Metropolitan Water Reclamation District of Greater Chicago

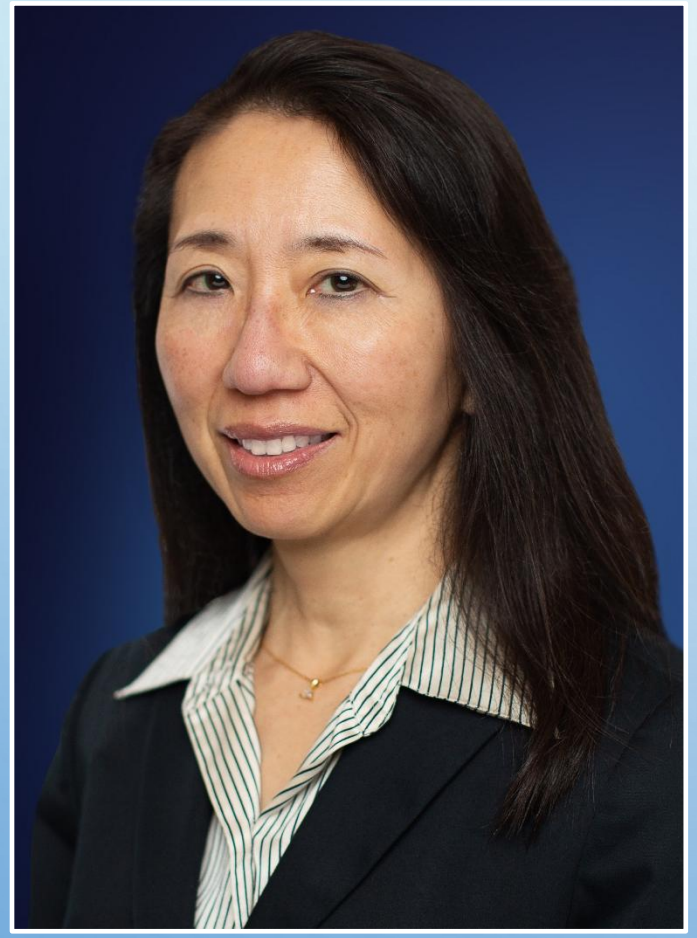
Welcome to the July Edition of the 2026 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- Remote attendees' microphones are muted at entry to minimize background noise. For attendees in the auditorium, please silence your phones.
- A question and answer (Q/A) session will follow the presentation.
- For remote attendees, please use "**Chat**" only to type questions for the presenter. For other issues, please send emails to MnRseminars@mwrd.org.
  For attendees in the auditorium, please raise your hand and wait for the microphone to ask a verbal question during the Q/A session.
- The presentation slides will be posted on the MWRD website after the seminar.
- This seminar has been approved by the Engineering Society of Illinois (ESI) for one PDH and is approved by the IEPA for one TCH. Certificates will be issued only to participants who attend the entire presentation. For PDH certificate seekers, **completing a brief course evaluation and submitting it are required**.

KAM LAW, PH.D., P.E., ENV. SP.

Senior Project Manager/Water Innovations Practice Leader
Donohue & Associates, Chicago, Illinois



Kam Law is the Water Innovations Practice Leader at Donohue & Associates located in Chicago. She is a licensed professional engineer with over thirty years of experience in wastewater treatment, with special interest in biological systems and nutrient removal. Kam served as the President of the Illinois Water Environment Association from 2018 to 2019 and currently serves as a Delegate-at-Large for the Water Environment Federation.

Kam earned both bachelor and master degrees in Civil and Environmental Engineering from University of Kansas, a Master of Project Management from Northwestern University, and a Ph.D. in Environmental Engineering from University of Nevada at Reno.

For PDH Certificate seekers,

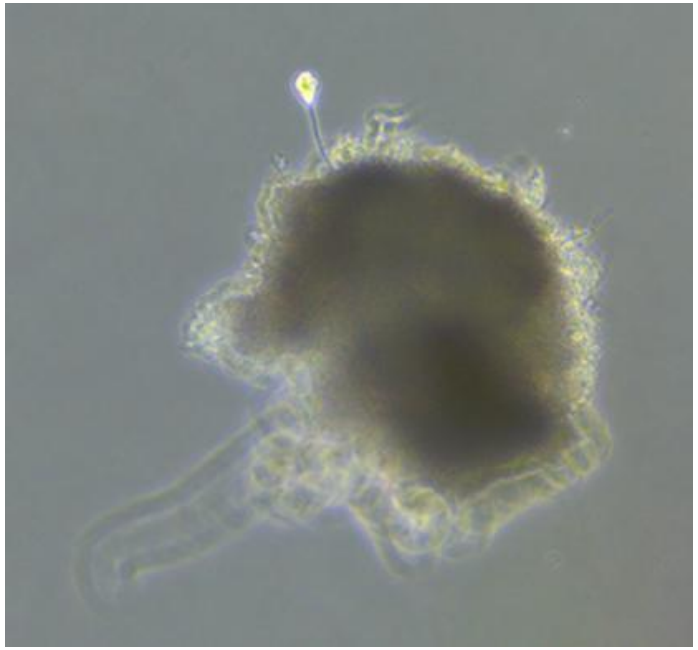
The link to the new on-line course evaluation form has been posted in the Chat. The link is also available on the District website. The form will only be available online until the start of next month's seminar. Please be sure to fill it out and submit promptly.

Metropolitan Water Reclamation District of Greater Chicago

M&R Seminar

July 31, 2026

Internal Selection of Granules in a Flow-Through Activated Sludge System via Biological Selectors



Kam Law, PhD, PE, ENV SP

DONOHUE

Outline

- Introduction of granules
- What prompted the investigation
- Facilities design
- Sampling, analyses, and results
- External selectors performance – Yorkville-Bristol Sanitary District
- Key takeaways

INTRODUCTION OF GRANULES

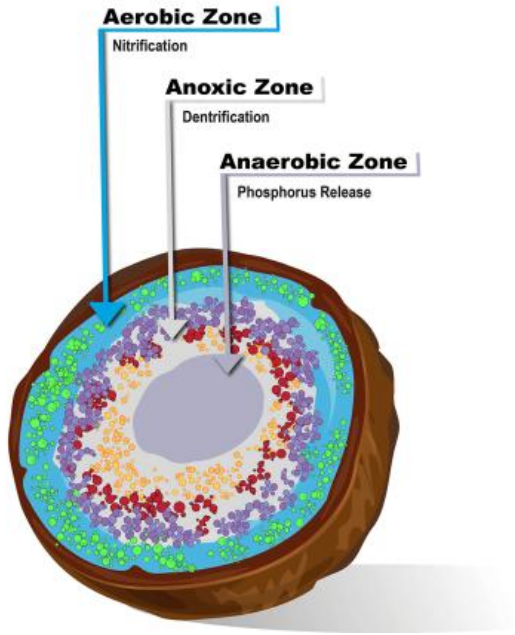
Process intensification with granules

- Increase both hydraulic and treatment capacities within existing footprint
  - Fast solids settling
  - Footprint reduction
- Energy reduction
- Capital and operation cost reduction

What are granules?

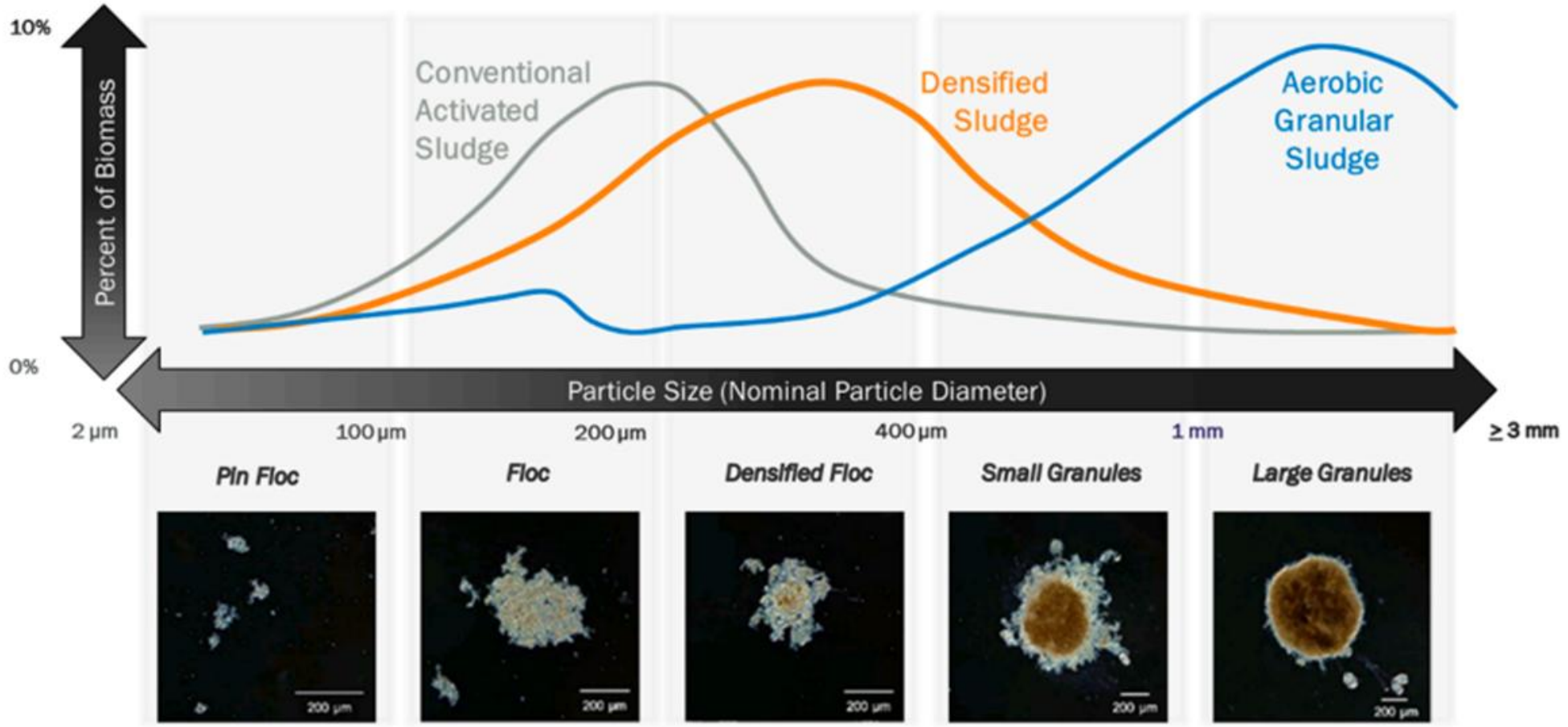
- Large, dense, spherical shape
- Aggregates of microbial origins… Form naturally in activated sludge systems
- Self-immobilization where different microbial species coalesce (via extracellular polymeric substances) to degrade organic and inorganic compounds in wastewater
- Rapid settling (low SVI)
- Particle size > 0.2 mm

Layers of microbial communities



Source: Parkson Corporation

Comparing CAS vs DAS vs AGS

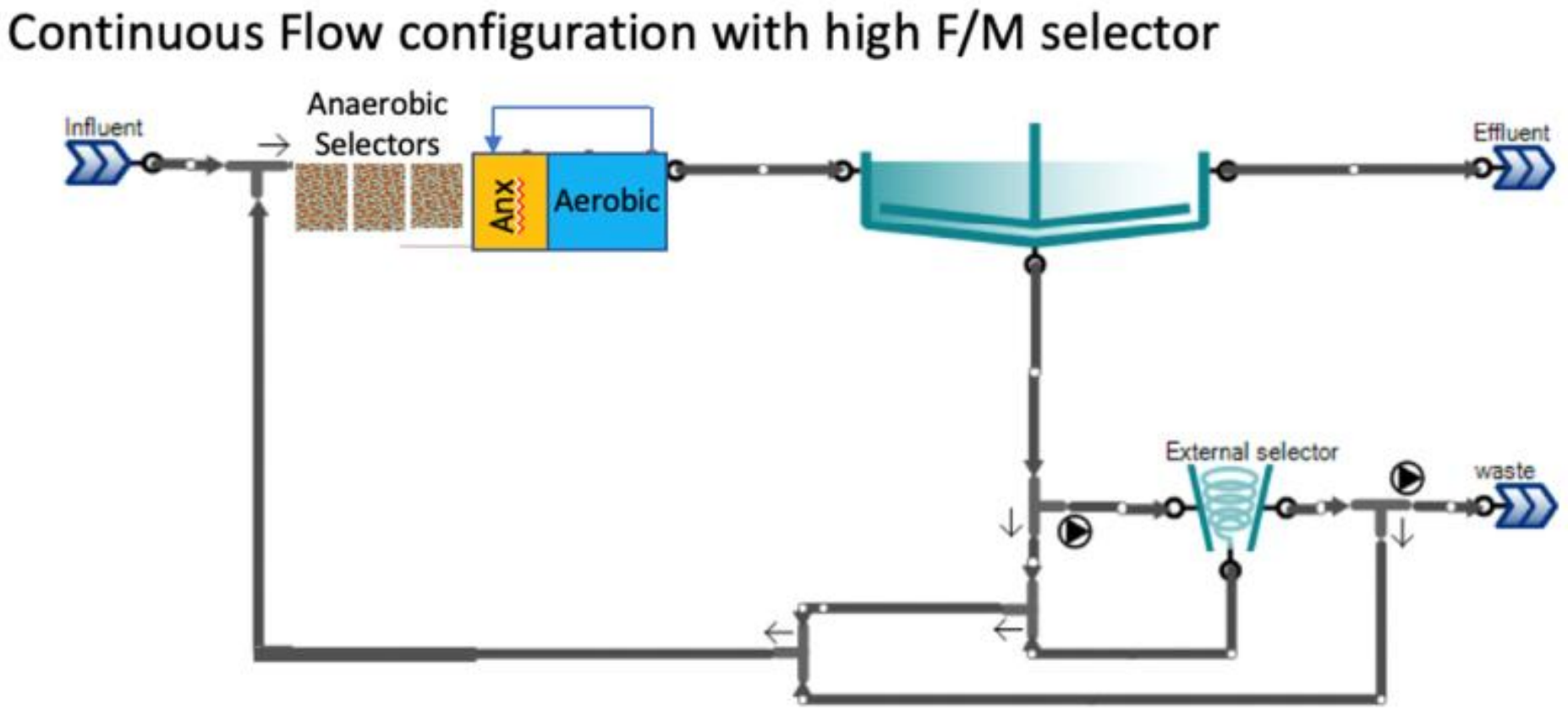


Source: Bahus, K; Armenta, M; Maltos, R; Sturm, B, Regmi, P., 2024. Making waves: Riding the densification wave from current understanding to advancement. Water Res. 257, 121690.

How to promote DAS in continuous flow system?

- Internal biological selection: high substrate concentration with high substrate uptake rate (or high F:M in selectors)
- Design guideline (WRF Project 4870)
  - Selectors with multiple compartments to drive F:M gradient
  - Target 10 gCOD/gMLSS/day in the first compartment of anaerobic selector
- Physical/mechanical (external) retainage
  - Hydrocyclones
  - Surface wasting
  - Physical screening (screens or sieves)

Combined internal and external selection



Source: Balancing Flocs and Granules for Activated Sludge Process Intensification in Plug Flow Configurations, 2021. (WRF Project no. 4870)

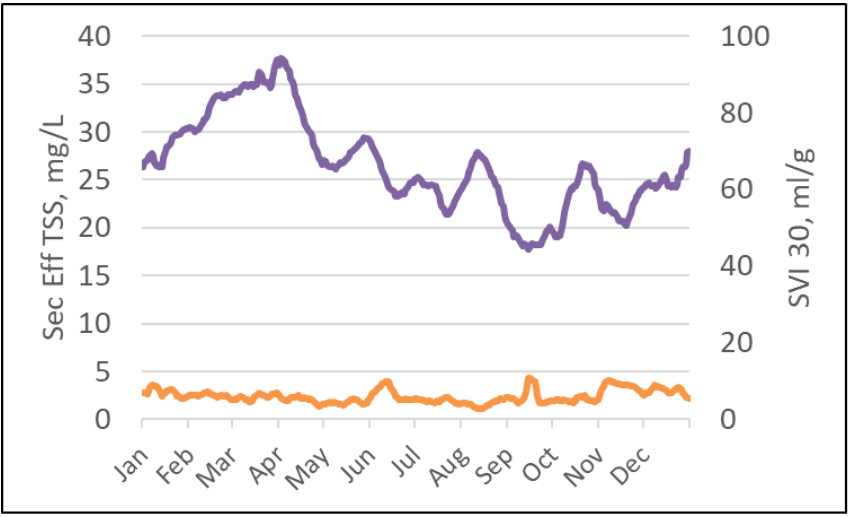
WHAT PROMPTED THE INVESTIGATION?

Facility	Design Average Flow, MGD
Eau Claire	11.5
Sun Prairie	4.2
Wausau	8.2

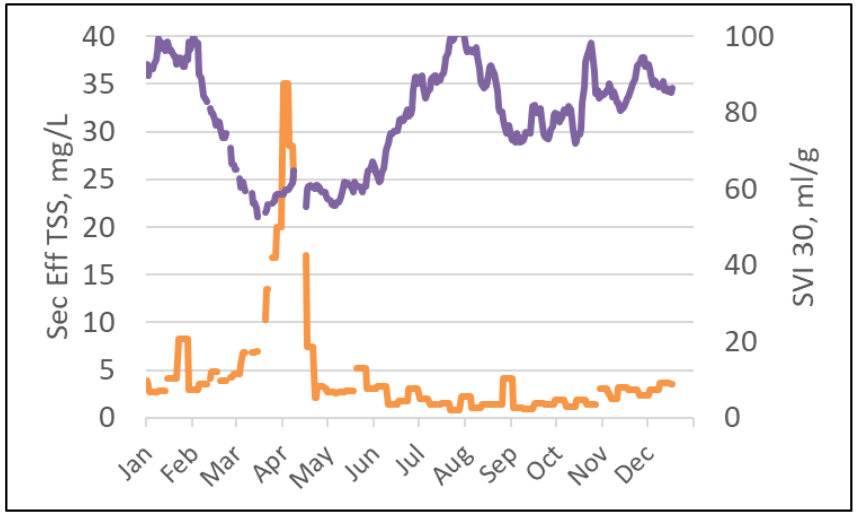
SVI30 and Secondary Effluent TSS

(7-day Running Averages in 2024)

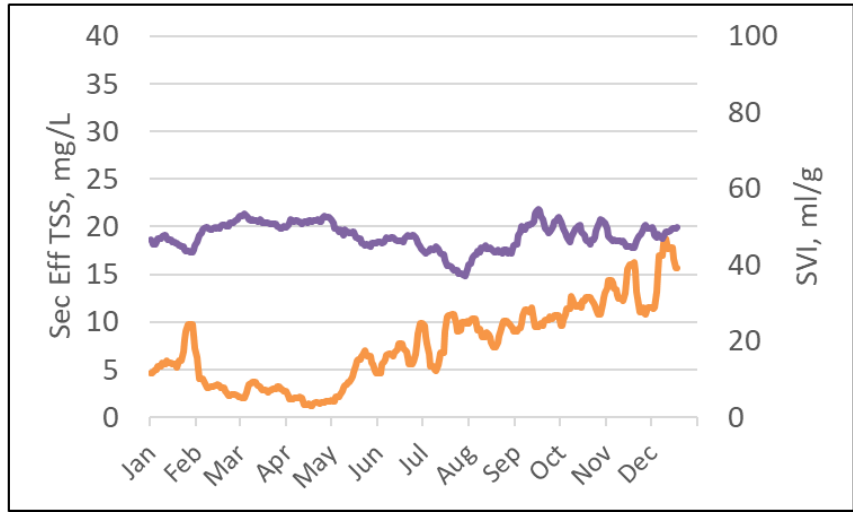
Eau Claire



Sun Prairie



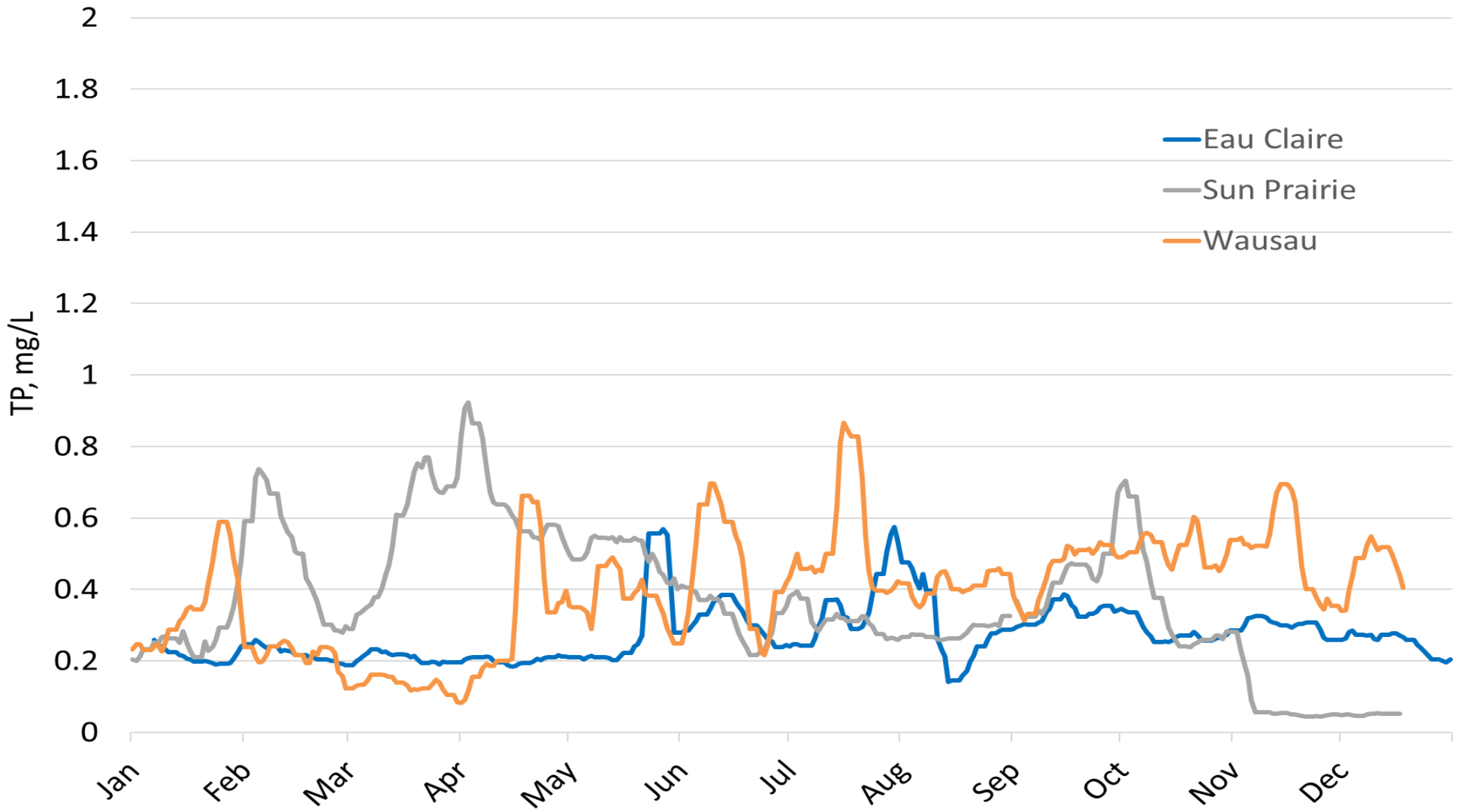
Wausau



TSS SVI

Secondary Effluent TP

(7-day Running Averages in 2024)

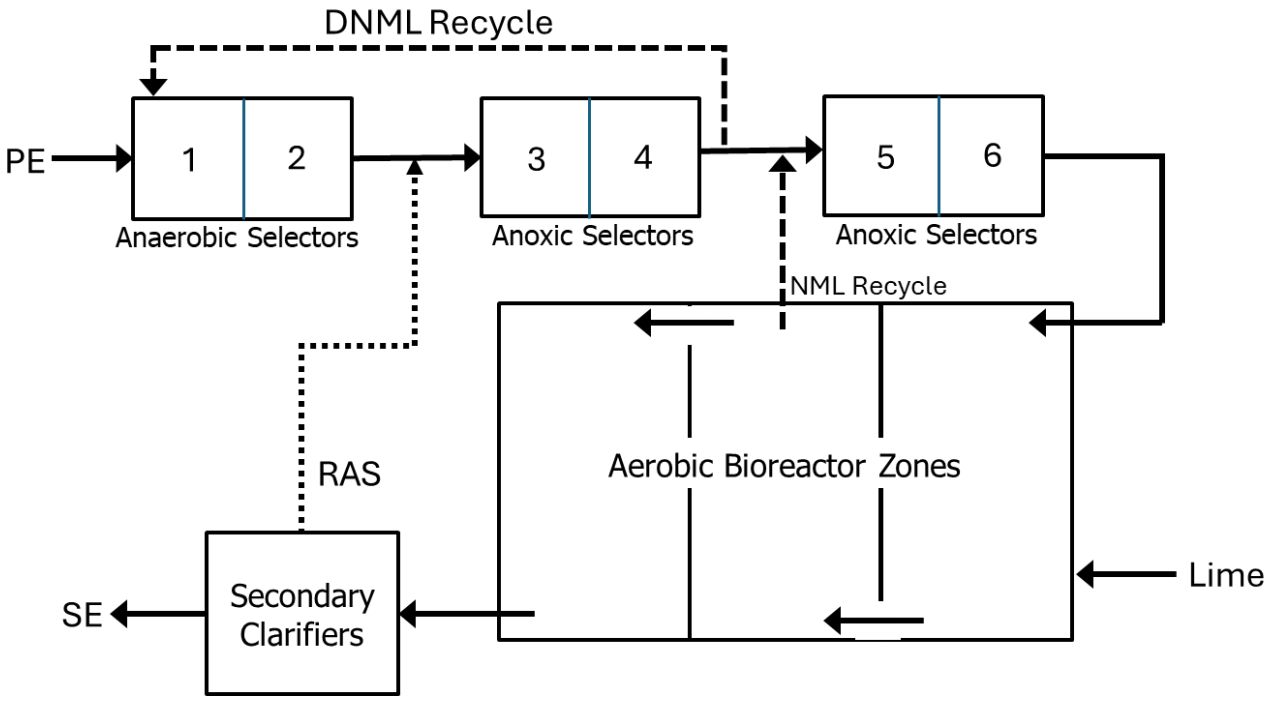


Similarities among the facilities…

- Low SVI
- Low effluent TSS
- Low effluent TP (without chemicals or tertiary filtration)
- Flocculating energy dissipating inlets in the final clarifiers
- Compartmentalized selectors (to provide operational flexibility under low and high load conditions)

FACILITIES DESIGN

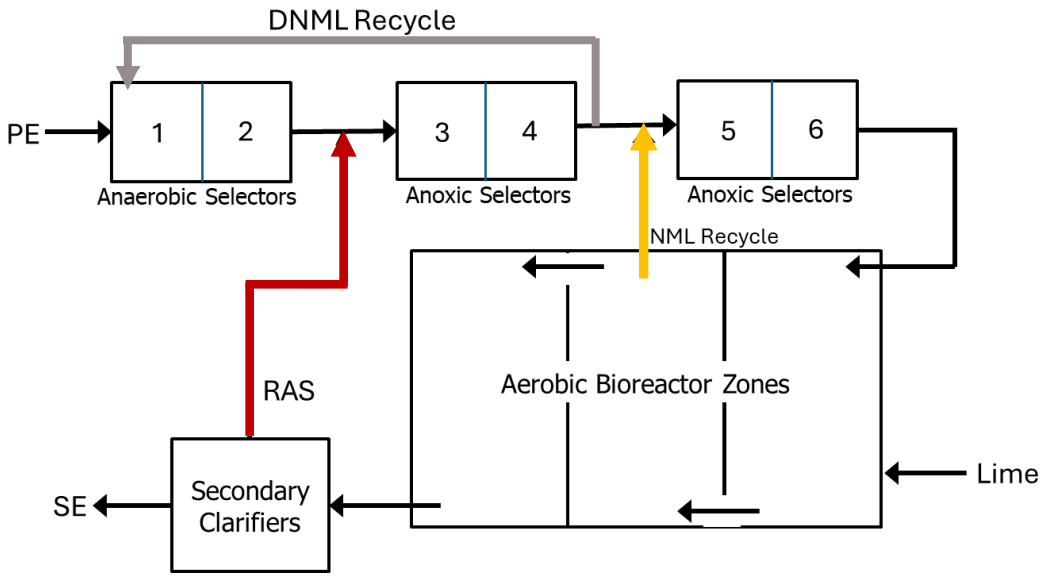
A brief history of…

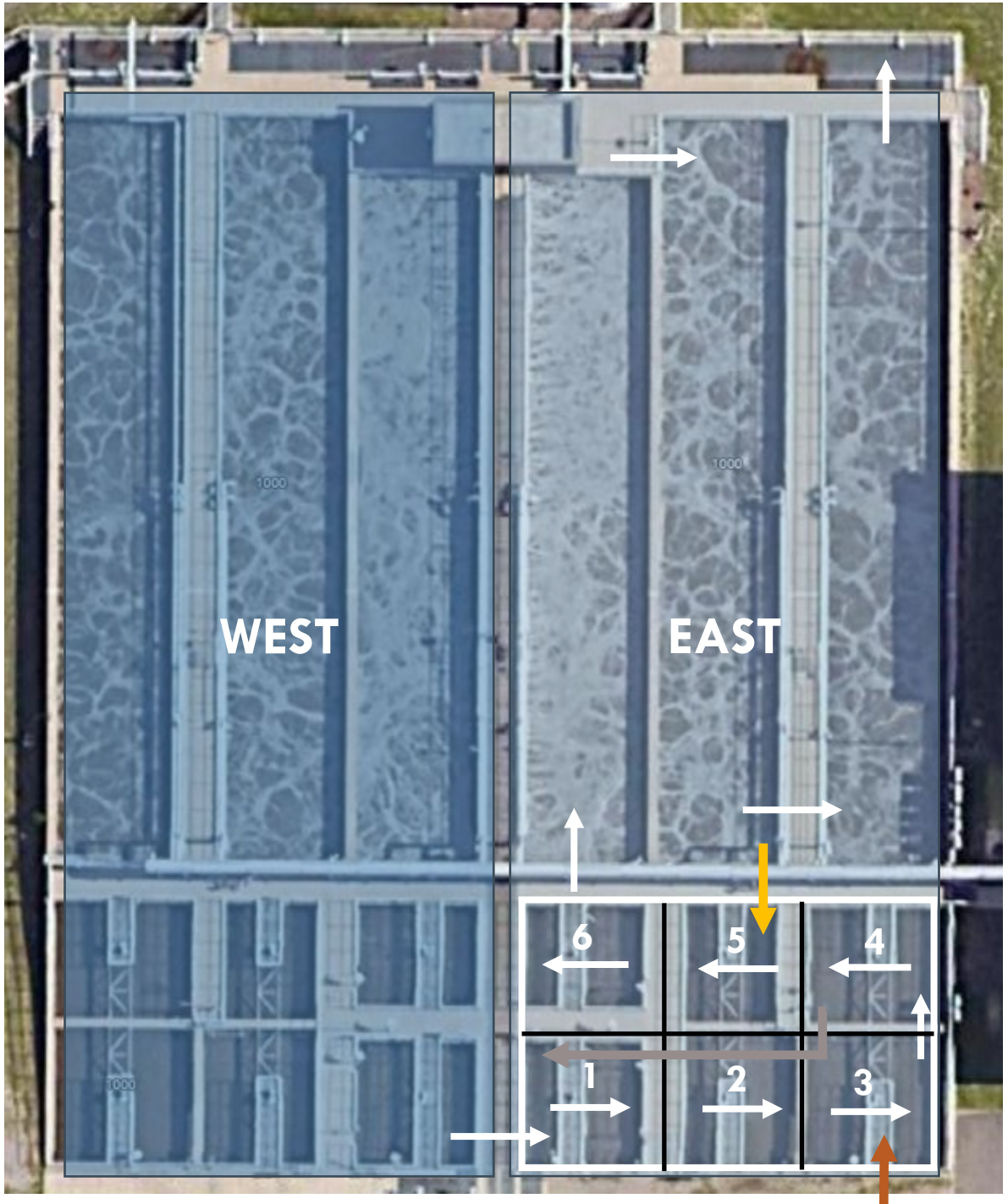


- RBC converted to MUCT in 2012
- Achieve EBPR and recover alkalinity through denitrification
- Discharge to Chippewa River which eventually joins Mississippi – not stringent effluent requirements
  - 30/45 BOD/TSS
  - 29 mg/L ammonia-N
  - 1 mg/L TP monthly avg

CITY OF EAU CLAIRE

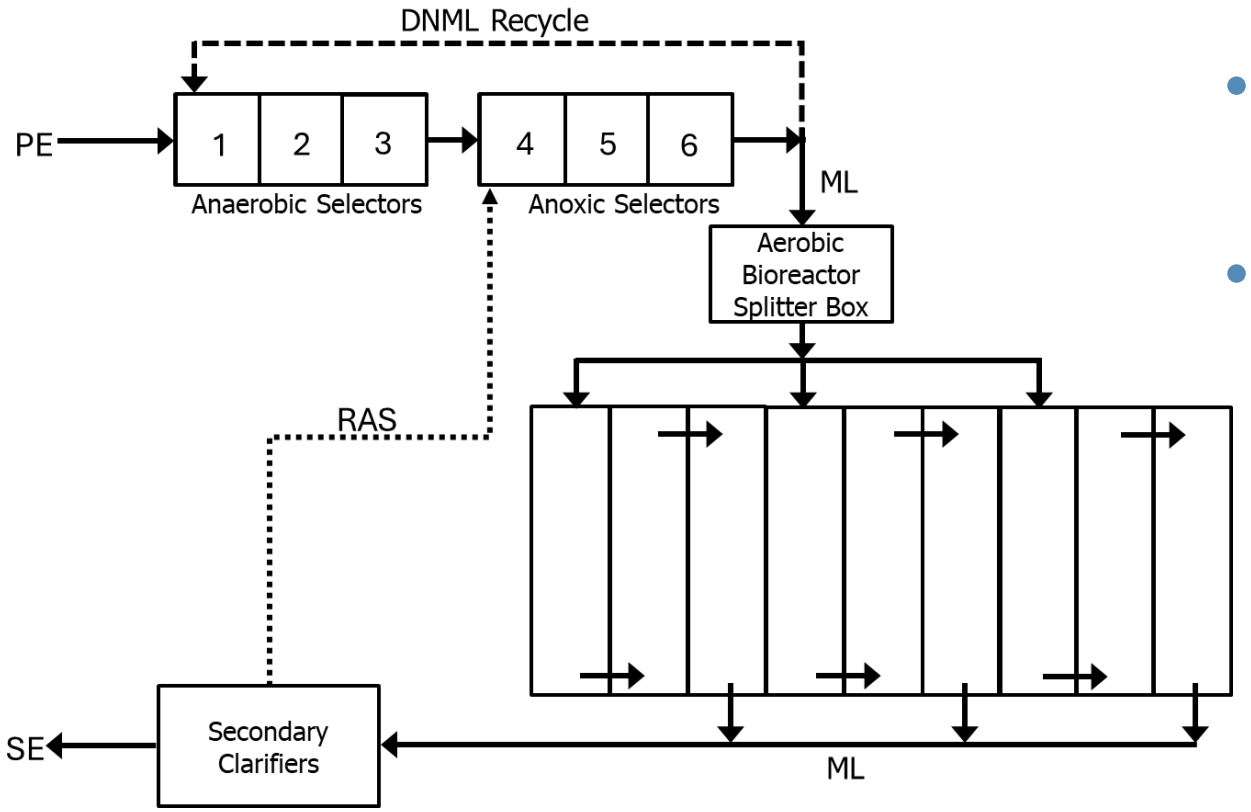
Two batteries: east and west (mirror image)





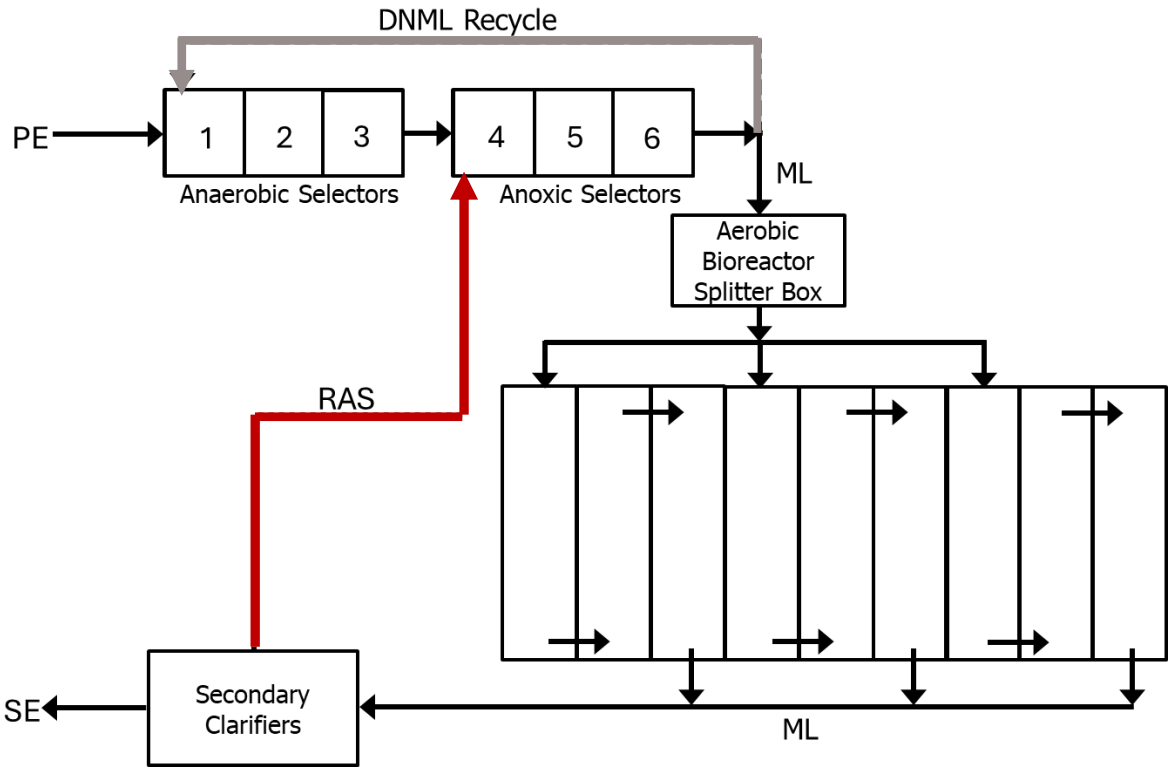
A brief history of…

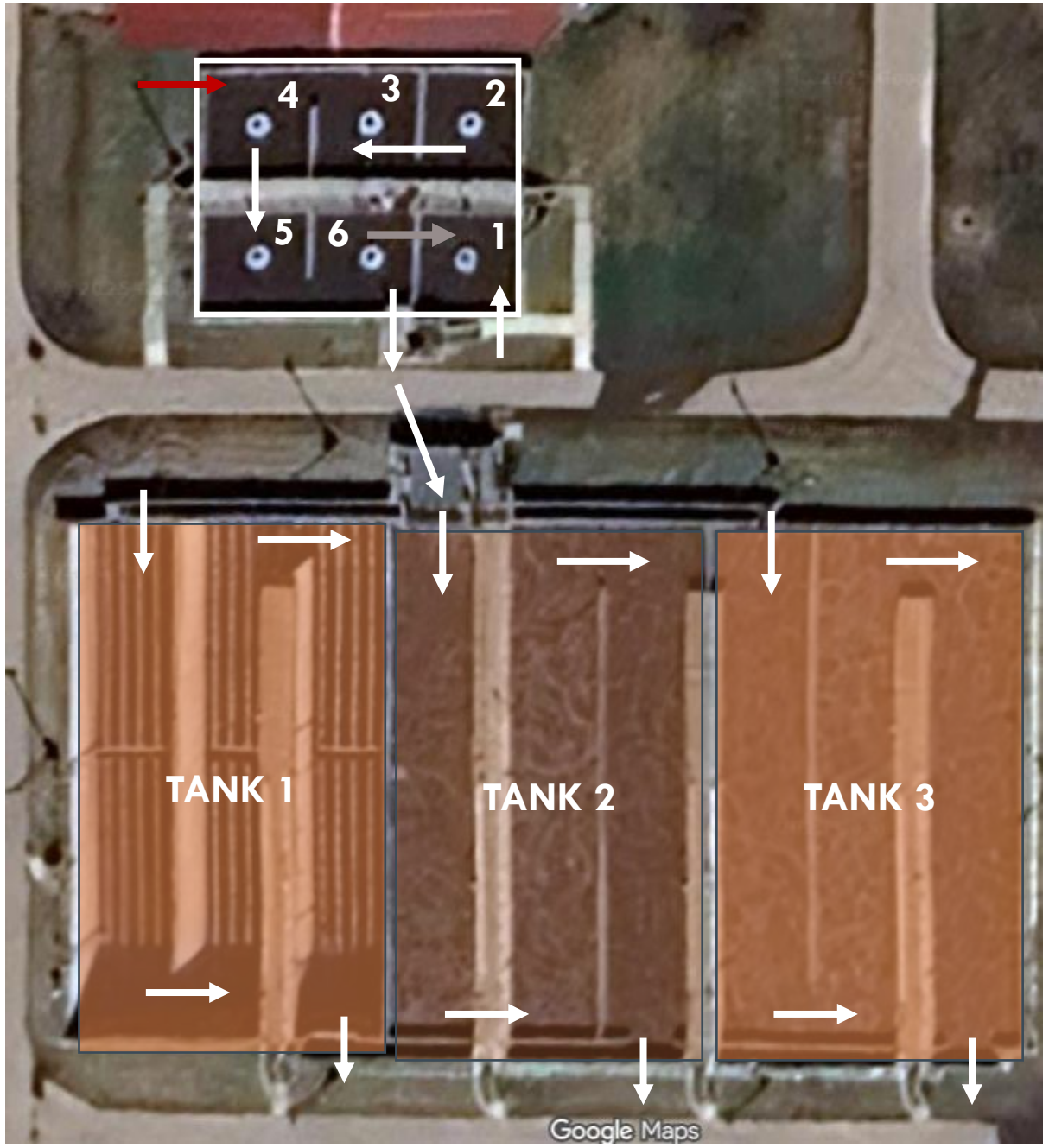
SUN PRAIRIE



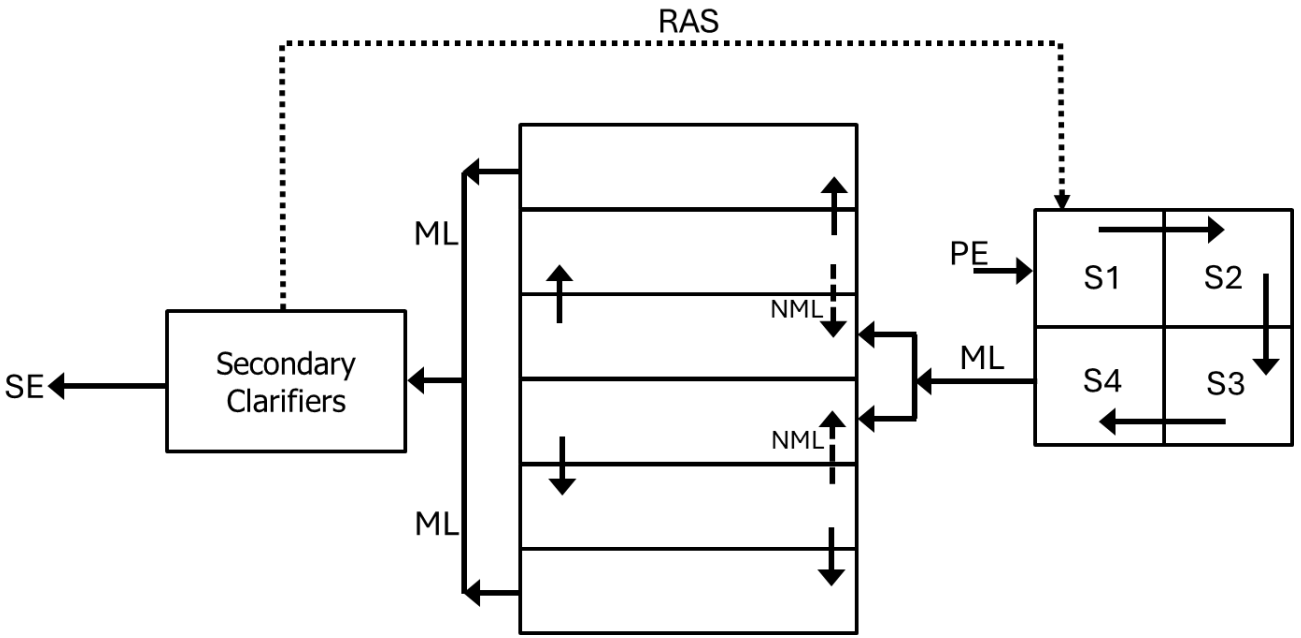
- RBC converted to MUCT* in 2005 (*no nitrified ML recycle)
- Very stringent seasonal effluent limits:
  - 5/10 BOD/TSS monthly avg
  - 1.1 mg/L ammonia-N monthly avg
  - 0.225 mg/L TP monthly avg and 0.075 mg/l TP 6-month avg

SUN PRAIRIE


DNML Recycle
PE
1
2
3
4
5
6
Anaerobic Selectors
Anoxic Selectors
ML
Aerobic
Bioreactor
Splitter Box
RAS
SE
Secondary
Clarifiers
ML


4
3
2
5
6
1
TANK 1
TANK 2
TANK 3
Google Maps

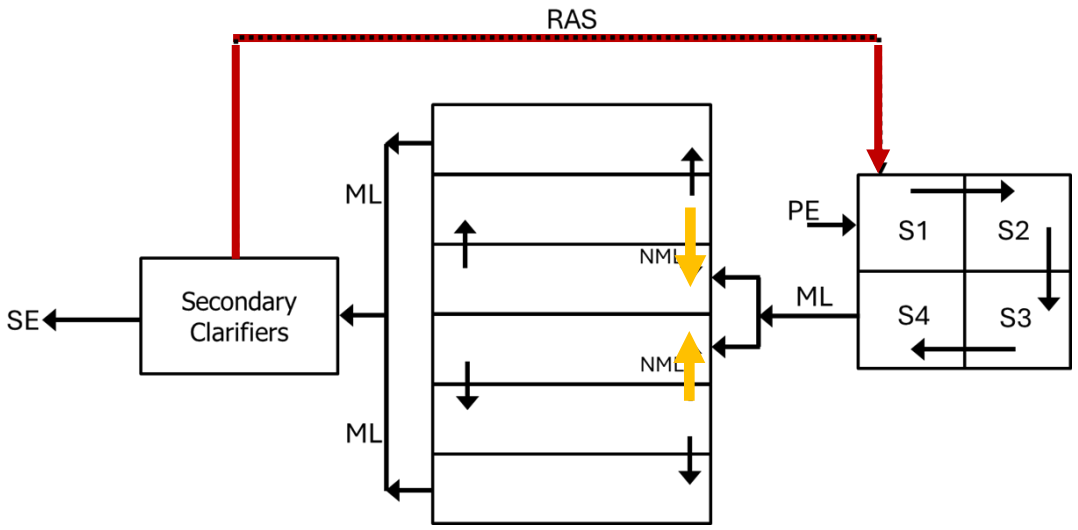
A brief history of…

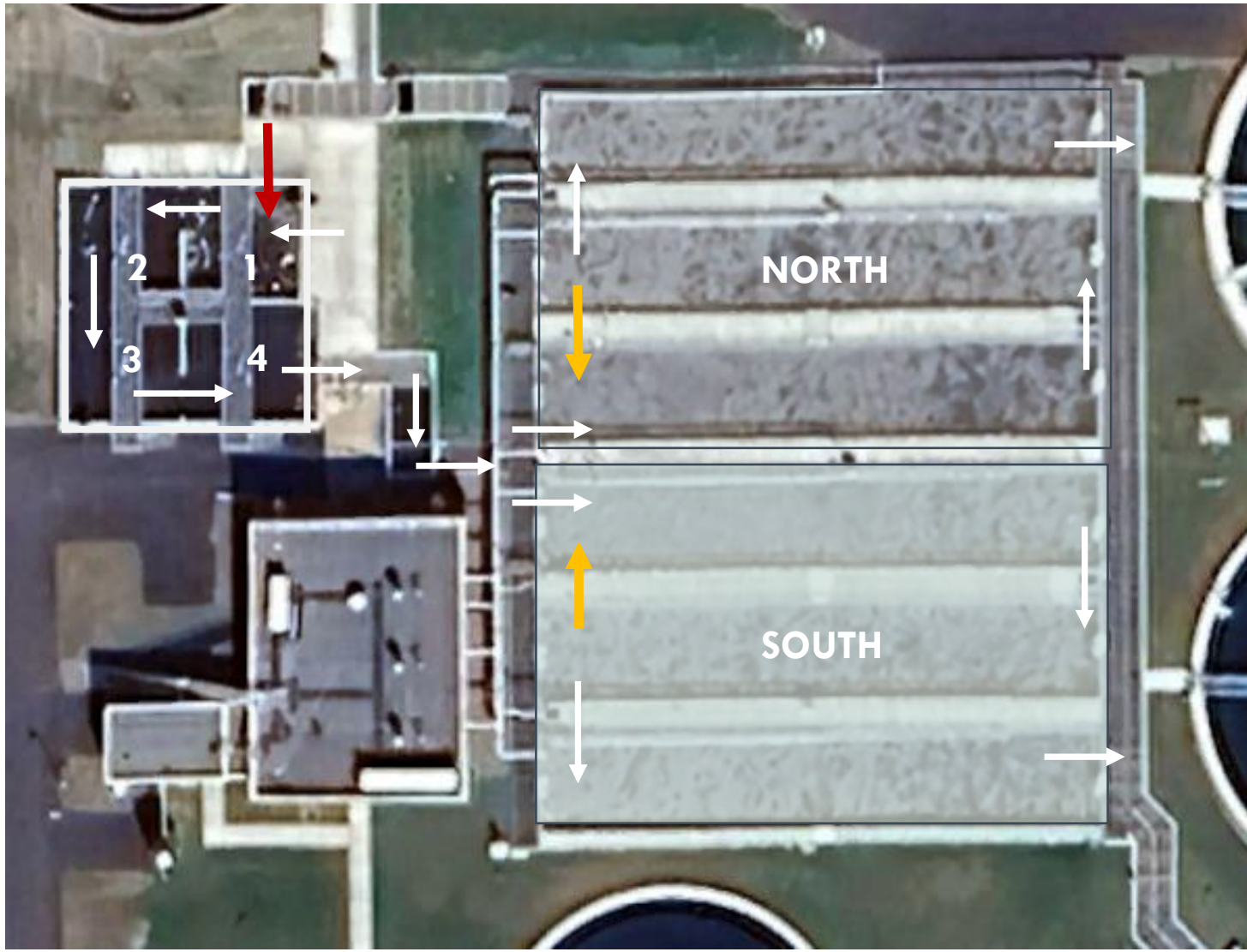


- A/O* configuration (*with nitrified ML recycle)
- Achieve EBPR and recover alkalinity through partial denitrification
- Discharge to Mississippi – not stringent effluent requirements
  - 30/45 BOD/TSS
  - No ammonia-N limit
  - 0.3 mg/L TP monthly
  - 0.1 mg/L TP 6-month avg

WAUSAU WATER WORKS
FOR YOU!

Two batteries: north and south (mirror image)





Compartmentalized selectors drive high F:M

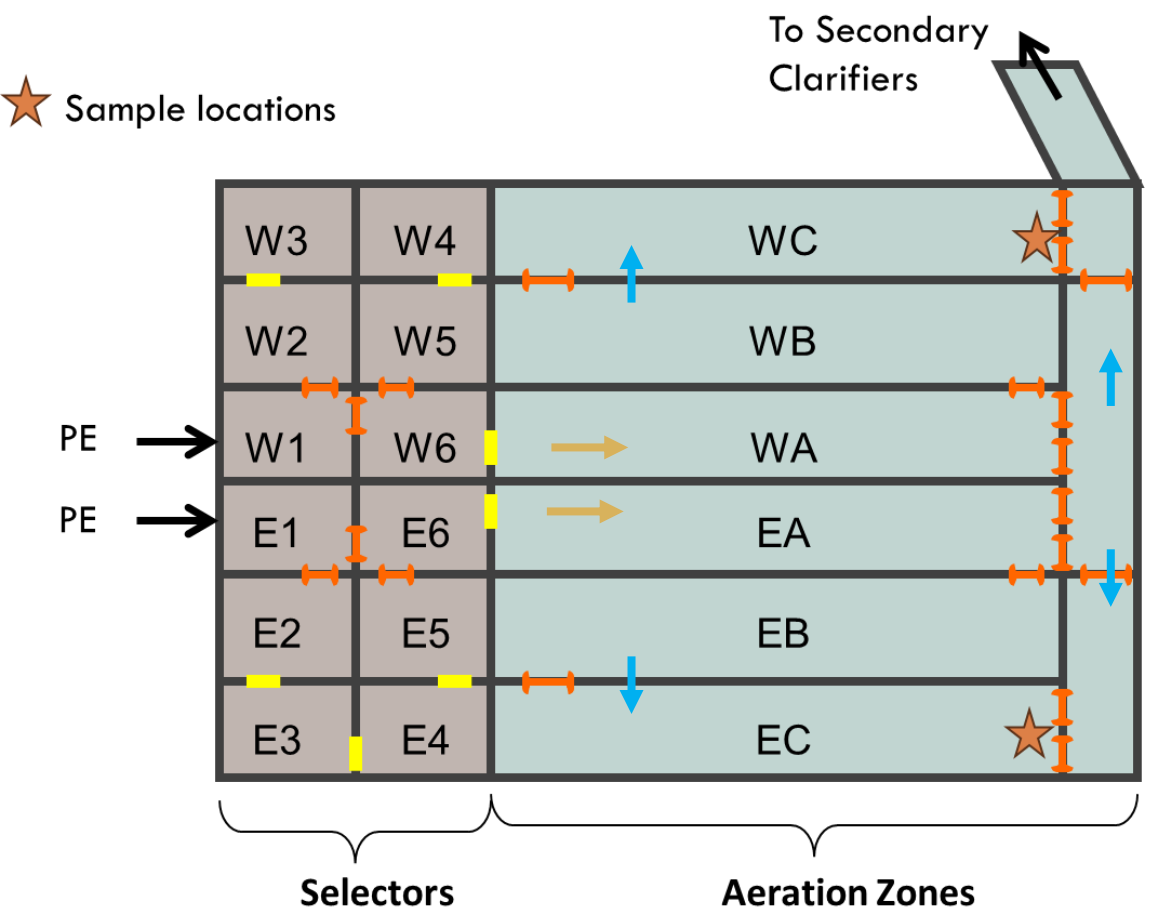
Parameter	Eau Claire (EC)	Sun Prairie (SP)	Wausau (W)
Design Flow (MGD)	11.5	4.2	8.2
BNR Configuration	MUCT	MUCT[1]	A/O[2]
Design F:M in First Compartment of Selectors (lb BOD_5/lb MLSS/day)	7.2	4.4	4.5
Design F:M in Bulk Selectors (lb BOD_5/lb MLSS/day)	1.2	0.73	1.13

Note:

1. No NML recycle
2. With NML recycle

SAMPLING, ANALYSES, RESULTS

Sampling and analyses



Eau Claire Sampling Locations

- Collected two MLSS samples (1-L each)
- Samples were sent to University of Kansas for analyses
- SVI5, SVI30
- TSS, VSS
- Sieve Analysis
- Image Analysis
- Followed Standard Methods for TSS analysis and *Experimental Methods in Wastewater Treatment* by van Loosdrecht et al. for sieve analysis

Results - SVI30 and SVI5

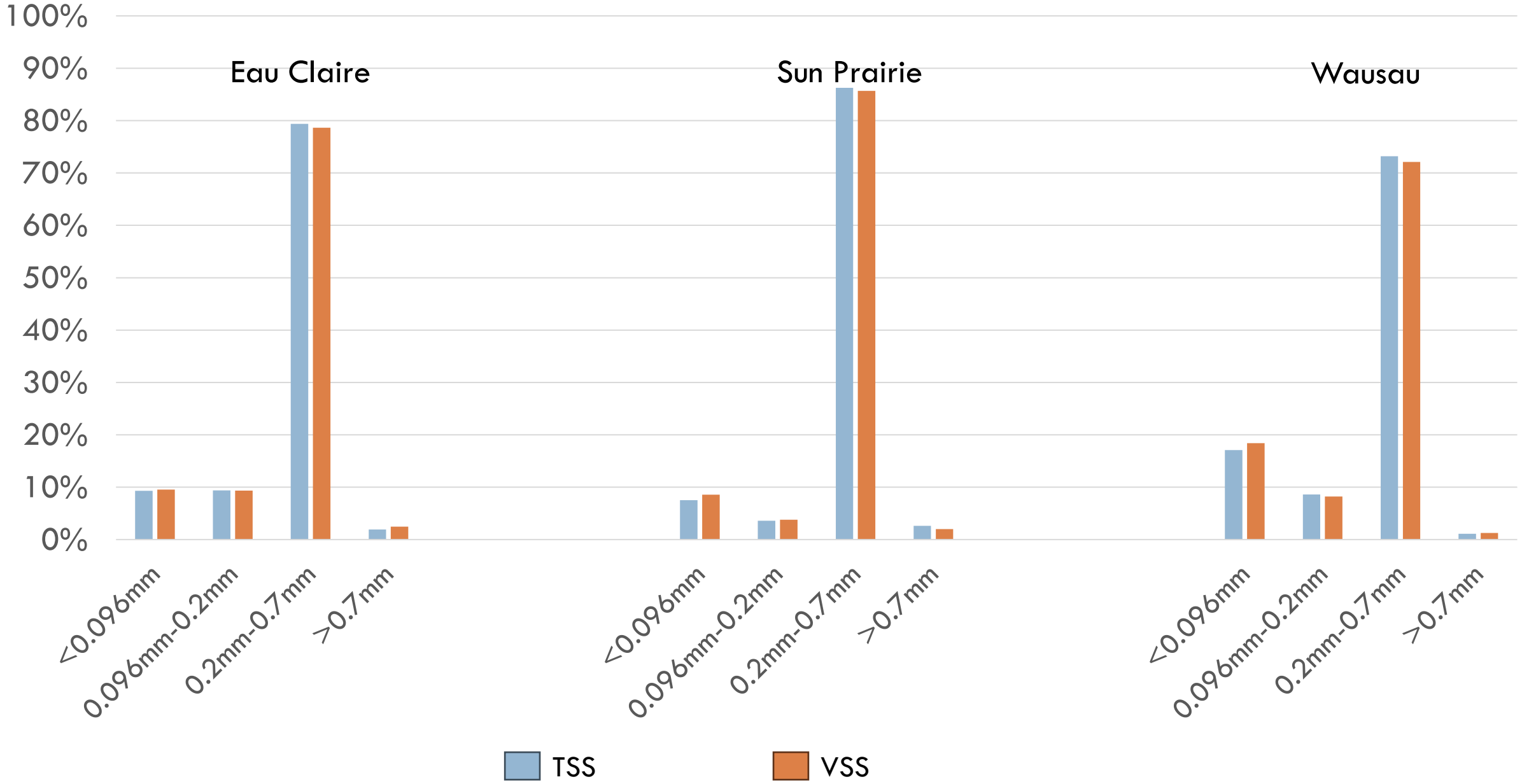
Sample Name	SVI5 (mL/g)	SVI30 (mL/g)	SVI5/SVI30*
Eau Claire Sample 1	92	68	1.3
Eau Claire Sample 2	96	64	1.5
Sun Prairie Sample	114	82	1.4
Sun Prairie Sample 2	131	82	1.6
Wausau Sample 1	95	53	1.8
Wausau Sample 2	105	56	1.8

*Good indication of abundance of granules: SVI5:SVI30 = 1

Particle size distribution

Sieve Analysis (abundance)	Eau Claire		Sun Prairie		Wausau	
	TSS	VSS	TSS	VSS	TSS	VSS
<0.096mm	9%	10%	7%	8%	17%	18%
0.096mm-0.2mm	10%	9%	4%	4%	9%	8%
0.2mm-0.7mm	79%	79%	86%	86%	73%	73%
>0.7mm	2%	2%	3%	2%	1%	1%

Sieve Fractions (Percentage)



Particle size and SVI30

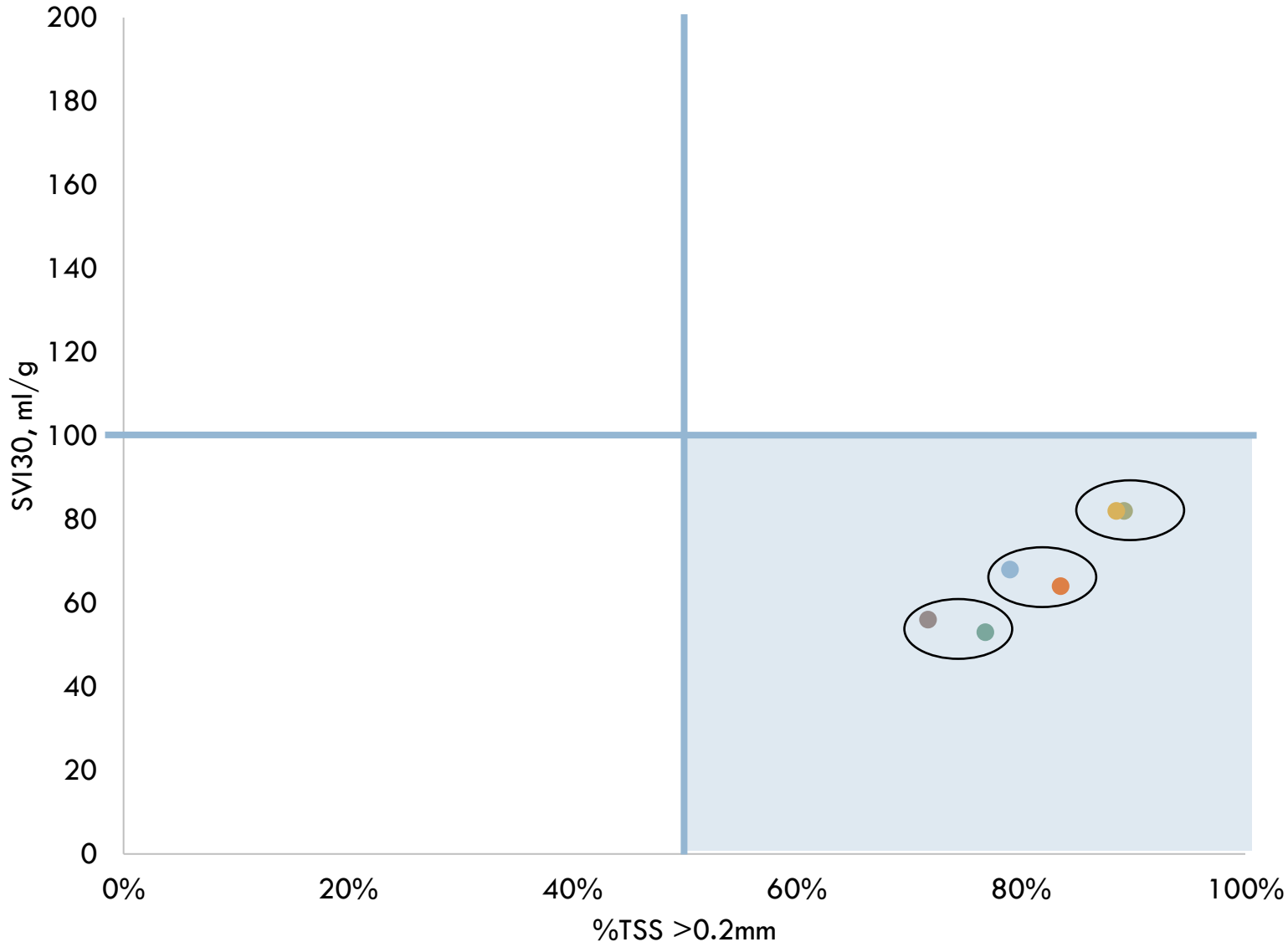
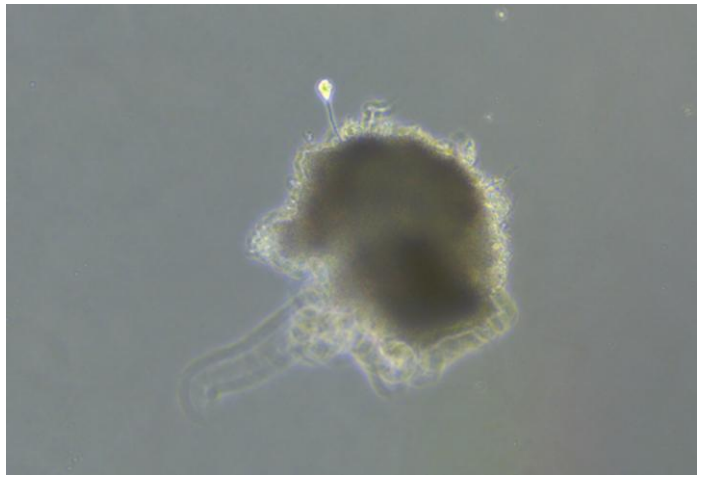
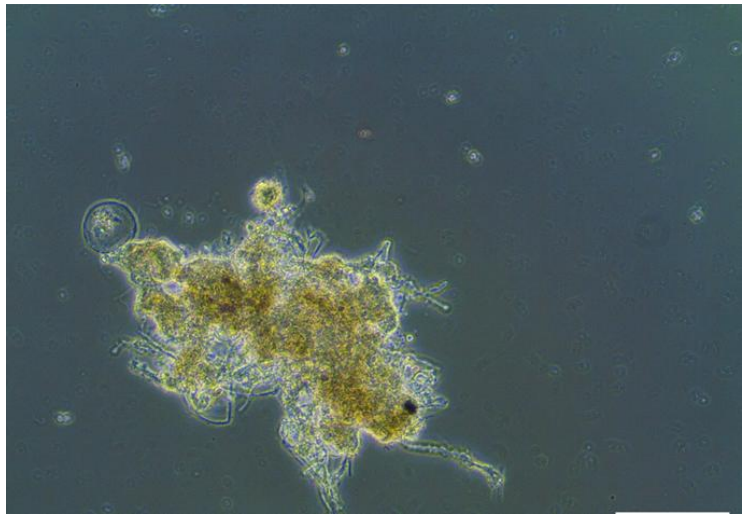


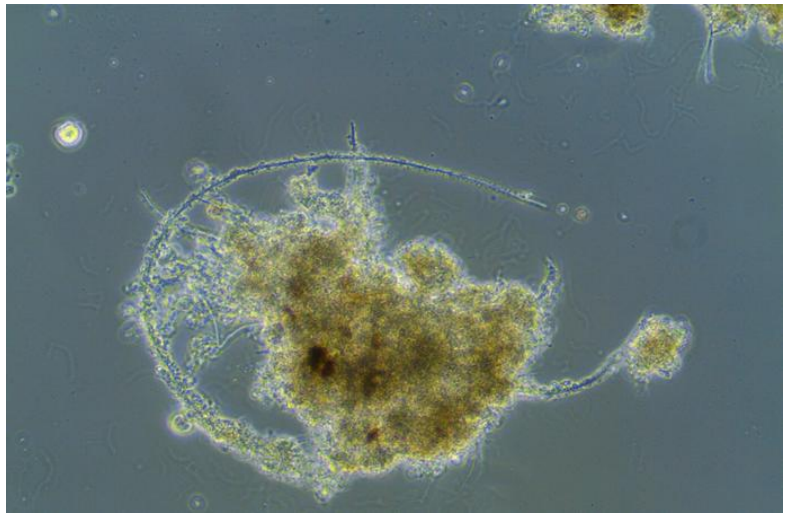
Image analysis



Eau Claire



Sun Prairie



Wausau

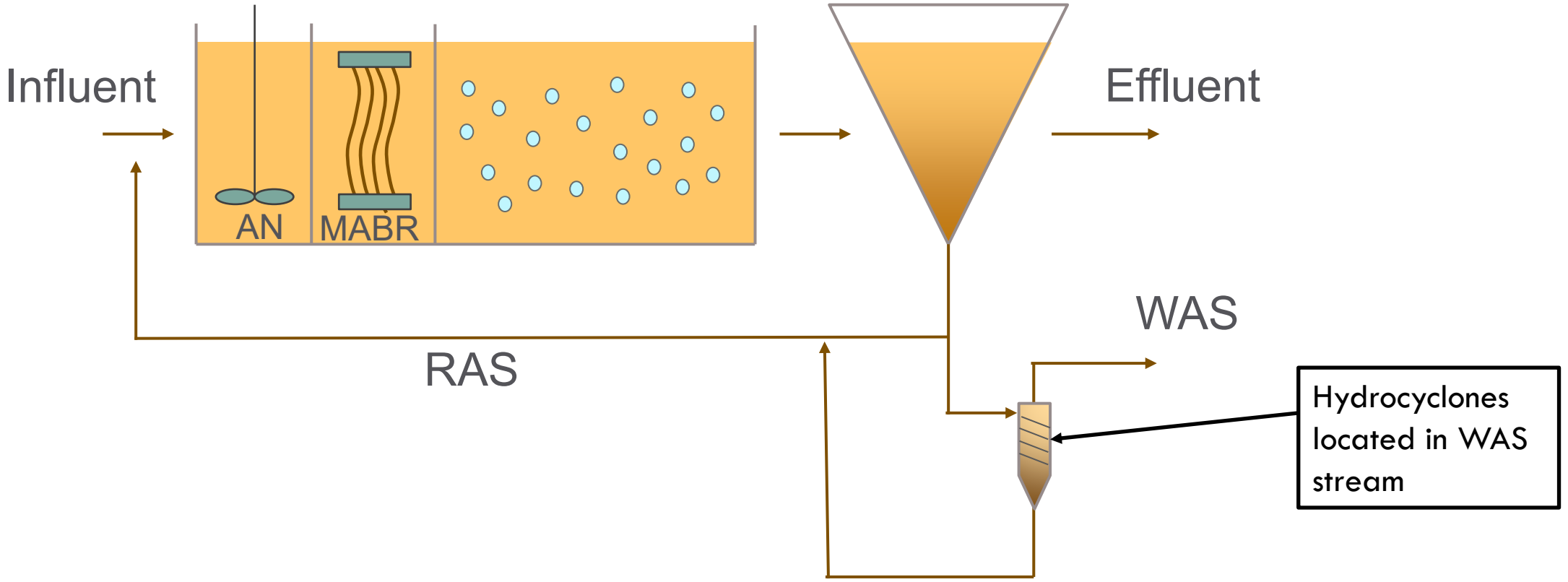
EXTERNAL SELECTORS PERFORMANCE

Hydrocyclones full scale demonstration program

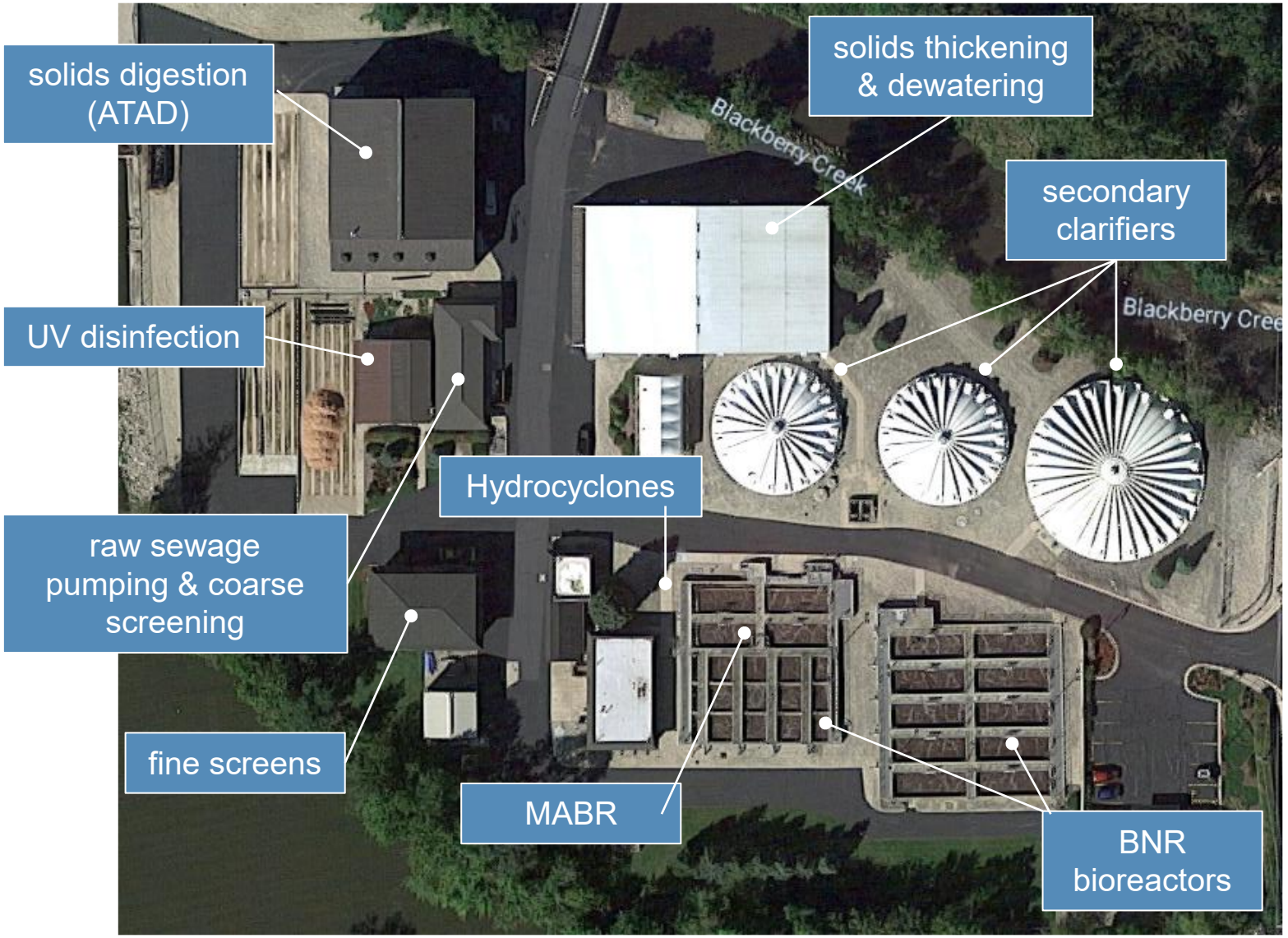
YBSD
YORKVILLE-BRISTOL
SANITARY DISTRICT

- 2023 to 2025
- Main goal is to increase hydraulic loadings without final clarifier expansion

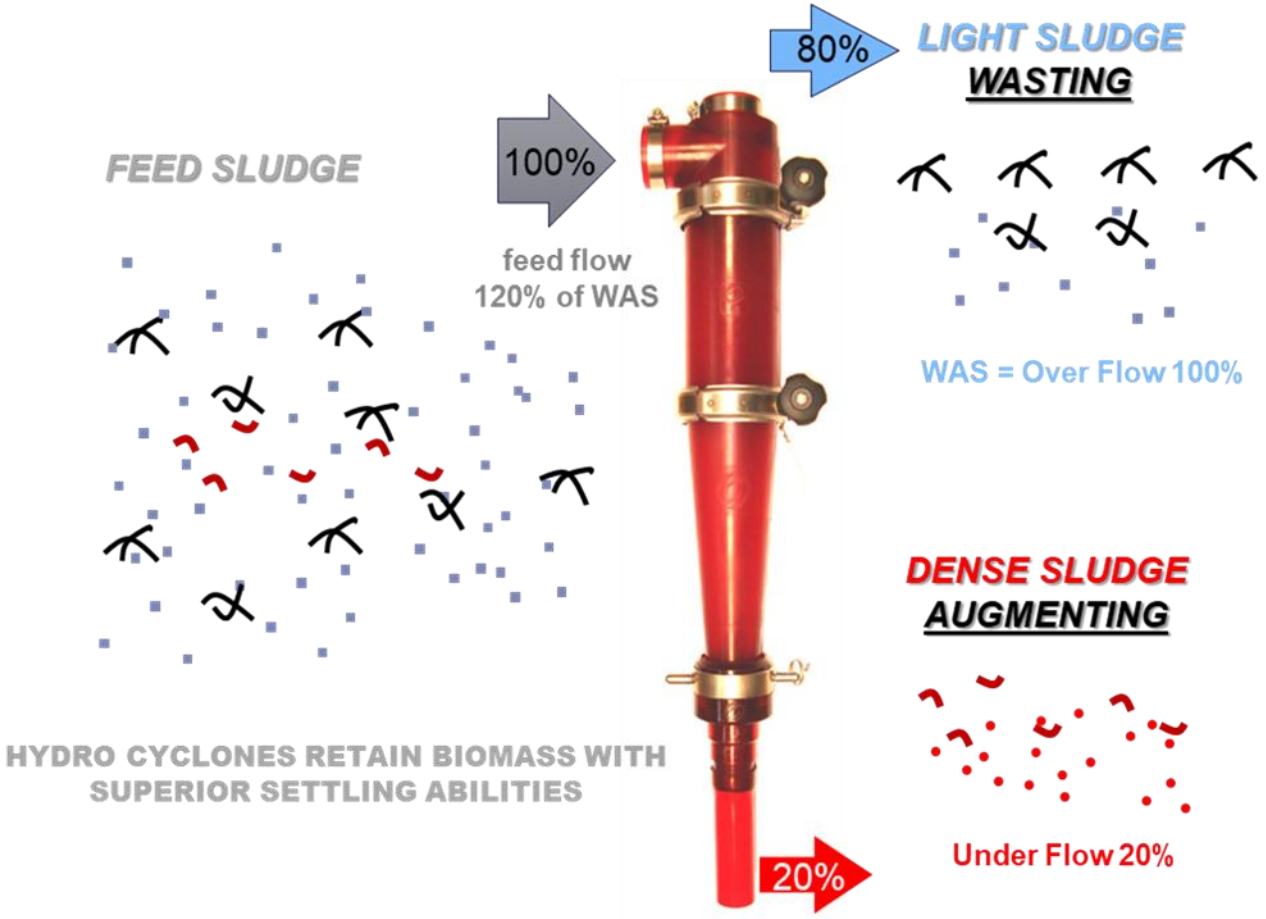
Flow diagram – AO configuration

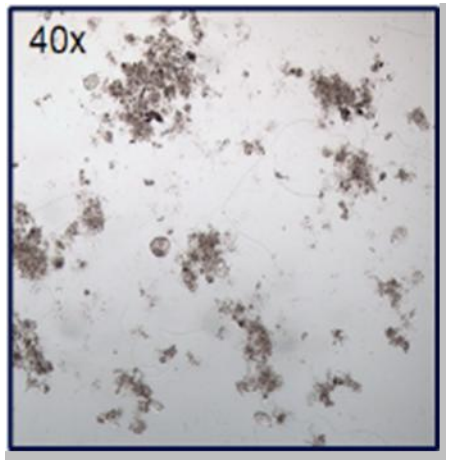


Plant layout (MABR with hydrocyclones)

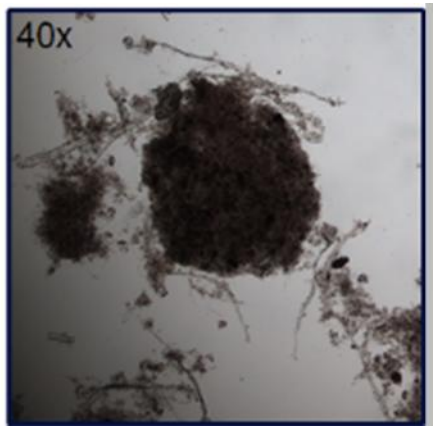


Hydrocyclones overview





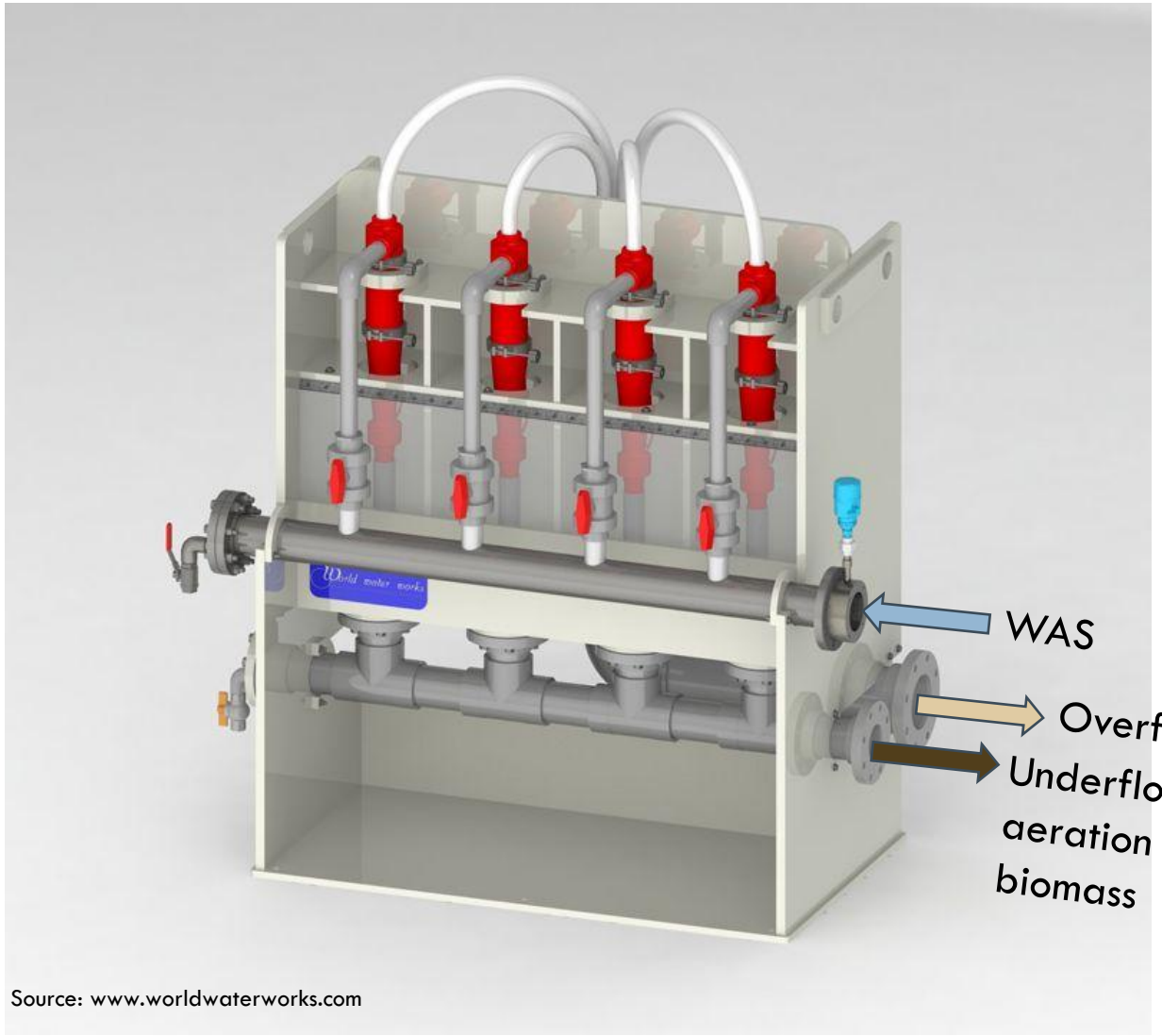
Conventional activated sludge



Densified activated sludge (DAS)

Source: Courtesy of Veolia

Hydrocyclone skid

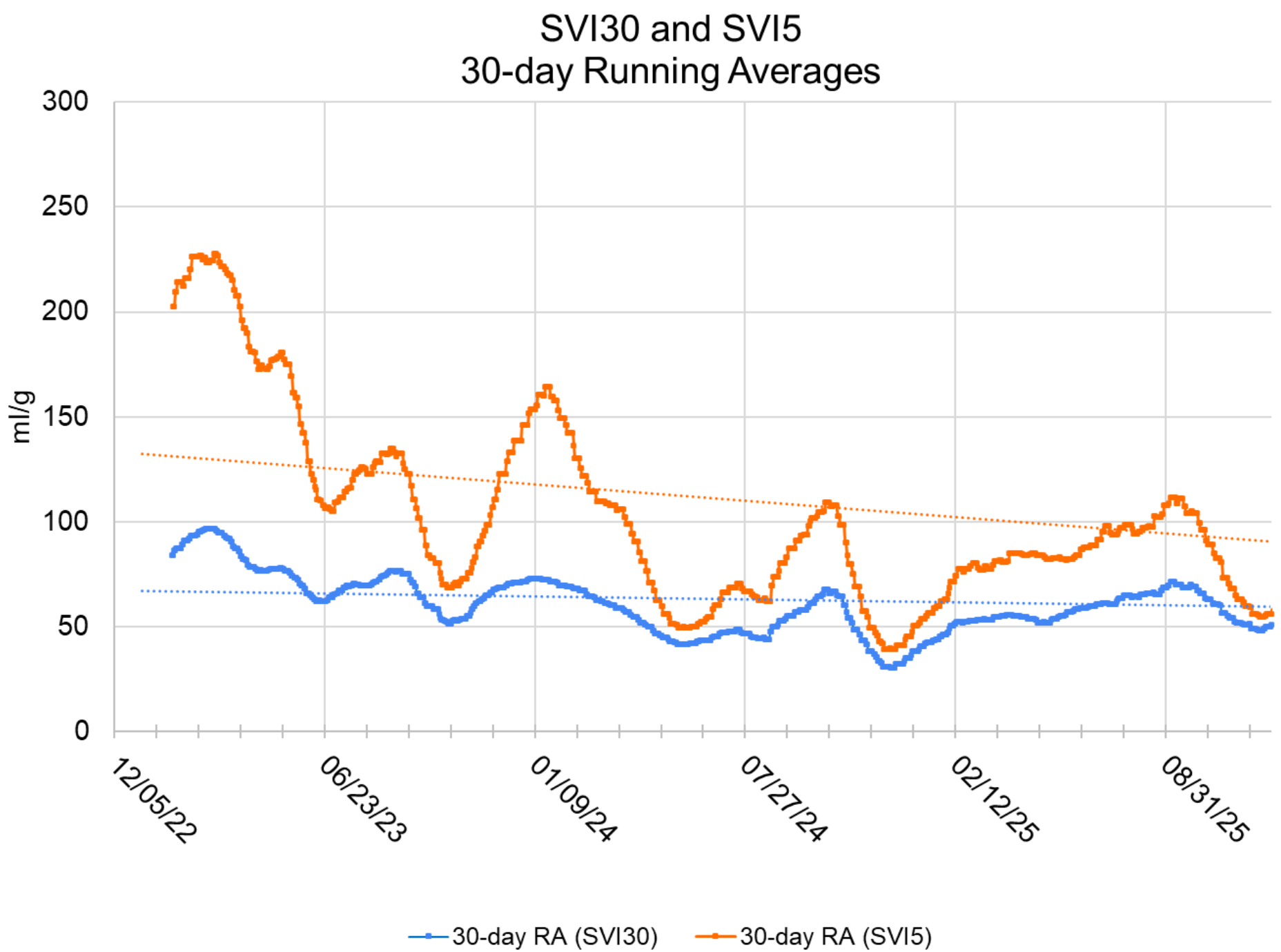


Source: www.worldwaterworks.com

- 6 hydrocyclones installed at YBSD
  - 100% redundancy
  - 44 gpm (or 10 m^3/hr) per hydrocyclone
- Operating pressure at 35 psi


Cyclone Feed


Overflow
Underflow


SVI30 and SVI5
30-day Running Averages
300
250
200
150
100
50
0
ml/g
12/05/22
06/23/23
01/09/24
07/27/24
02/12/25
08/31/25
30-day RA (SVI30)
30-day RA (SVI5)

Performance highlights

- Gradual increase in densification index (DI) throughout the demonstration program
  - Improved DI from 30% to 67% (the latest)
- More stable operation (final clarification) during peak flow events
- Lower alum dosage
  - over 90% saving to achieve 0.5 mg/L eff TP
- Decision to keep the hydrocyclones with on-going optimization

FINAL THOUGHTS

Key Takeaways

- Granules exist in conventional activated sludge systems - biological selectors is key to promote granule growth
- Properly sized selectors with substrate gradients using multiple compartmental series layouts is crucial – regardless of BNR configuration
- External/physical selectors are useful tools for retaining granules, but biological selection is critical for success

Acknowledgements

- Donohue (Milwaukee) – Bill Marten
- City of Eau Claire – Cole Clouiter, Mark Nelson
- City of Sun Prairie – Pat Heineck, Logan Hron, Jeremy Cramer
- Wausau Water Works – Ben Brooks, Jason Schill
- Yorkville-Bristol Sanitary District – Cyrus McMains, Lee Melcher, Josh Haggard, Renee Farren
- University of Kansas - Dr. Dev Hiripitiyage and Dr. Belinda Sturm

THANK YOU

DONOHUE

Contact: klaw@donohue-associates.com