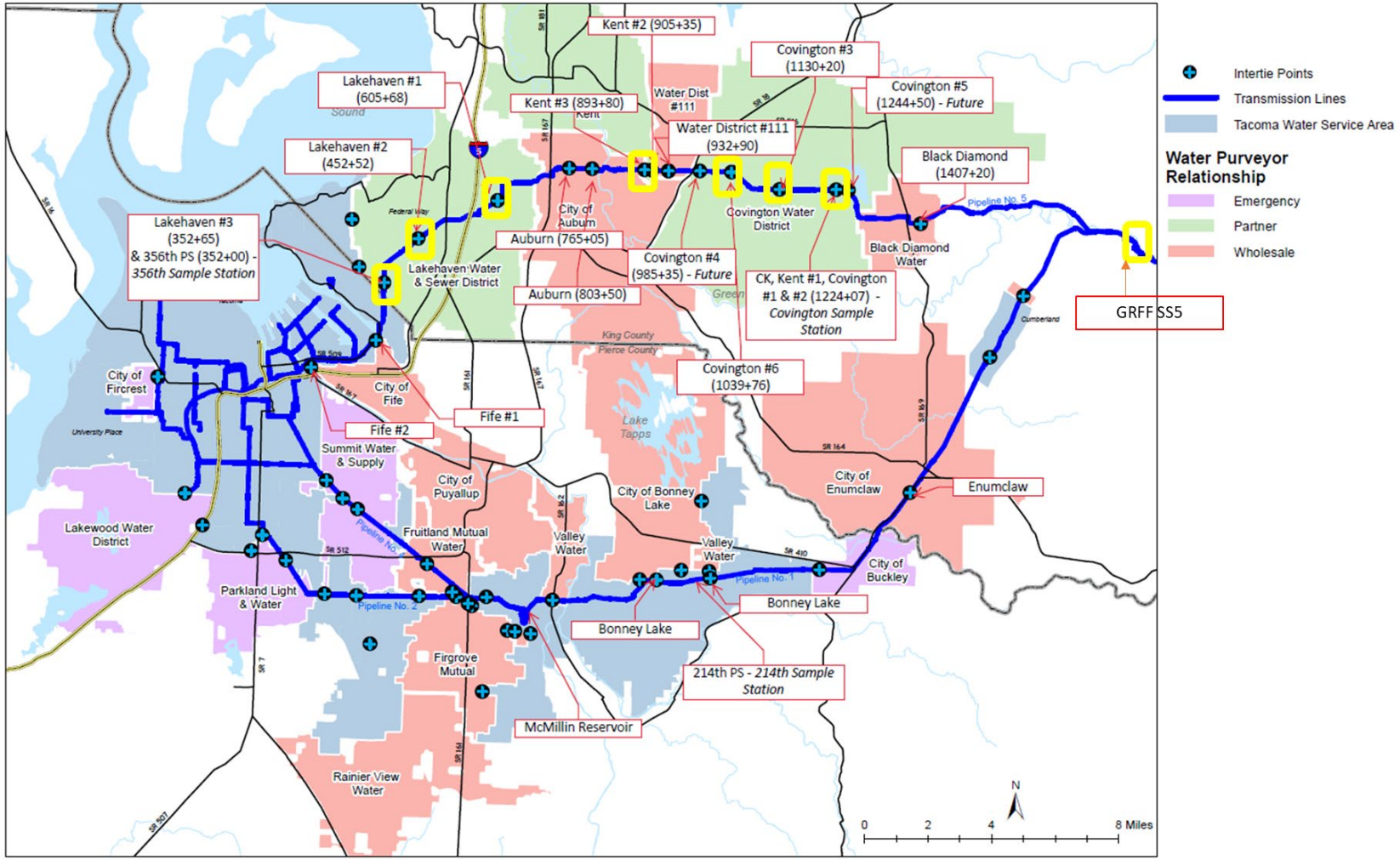


	Turb (NTU)	Fe-T (mg/L)	Mn-T (mg/L)
TW-CK	1.71	<0.005	0.192
TW-356th	1.82	<0.005	0.190
TW-PA	2.50	0.006	0.249

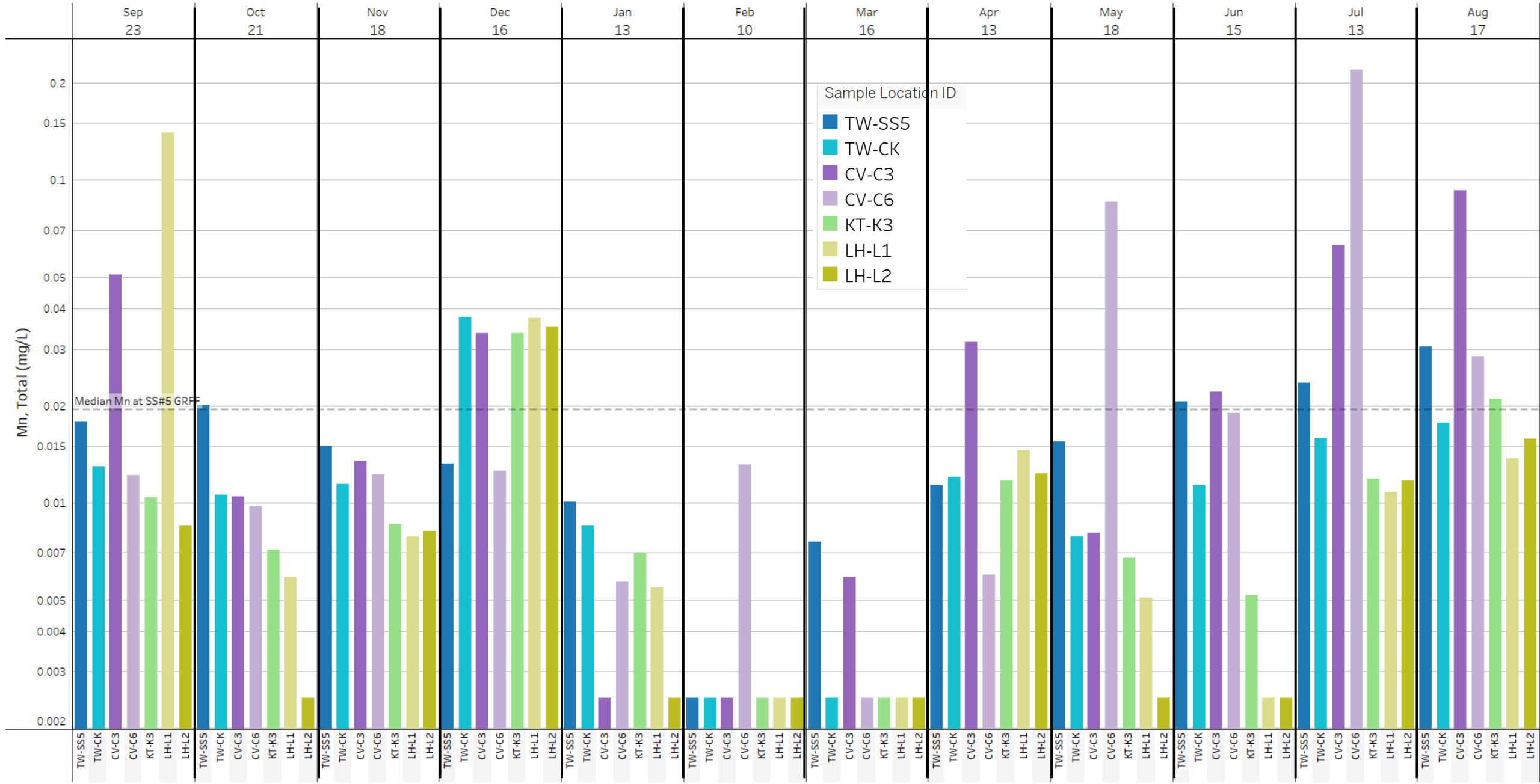
2 Coordinated Monitoring Plan

Coordinated Monitoring Plan (CMP) Overview

- Year long, once monthly coordinated effort between TW and Partners
- Sept 2019-Aug 2020
- Along P5 and within distribution systems
- Opportunity to obtain paired data:
  - Mn (total and dissolved)
  - Fe
  - turbidity
  - pH
  - chlorine
  - conductivity
  - TDS
  - temperature
  - alkalinity



Coordinated Monitoring Plan Mn Results for P5 (2019-2020)



Issues at Covington Turnouts in 2020

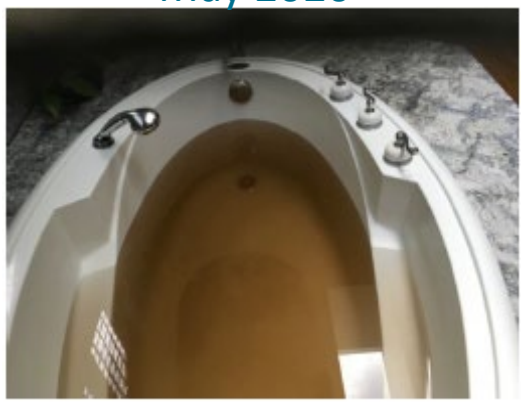
Customer filter, Covington

June 2020

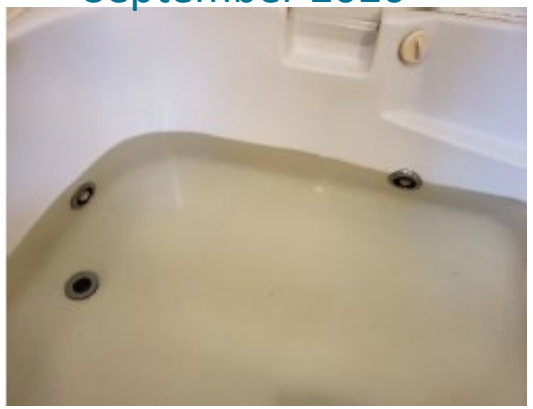
July 2020

Analyzers at end of CK transmission line September 2020

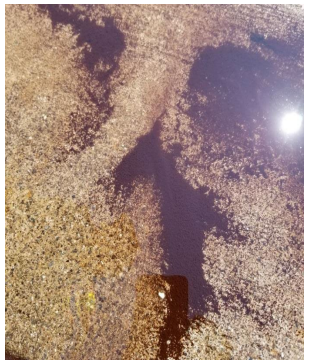
Near C3
May 2020

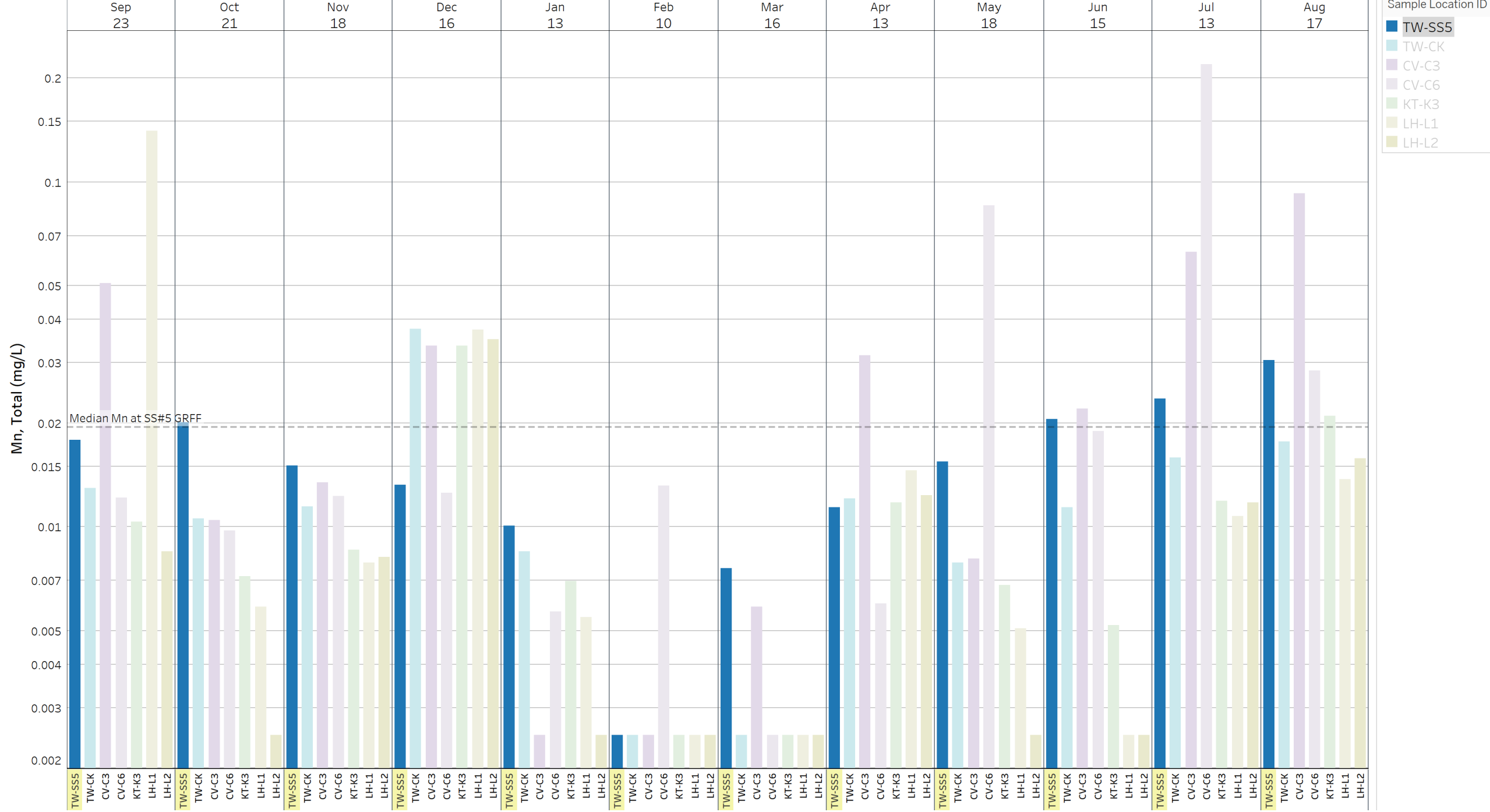


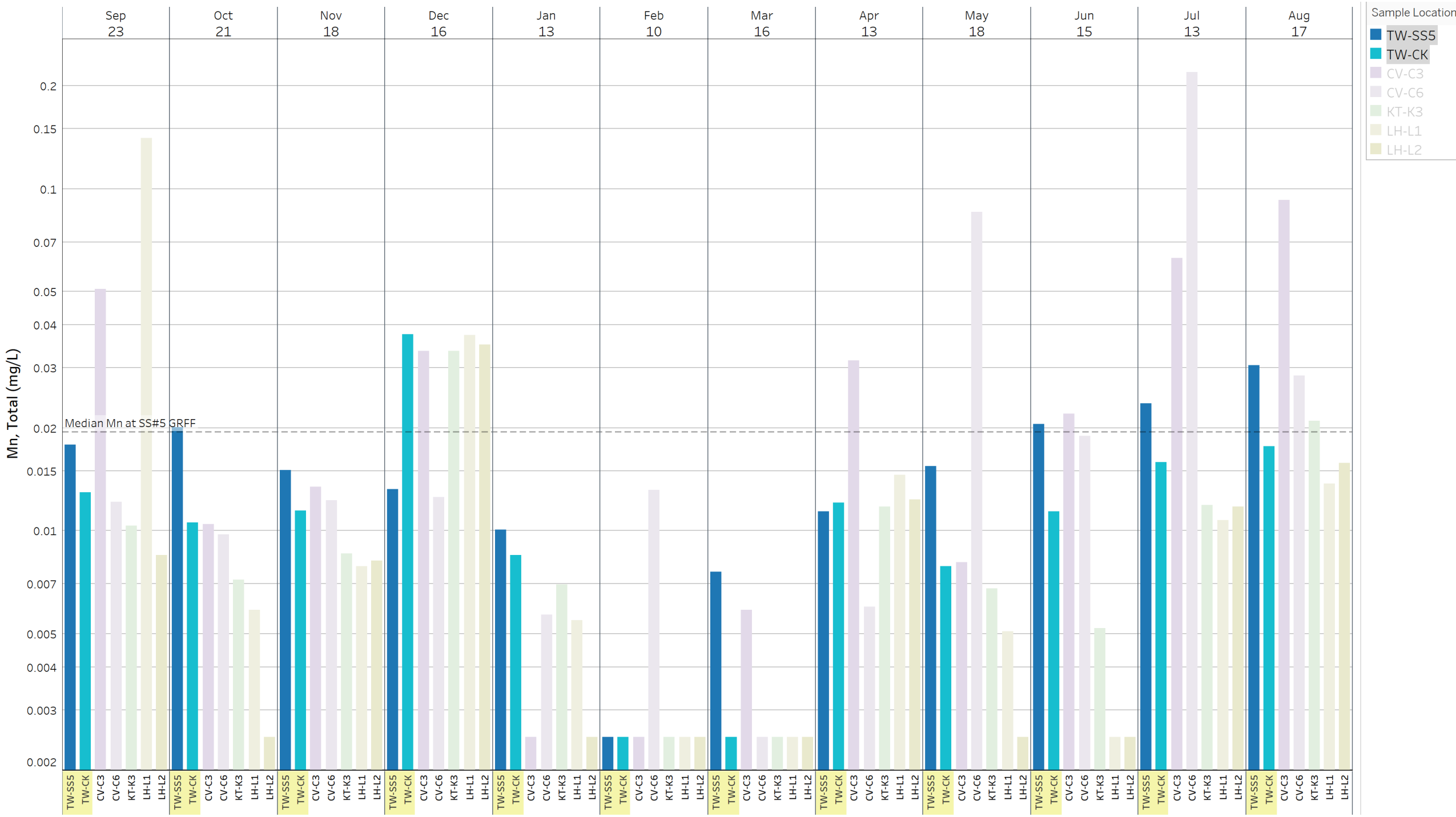
Near C6
September 2020



Observed very fine light sediment that is easily stirred up in the main (770 zone) August 2020




Sep 23
Oct 21
Nov 18
Dec 16
Jan 13
Feb 10
Mar 16
Apr 13
May 18
Jun 15
Jul 13
Aug 17
Mn, Total (mg/L)
0.2
0.15
0.1
0.07
0.05
0.04
0.03
0.02
0.015
0.01
0.007
0.005
0.004
0.003
0.002
Median Mn at SS#5 GRFF
TW-SS5
TW-CK
CV-C3
CV-C6
KT-K3
LH-L1
LH-L2
Sample Location ID
TW-SS5
TW-CK
CV-C3
CV-C6
KT-K3
LH-L1
LH-L2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0.007
0.005
0.004
0.003
0.002
Median Mn at SS#5 GRFF
TW-SS5
TW-CK
CV-C3
CV-C6
KT-K3
LH-L1
LH-L2
Sample Location
TW-SS5
TW-CK
CV-C3
CV-C6
KT-K3
LH-L1
LH-L2

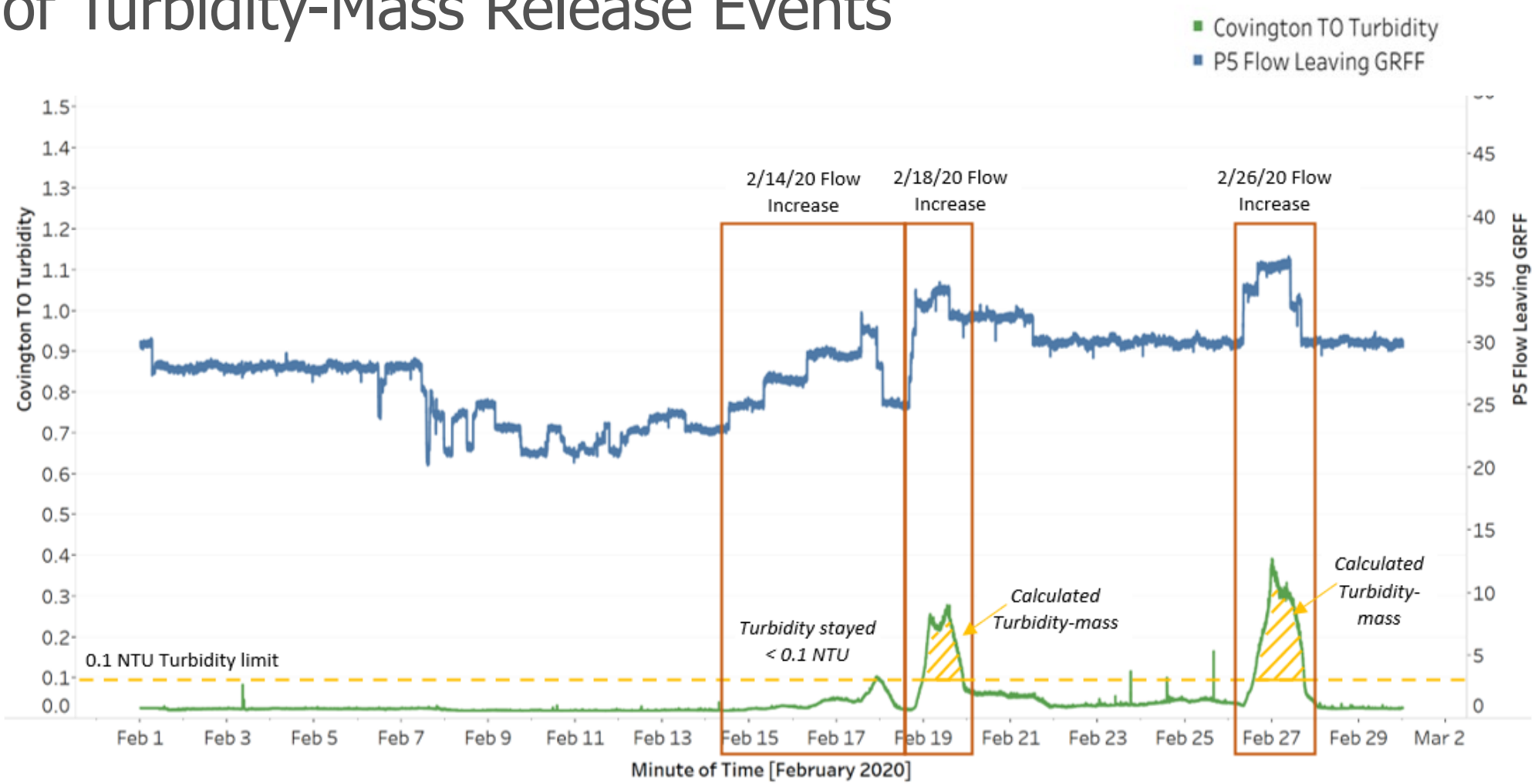
Conceptual Mn Accumulation/Release in P5 before CK – Coordinated Monitoring Plan Data Only

	Conceptual Accumulation Rate (lbs/yr)
Source loading	1855
Accumulation before CK	436
Percent of loading accumulated before CK	23.5%
Remainder passing downstream	1419
Add'l accumulation prior to LH2	215 (15% of remainder, 12% of total)

3 Turbidity-Mass Assessment

Evaluation of Turbidity-Mass Release Events

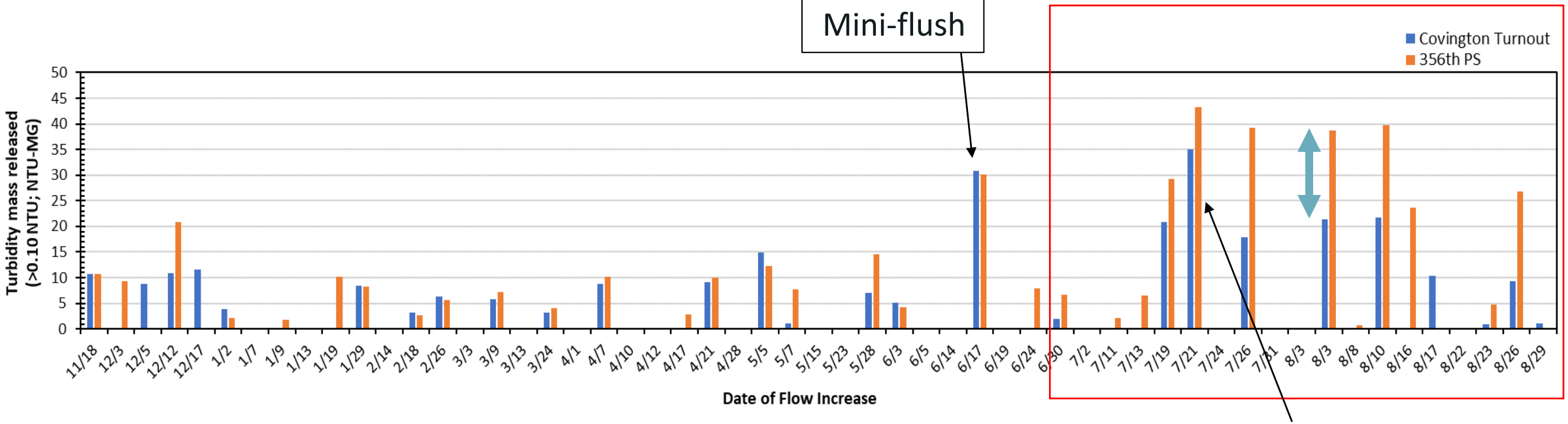
- Area under the turbidity-curve
- Calculated parameter:
  - NTU-reading x water volume (MG) each minute
- Represents the "mass" of material that traveled with the flow to CK and then to 356th
- Any spike > 0.1 NTU



Evaluation of Turbidity Release Events

In summer, when flows > 40 MGD, Turb-mass higher at 356th indicating additional release of turbidity-causing material

June 17-18, 2020 Mini-flush



If material represented by the blue lines can be removed (originating in the 72" section of P5), the rest of P5 would only see the delta between orange and blue

July 21 – Covington Discolored Water

4 Mitigation Options and Conclusions

Mitigation Options

1

Minimize Source Loading

2

Reduce Inventory of Accumulated Solids

3

Minimize Release Events through Strict Flow Control

4

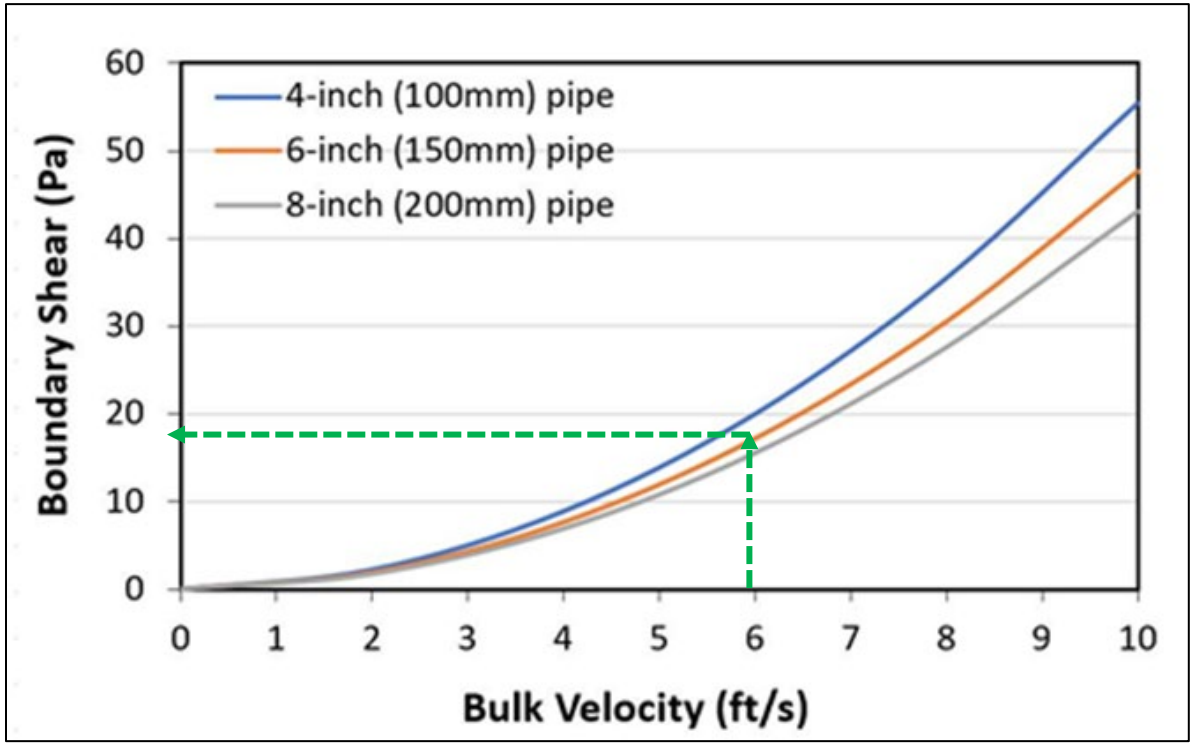
Conduct Additional Data Collection and Analysis

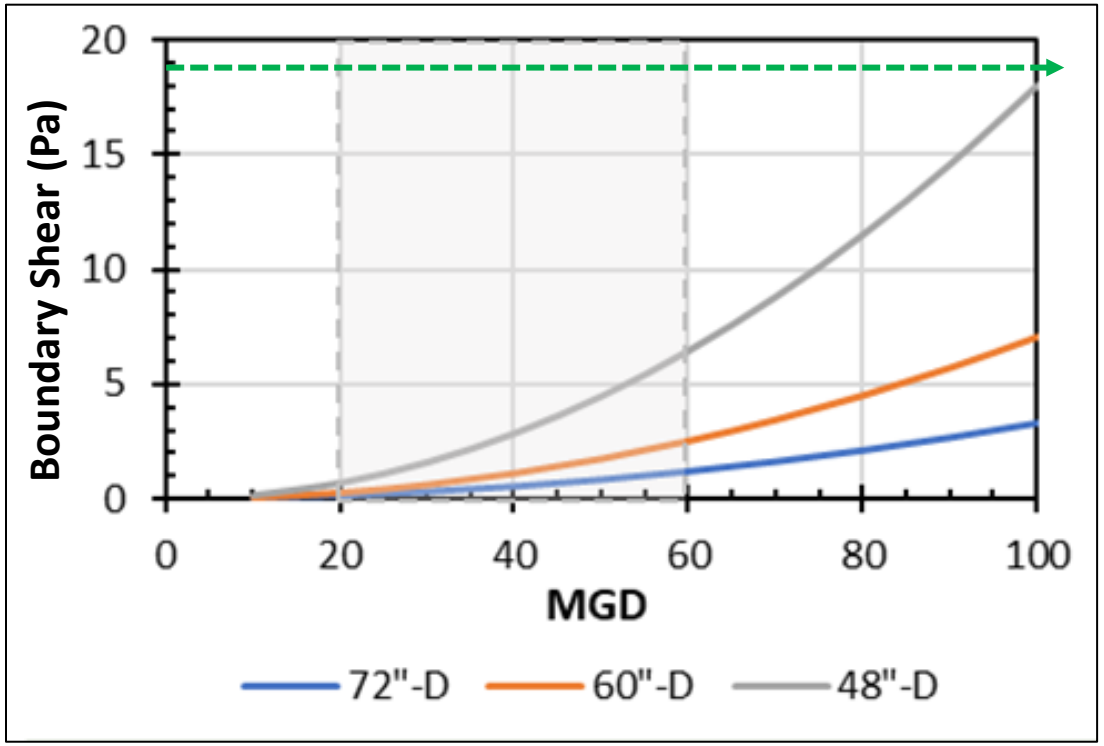
Not talking about this today!

② Reduce Inventory of Accumulated Solids

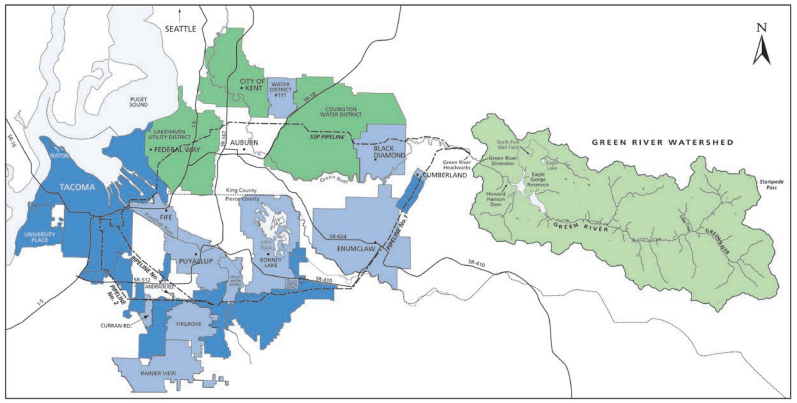
- Cannot achieve cleaning shear force in 72-inch main
- Possible to provide some scouring of 48-inch main
- Can certainly release some material, but Mn is notoriously "sticky"
- Likely need physical cleaning of 72" section

Flowmore Services, Houston, TX





Conclusions



- P5 has reached its carrying capacity and/or….Nature of Mn may have changed with filtration
- Fe easily removed through mini-flushes but not Mn
- “Flow-conditioning” currently not feasible without causing water quality issues downstream
- Cleaning of 72” section should remove the majority of material causing problems downstream
- Flows > 40 MGD cause additional release in 60” main
- Additional study/analysis of hydraulic behavior at Covington turnouts needed
- Tacoma Water is planning for P5 shutdown, inspection, and sampling in 2022

THANK YOU

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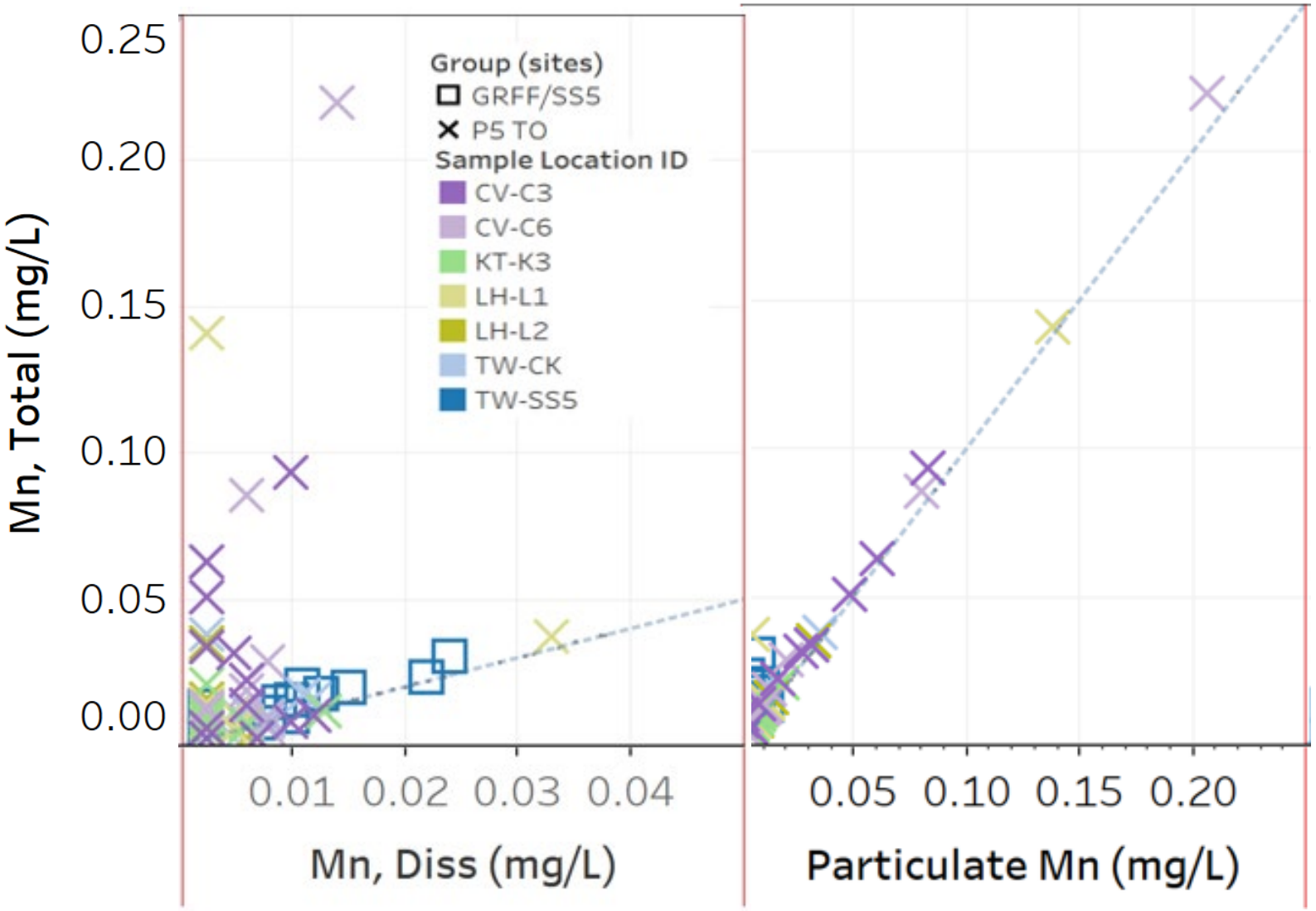
P5 Dissolved and Particulate Mn Results

- Mn tended to be in soluble form leaving plant
- Mn tended to be in particulate form along P5 and in DS
- Stable water chemistry
  - pH > 8.2 = promotes formation of particulate Mn(4+) species
  - Free chlorine residuals ≥ 0.80 mg/L



P5 Hydraulic Release Events – CK vs. 356th St Pump Sta.

- Flow increases often resulted in turbidity increase that traveled past CK
- Often traveled in plug-flow manner to 356th St. Pump Station
  - Peak of the turbidity spike typically incurred at close to hydraulic residence time between the sites
- Larger turbidity spikes at 356th indicate additional release from P5 between the two sites