Metropolitan Water Reclamation District of Greater Chicago

Welcome to the November Edition of the 2023 M&R Seminar Series

NOTES FOR SEMINAR ATTENDEES

- Remote attendees' audio lines have been muted to minimize background noise. For attendees in the auditorium, please silence your phones.
- A question and answer session will follow the presentation.
- For remote attendees, please use the "**Chat**" feature to ask a question via text to "**Host.**" For attendees in the auditorium, please raise your hand and wait for the microphone to ask a verbal question.
- The presentation slides will be posted on the MWRD website after the seminar.
- This seminar is pending approval by the ISPE for one PDH and has been approved by the IEPA for one TCH. Certificates will only be issued to participants who attend the entire presentation.

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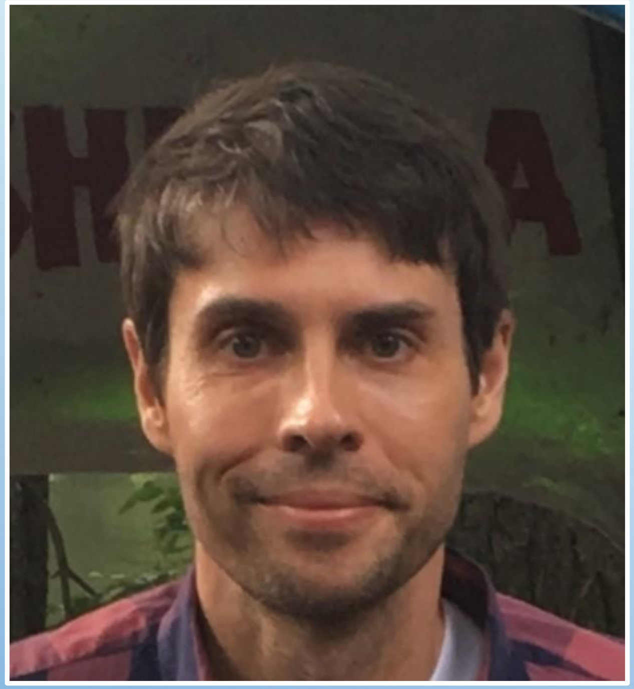


Joseph Kozak is a Principal Environmental Scientist for the Metropolitan Water Reclamation District of Greater Chicago. He has over twenty-five years of experience in environmental, wastewater, and natural systems engineering. His current research interests includes biological nutrient removal, anaerobic digestion, sludge dewatering, and greenhouse gas emissions from wastewater treatment. He has over 50 published papers and has given many presentations on his research. He holds a Bachelors from the University of Notre Dame, a Masters from Michigan State University, and a Doctorate in Environmental Engineering from Northwestern University and is also a registered professional engineer with the state of Illinois.

Updates on the MWRDGC’s Phosphorus Removal Efforts

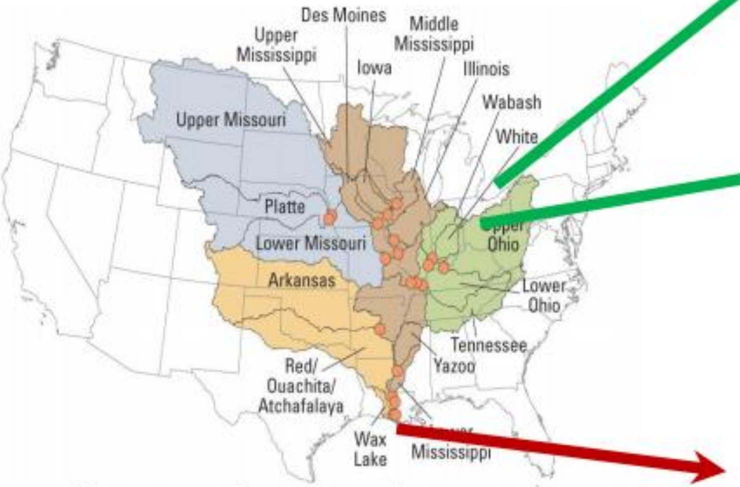
November 17, 2023

Outline

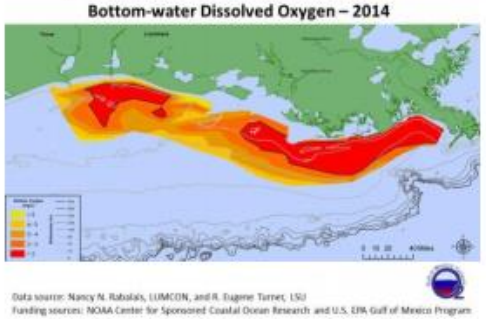
- Overview
  - Need for P removal
  - NPDES Permits Schedule
- MWRDGC's Phosphorus Removal Efforts in Each WRP
  - WRP Overview
  - Phosphorus Removal Timeline
  - Existing Phosphorus Removal Conditions
  - Ongoing/Planning Projects to Meet the Goals
- Summary
- Acknowledgements

Why do we need to remove P?

Near and far.
Large and small.
Point and non-point.



http://water.usgs.gov/nasqan/images/nasqan_ms_web.jpg



Phosphorus → freshwater harmful algal blooms (HAB)
Nitrogen → Estuary and marine eutrophication and hypoxia

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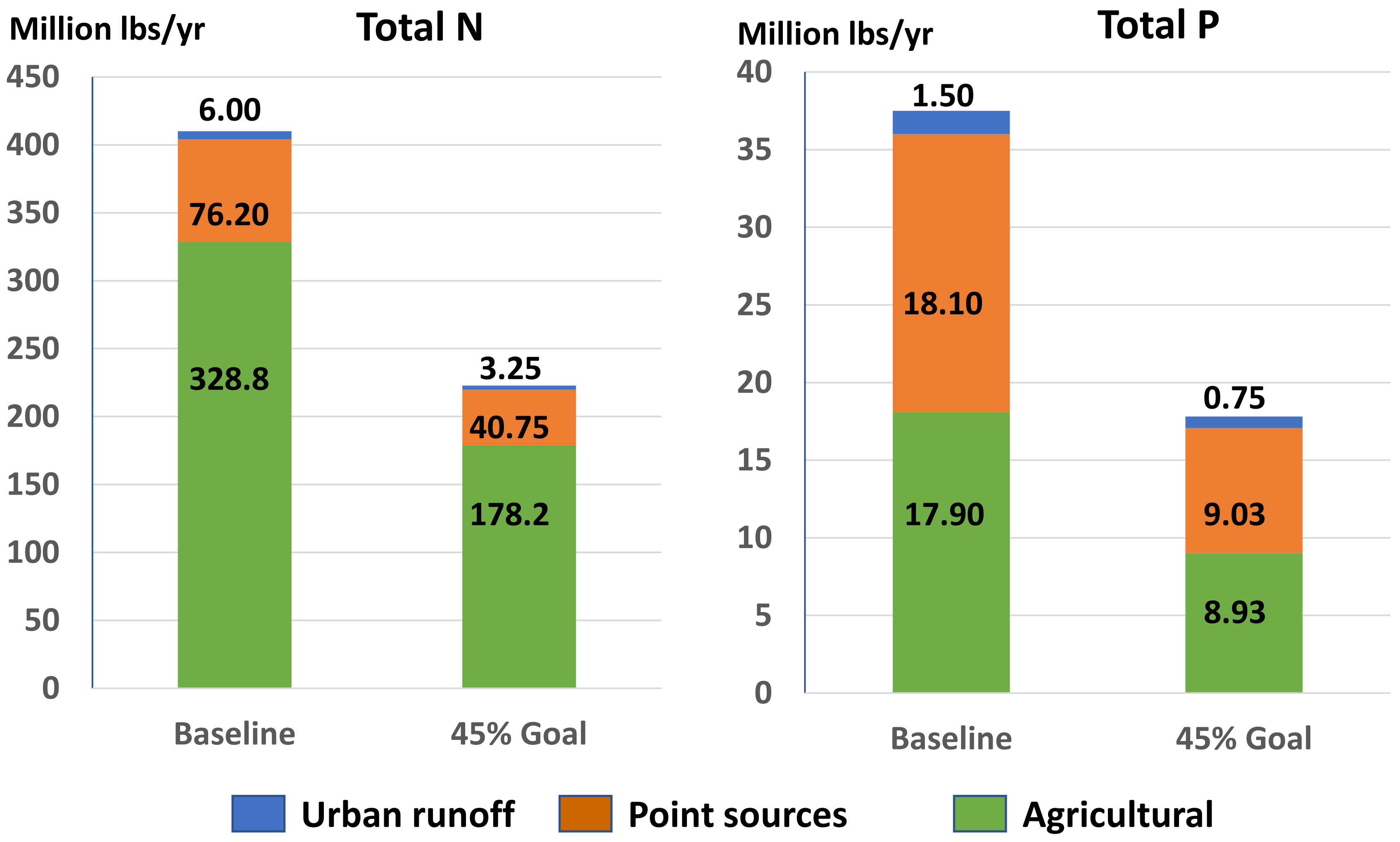
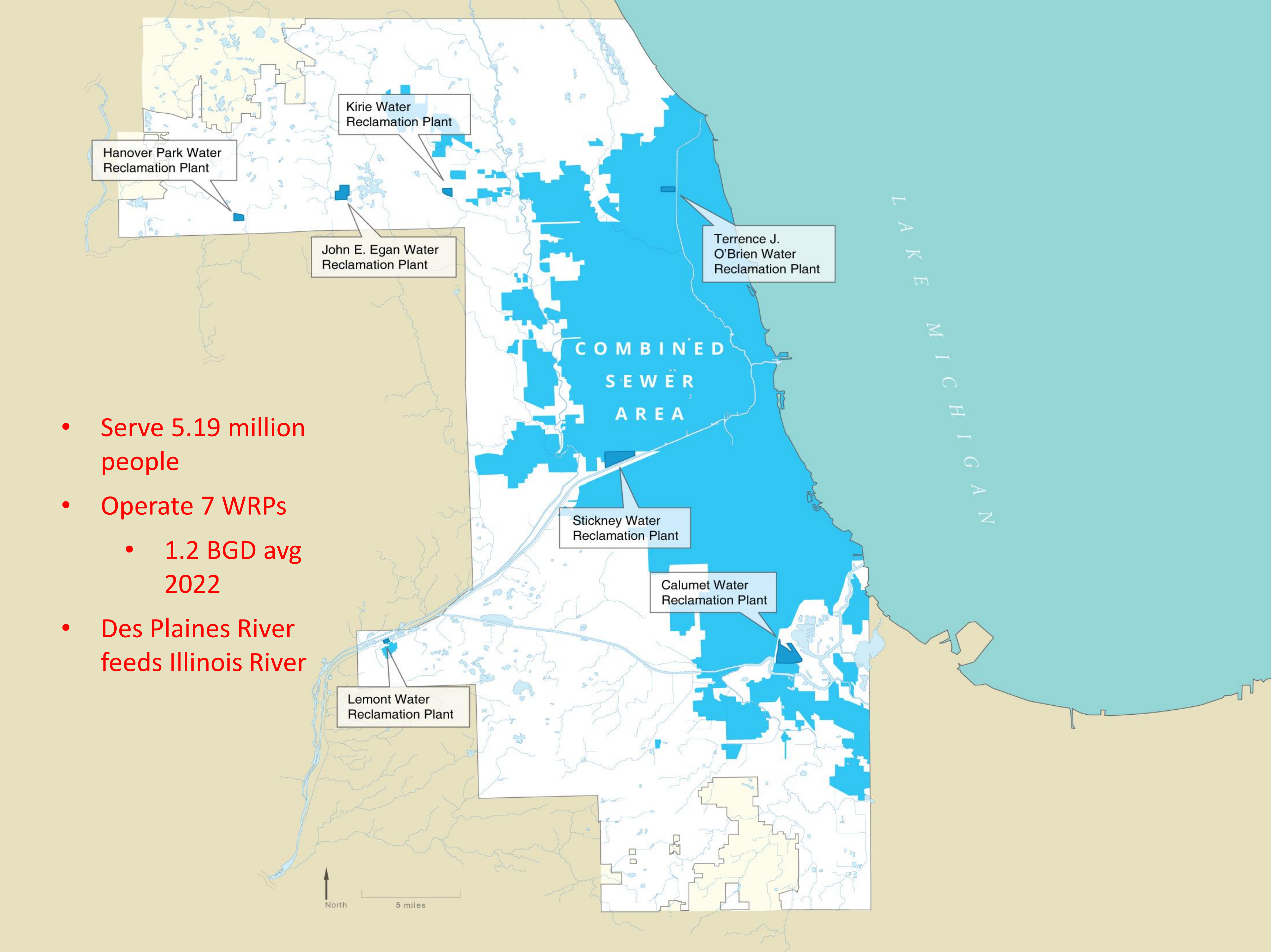
- Algal blooms from eutrophication
  - Release cytotoxins
  - Cause odors
  - Prevent light penetration for other aquatic life
  - Algae dies→consume DO→negatively affect aquatic life

Illinois Nutrient Loads at Baseline and 45 Percent Reduction Goal



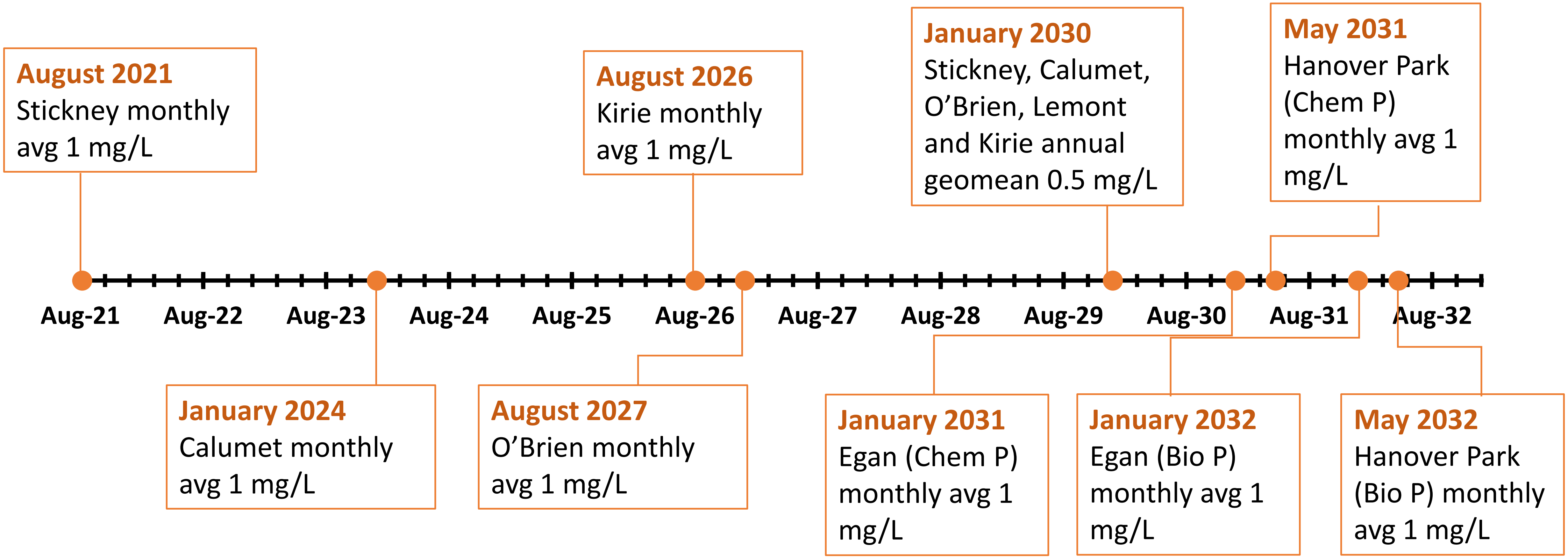
- Baseline 1980-1996
- Illinois River
  - 14.6 million lb/yr
- District plants 2021
  - 5.5 million lb/yr

Source: Illinois Nutrient Loss Reduction Strategy (2014)



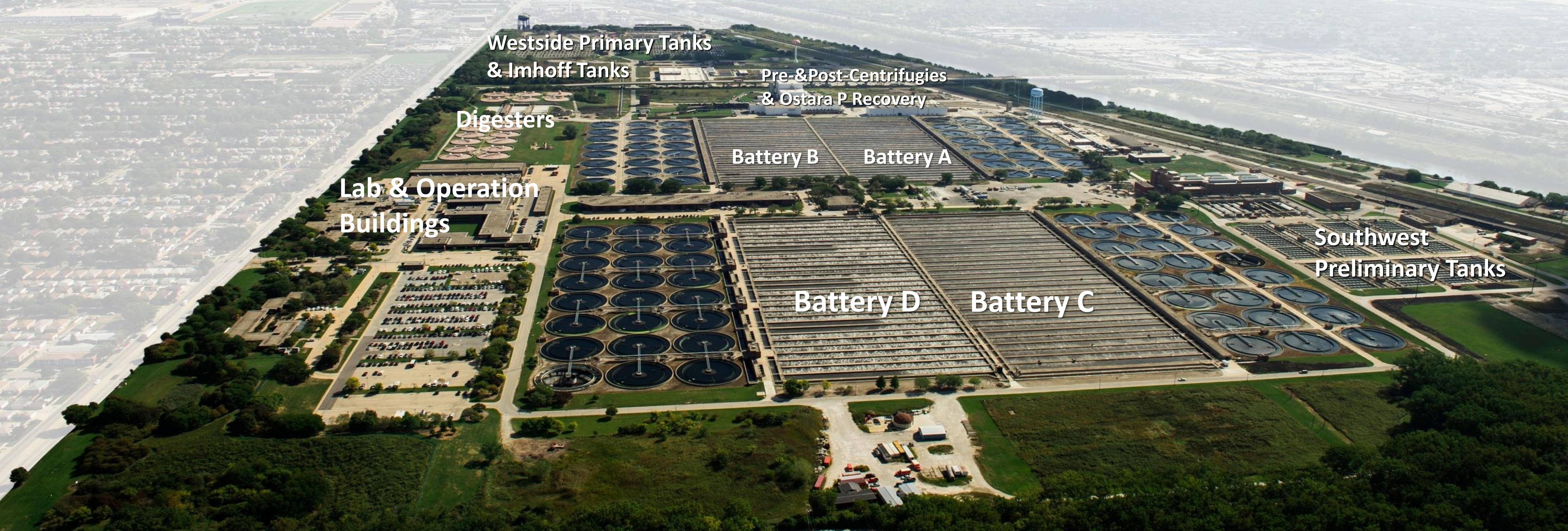
- Serve 5.19 million people
- Operate 7 WRPs
  - 1.2 BGD avg 2022
- Des Plaines River feeds Illinois River

NPDES Permit Schedule

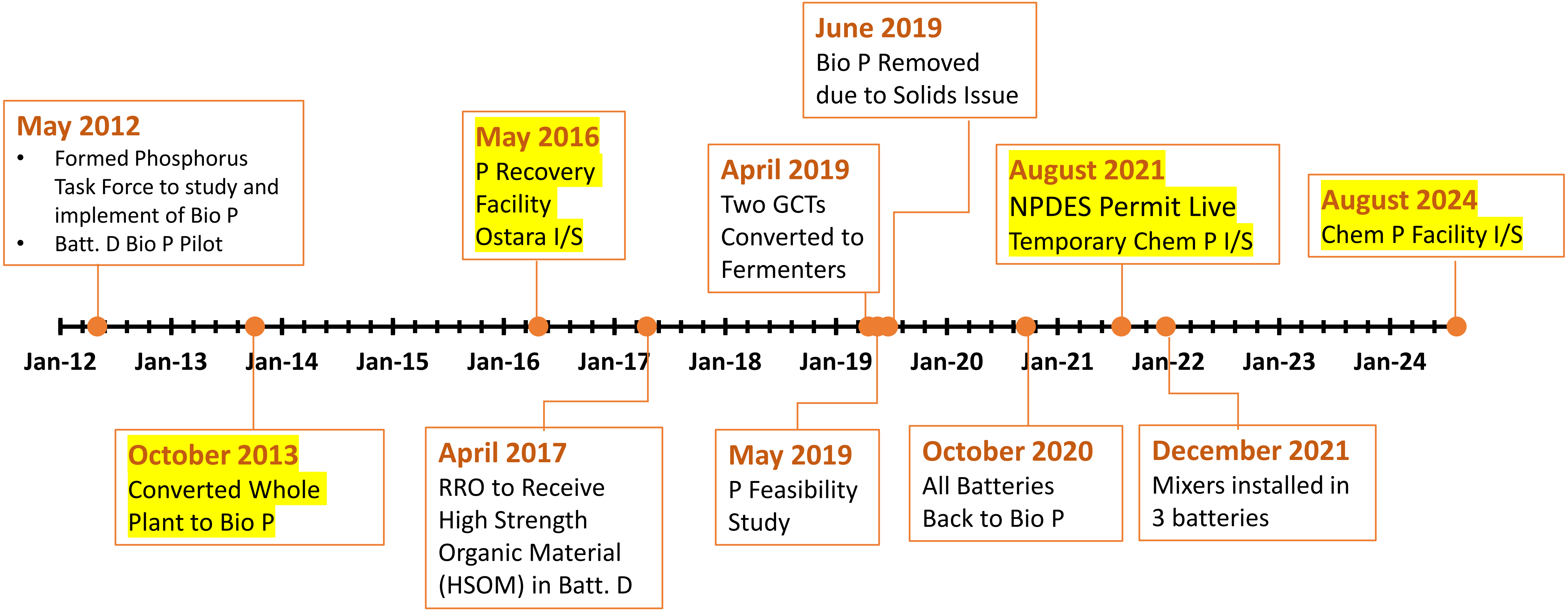


Stickney Water Reclamation Plant

- Serves 2.3 million people
- Flows:
  - Avg. Design Capacity: 1,200 MGD
  - Max Design Capacity: 1,440 MGD
  - 2022 Average: 678 MGD
- 4 aeration batteries
  - 8 tanks/battery
  - 4 passes/tank
  - 24 circular secondary clarifiers/battery
- Anaerobic digesters:
  - 24 Mesophilic, floating cover
- Ostara P recovery facility
  - 3 reactors
  - Each unit 14,000 pounds per day fertilizer capacity



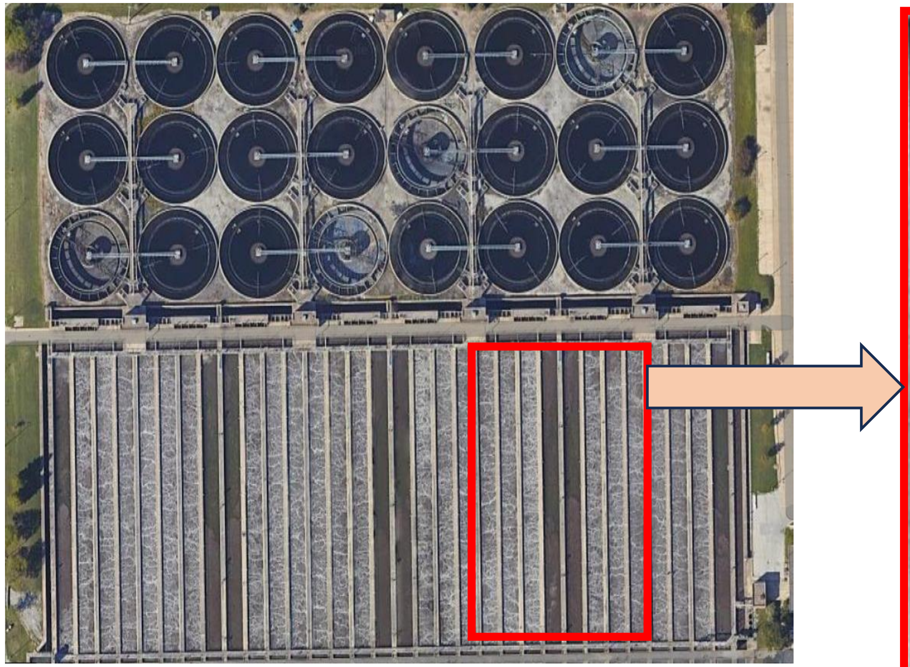
Stickney Phosphorus Removal Timeline

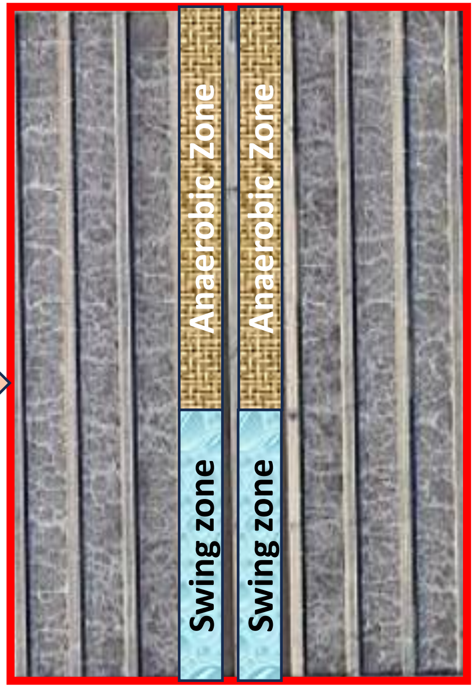


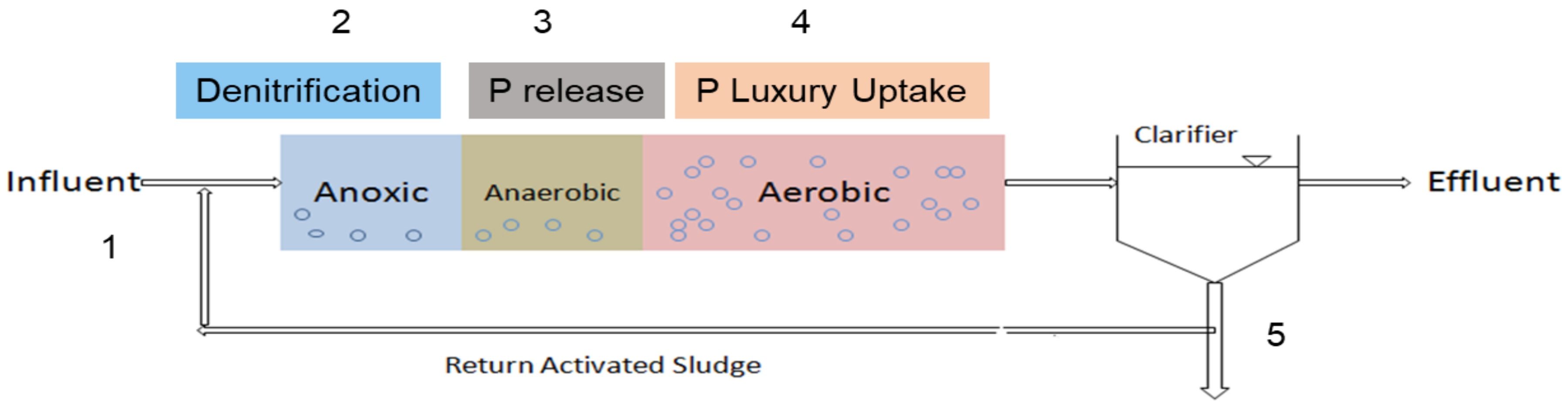
Stickney Mainstream Bio P Configuration (AAnO)

AAnO Process:

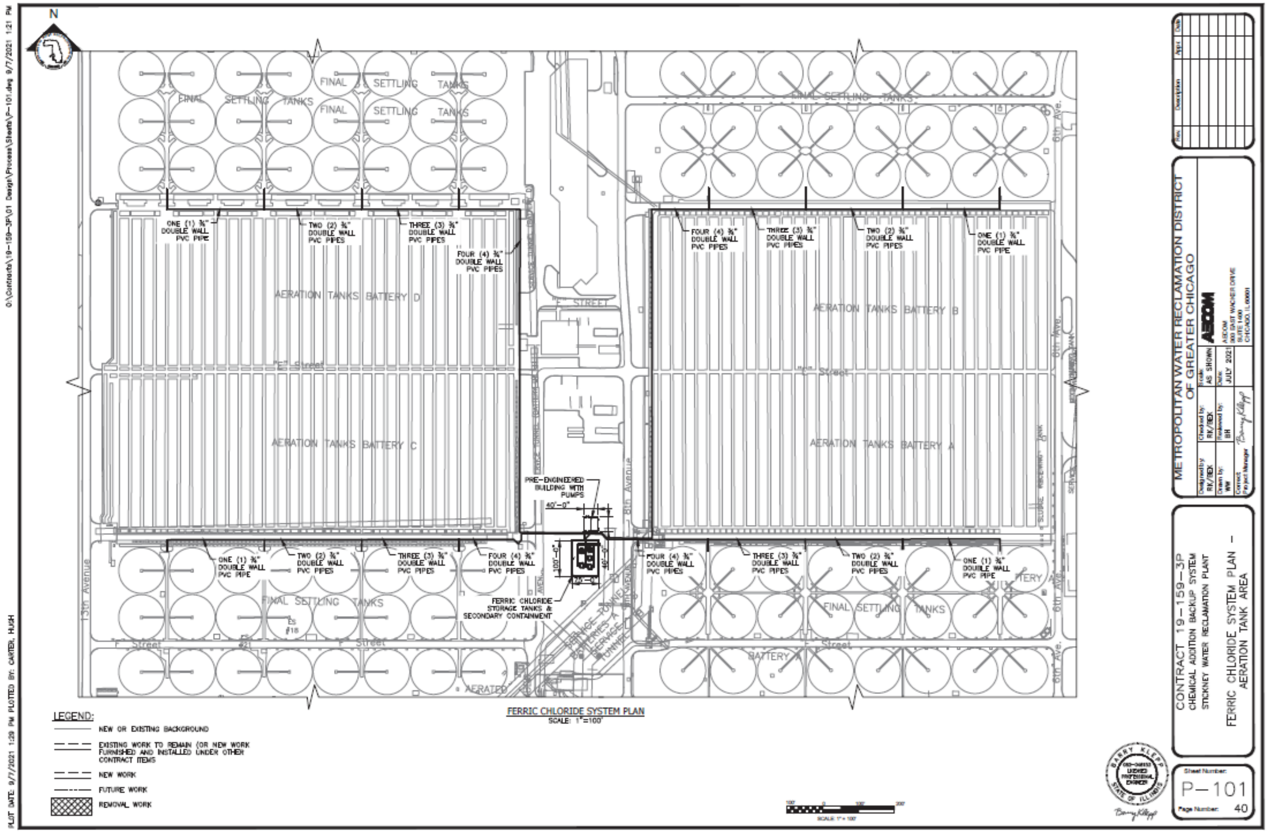
- Anoxic (A) – utilizing RAS, mixing, and influent channels
- Anaerobic (An) – using the first half (Dec – May) to full (Jun – Nov) of Pass 1s
- Aerobic (O) – using the rest of aeration tanks for P uptake and C&N removal







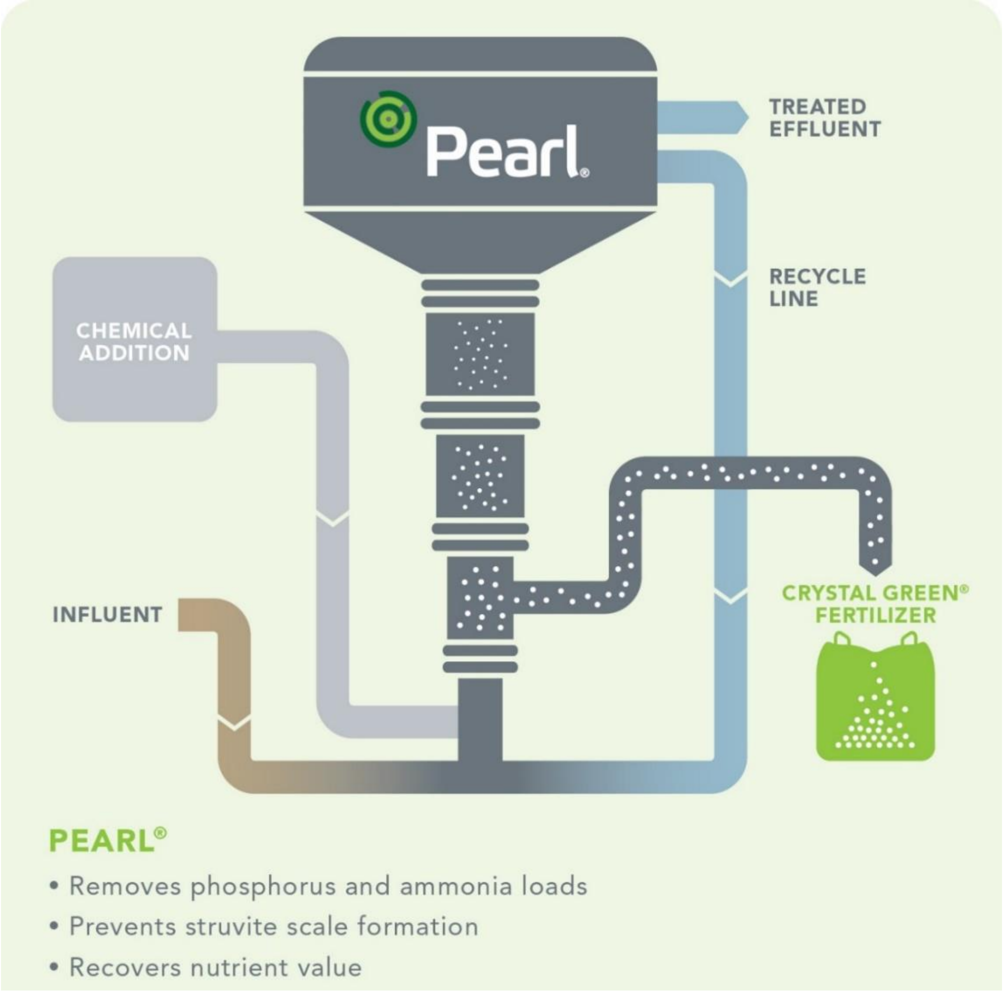
Temporary and Permanent Chemical P Removal Facilities



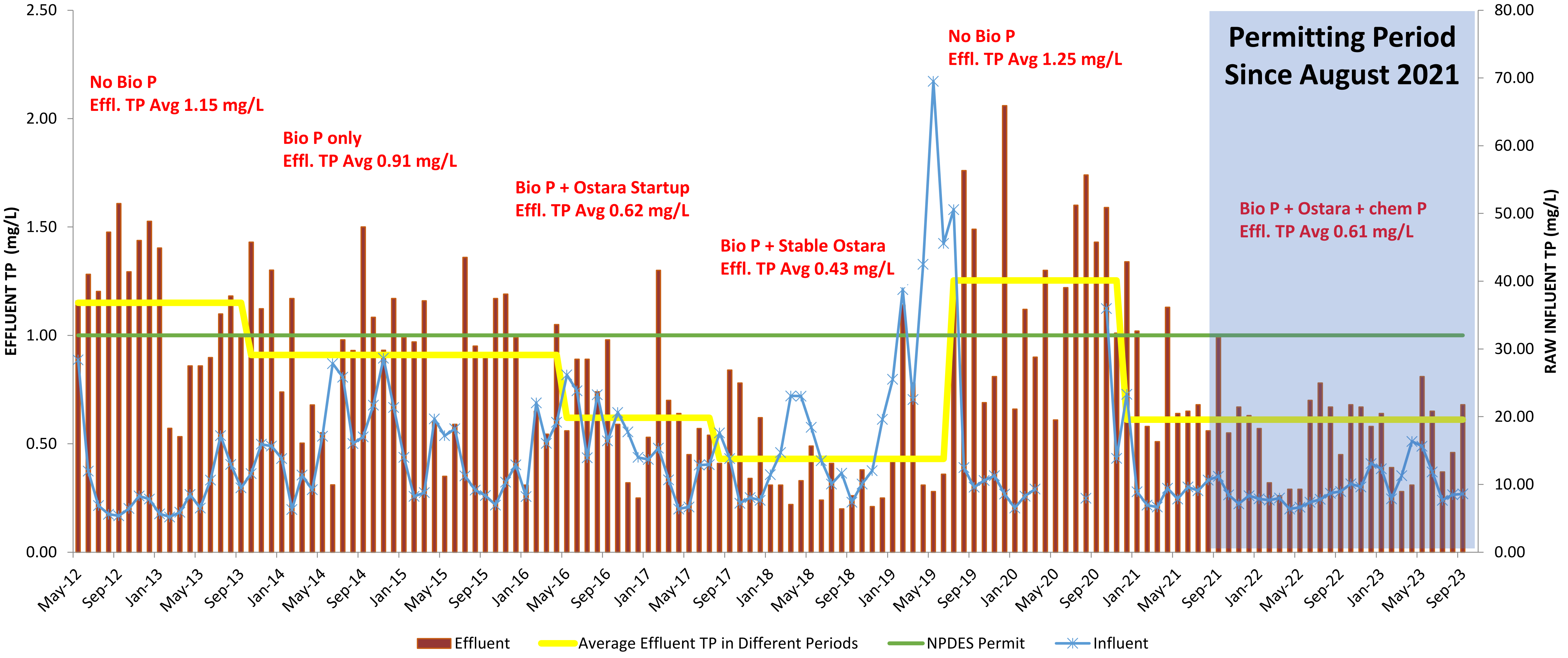
- Dosing starts if outfall ortho P goes above target (0.7 mg/L)➔14 gal $FeCl_3$/(MG-mg/L P)
- Five (5) 16,600 gallons Fiberglass Reinforced Plastic Tanks
- Expected completion in August 2024

Ostara® Post-centrate Treatment

- Fluidized bed reactor
- Crystallization of struvite
  - Inject NaOH to raise pH to 7.7/7.8
  - Inject $MgCl_2$ at a molar ratio of 1.1 to 1 (Mg to P)
- Crystals grow to pellets and then harvested



Current Influent and Effluent Monthly Average TPs at Stickney WRP



Operational Optimizations to Improve Phosphorus Removal

- DO Optimization - Reduce air flow
    - Close air valves in RAS, mixing, and influent channels; mixers in anaerobic zones
    - Flow control in the first 2 passes and DO control in the second 2 passes
- Nitrate optimization - Reduce RAS flow
    - Single lifting airlifts (25% of full capacity)
- Carbon optimization
    - Reduce preliminary tanks I/S during low flow
    - Rotate preliminary tanks and allow some fermentation
    - Receive high strength organic material through RRO Bio P program
- HRT optimization
    - Isolate final tanks to reduce secondary release during low flows
- Recycle stream optimization
    - LASMA recycle equalization when needed
    - Resource recovery of post-centrate

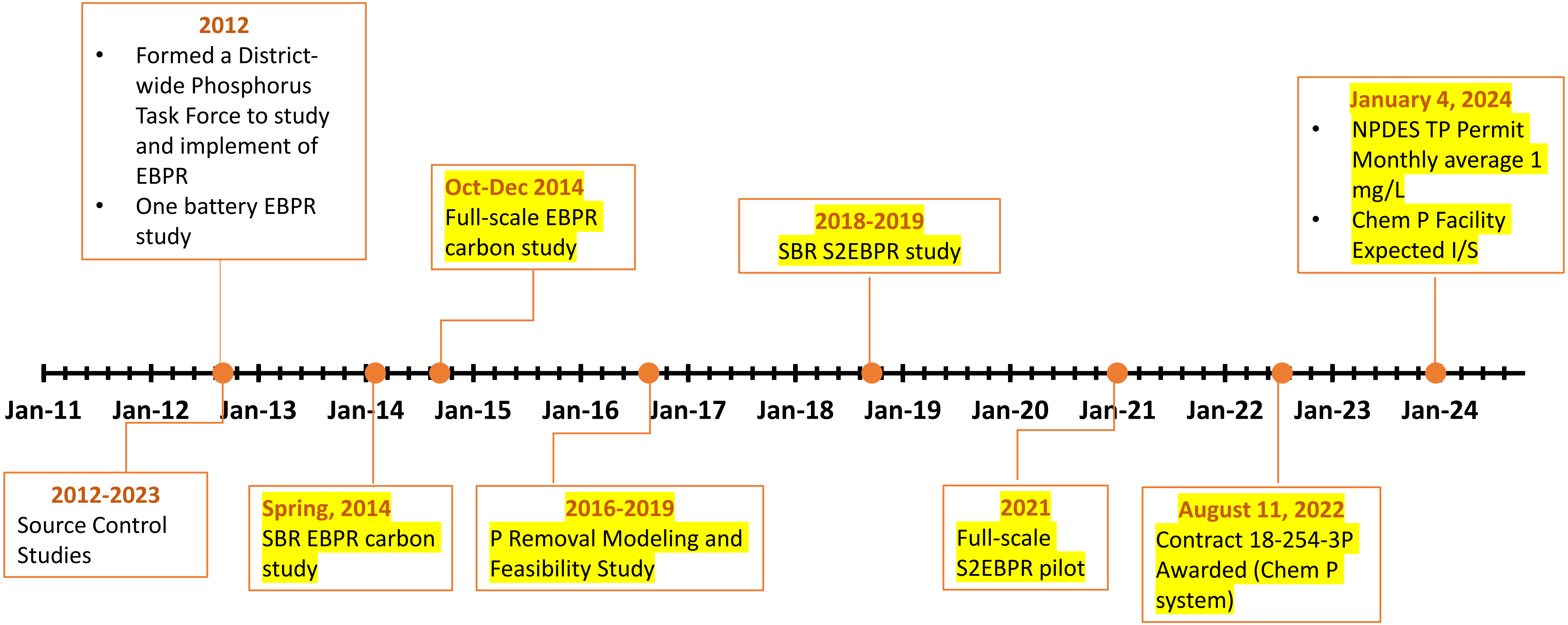
Ongoing Operational Challenges

- The biggest combined sewer Bio P system (320 MGD-1440 MGD in short time)
  - First flush DO sags ➔ NH_3-N and P spikes
  - Low flows, especially in Summer & Fall when influent unfavorable to Bio P ➔secondary release
- Receive solids from 4 other WRPs (O'Brien, Kirie, Egan, and Lemont)
  - Additional recycle nutrient loads
  - Ostara® not staying online consistently can cause unstable Bio P performance
- Biology takes time to acclimate to the operational changes
- Winter solids - balancing between NH3-N, SS, and TP permits
  - Reduced nitrification capacity ➔higher MLSS➔more prone to SS washout➔particulate P
  - When we go from 320 MGD to 1,440 MGD➔poorer settling observed
- New processes could require new operational strategies
  - West Side primary settling tanks
  - McCook Phase 2 Reservoir (6.5 MG) online in 2029

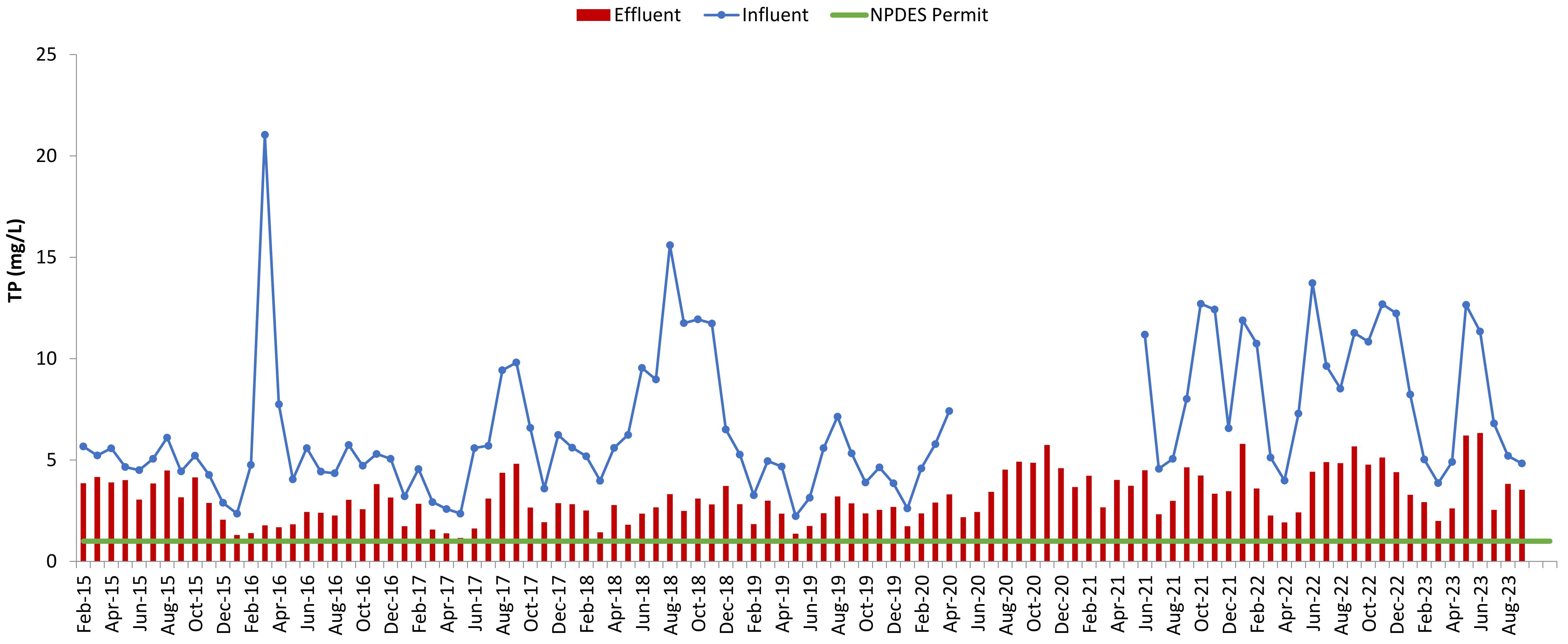
Calumet Water Reclamation Plant

- Serves over 1 million people
- Flows:
  - Avg Design Capacity: 354 MGD
  - Max Design Capacity: 430 MGD
  - 2022 Average: 236 MGD
- Full nitrification
- 5 aeration batteries
  - 48 aeration tanks
  - Conventional one or two passes/tank
  - 52 circular secondary clarifiers
- Anaerobic Digester
  - 12 Mesophilic, floating cover

Calumet Phosphorus Removal Timeline

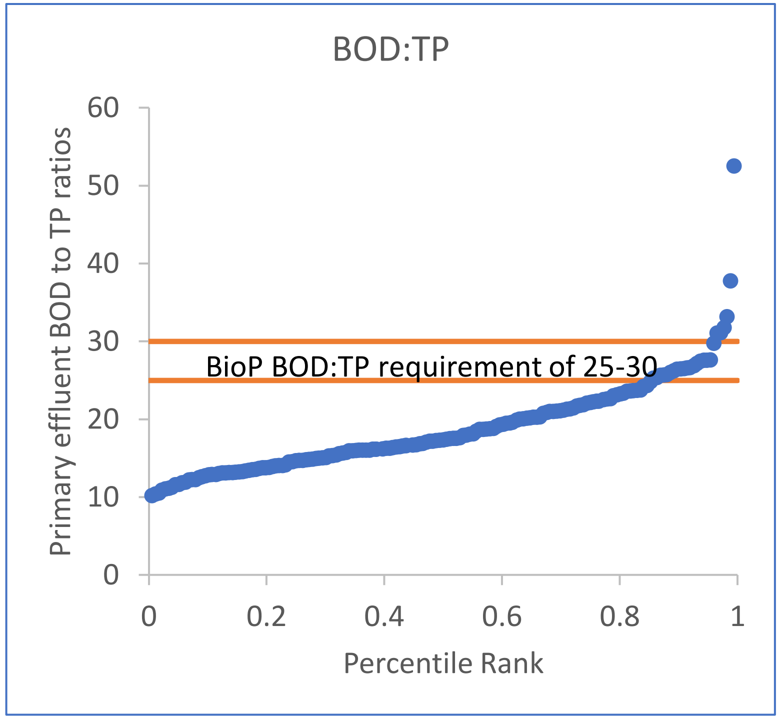


Current Influent and Effluent Monthly Average TPs at Calumet WRP



2012-2020 SBR and Pilot Testing Outcomes

- Biological P removal?
  - Low C/P ratios of influent
  - High industrial P loading that causes variable influent P and spikes

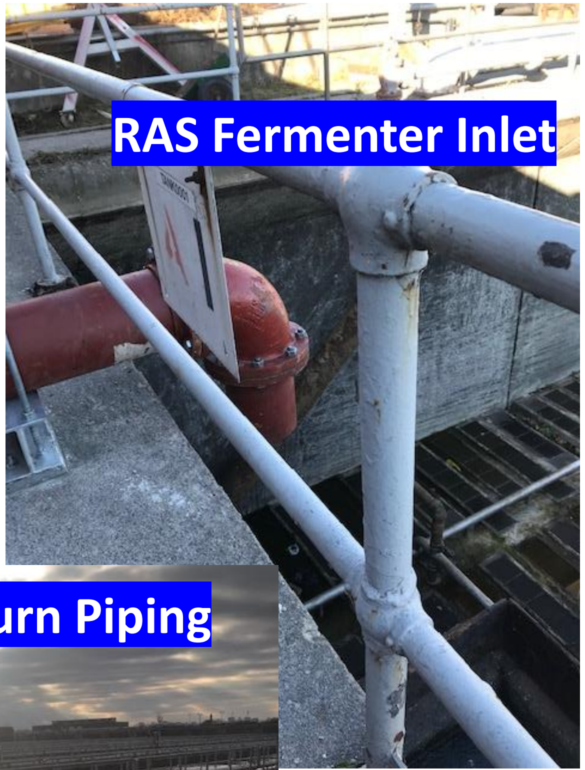


- 2012: Full-scale EBPR pilots in Batteries A and E1 failed due to low C/P
- 2014: SBR EBPR pilot worked with carbon dosing
- 2014: Full-scale EBPR pilot in Battery A worked with carbon dosing but not enough to handle high P peaks
- 2018-2019: SBR S2EBPR pilot worked well with 25% carbon needed for conventional EBPR
  - Utilizes sidestream RAS fermentation to select for PAOs that can use more complex carbon and to convert these complex carbon to usable form for normal PAOs➔ diversifies communities and makes process more stable

2021 Calumet Battery A S2EBPR Pilot Pictures


RAS Fermenter w/ Mixers

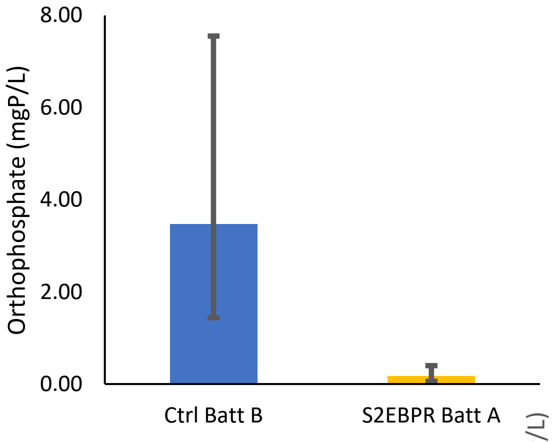

External Carbon Dosing Pumps


RAS Fermenter Inlet


Fermented RAS Return Piping

Findings – S2EBPR Pilot Achievements

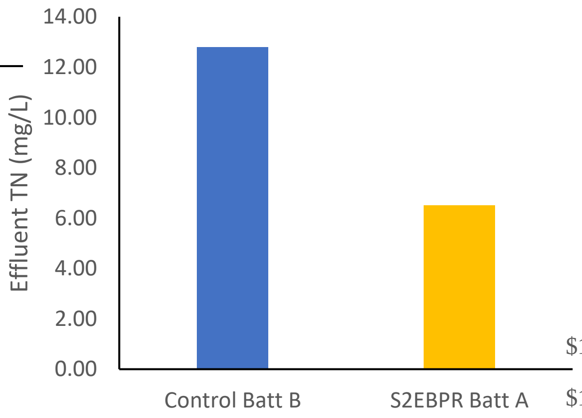
- Low effluent P



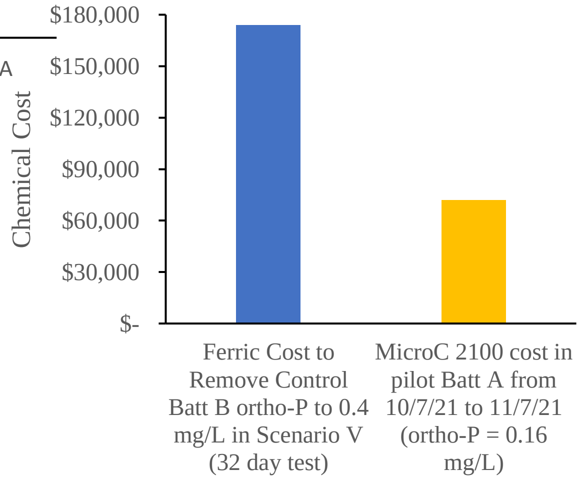
✓ More environmentally friendly

✓ More economical in chemical

- Lower effluent TN



- Lower chemical cost



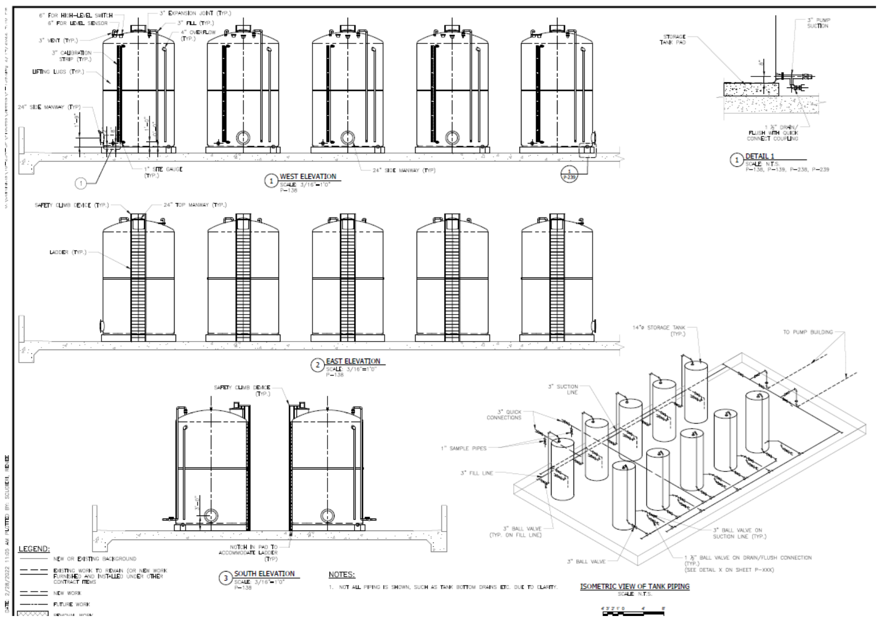
Which Direction to P removal Should We Take?

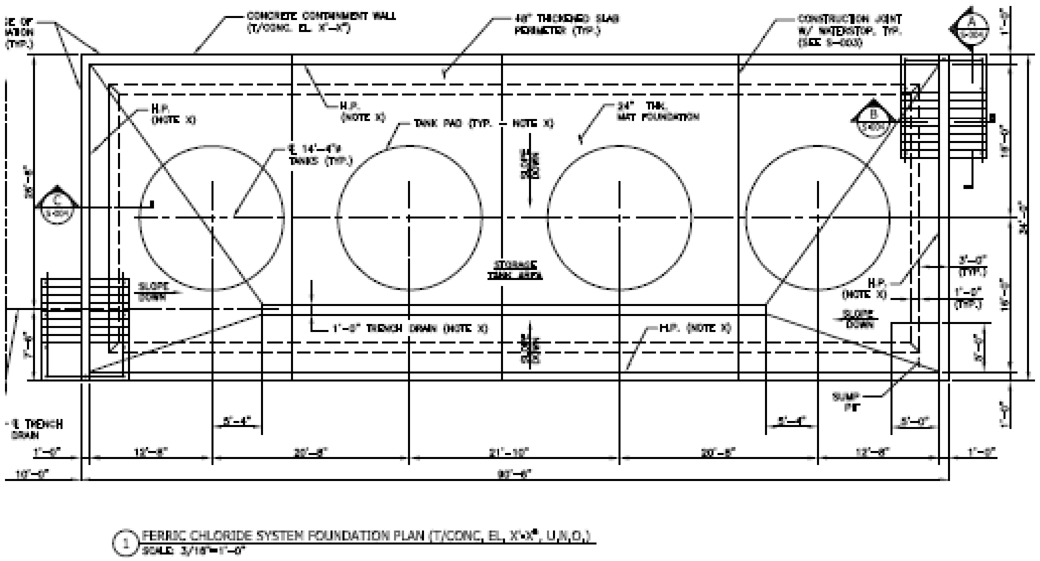
- Chemical P removal suggested by the Feasibility Study but recommended further look into S2EBPR
- Engineering Evaluation being performed on various alternatives
  - CAPEX, O&M, environmental benefits, etc.

Pros and Cons of S2EBPR vs Chem P Options

Chem P	S2EBPR
Pros • Reliable • Effective • Negligible toxicity issues • Reduce struvite formation • Reduce scum in secondary treatment • Reduce sulfides and odors in anaerobically digested sludge • Fixed P that not released in digester	Pros • Reliable with consistent and sufficient carbon addition • Efficient • Increased efficiency of carbon utilization • Less chemical costs • Resource recovery as P fertilizer • Lower GHG emission
Cons • High ongoing chemical costs • Alkalinity depletion and reduced pH which can negatively affect nitrification • Storage requirements due to its corrosive character • Increased mixed liquor suspended solids • Increased sludge production • Increase in total dissolved solids • P cannot be recovered for resource recovery	Cons • High capital costs • Reduce nitrification capacity • Struvite formation • Affected by toxins in influent

Permanent Chem P Facility

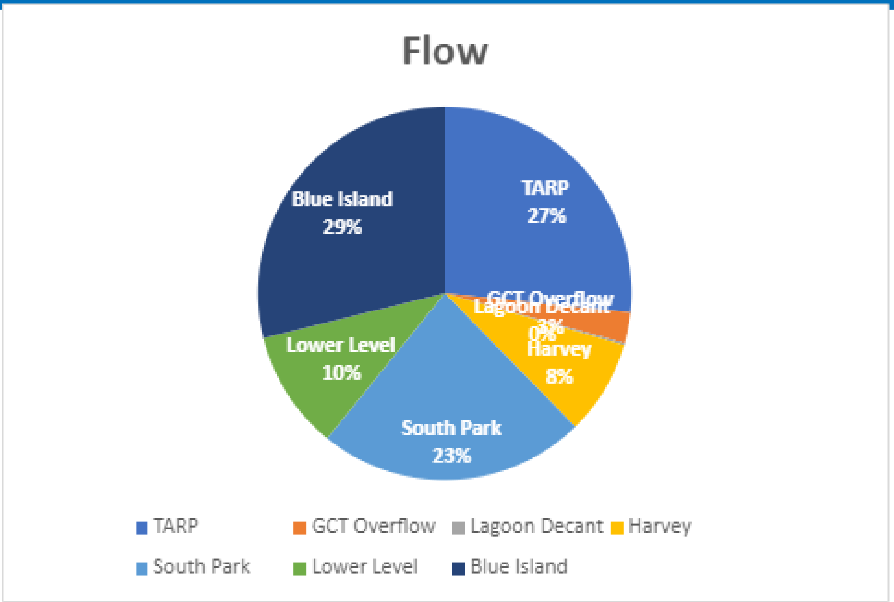


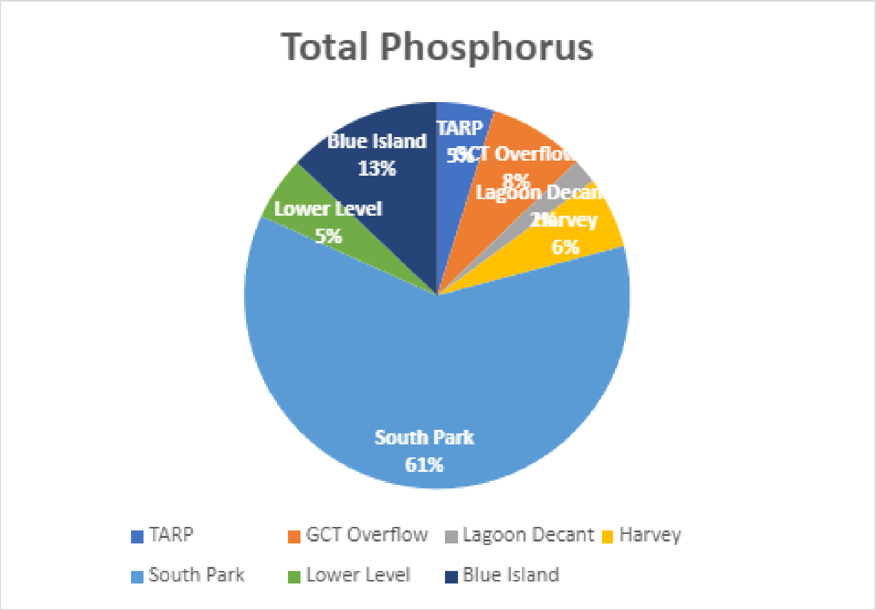


Locations	Volume per Tank (gal)	Qnty. (ea)	Diameter (ft)	Height (ft)	Storage Time for Median P Loads (days)
Primary Tanks	23,000	8	14	21	21
Bat. A/B/C	22,000	4	14	20	29
Bat. E1/E2	22,000	3	14	20	29

Permanent Chem P Facility

Source Investigation of High Influent P



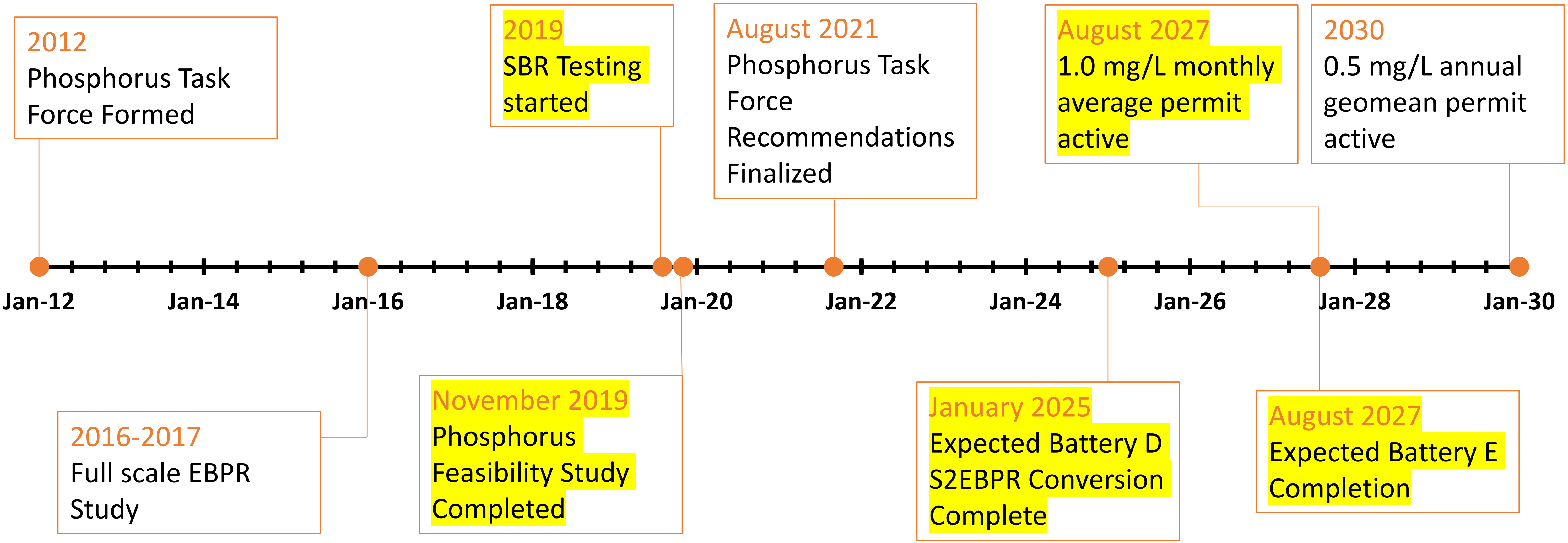


- Conducted a special sampling of the interceptor sewers and internal plant recycles to identify major sources of phosphorus.
- The South Park Interceptor contains a disproportionately large phosphorus load.
- Working with industries to reduce their phosphorus discharge.
- A user or surcharge is being considered by IWD at this time.

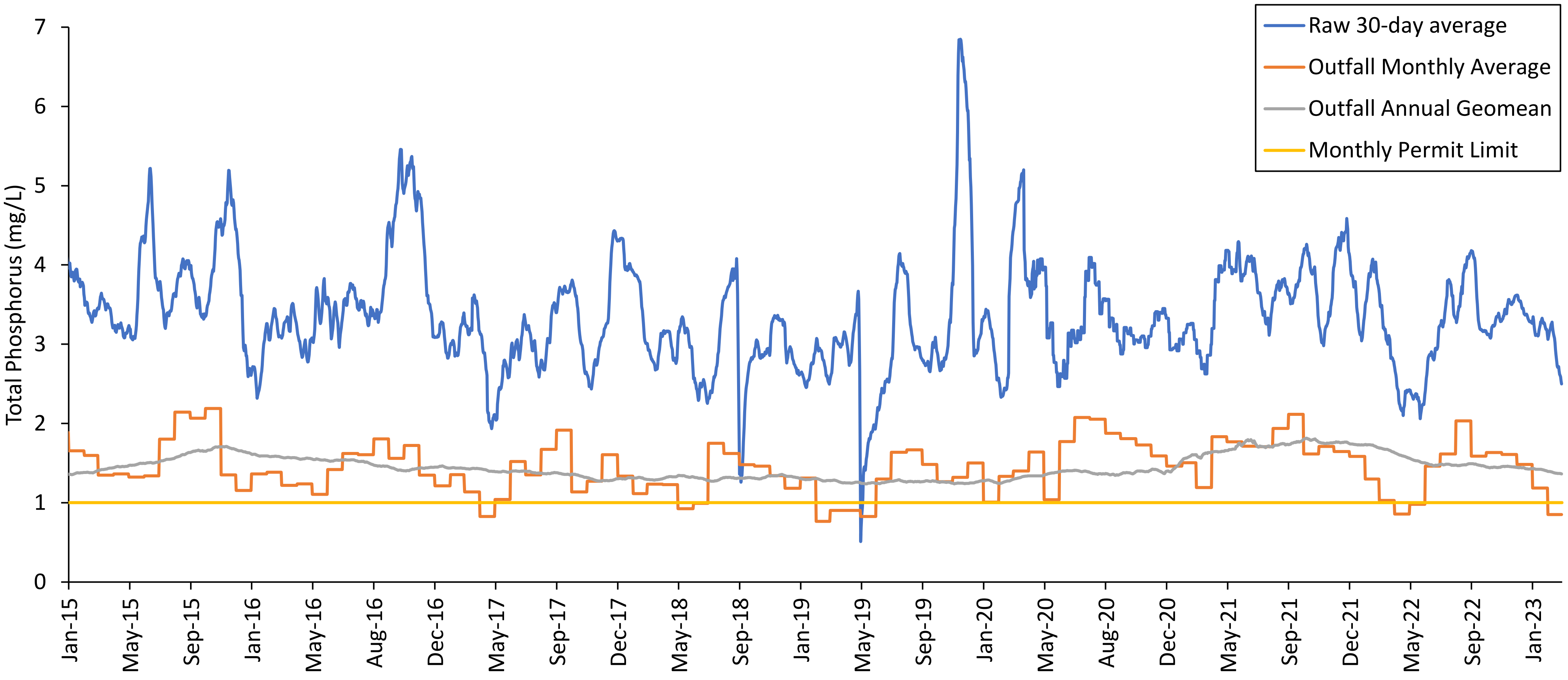
Terrence J. O’Brien Water Reclamation Plant

- Serves 1.3 million people
- Flows:
  - Avg. Design Capacity: 333 MGD
  - Max Design Capacity: 450 MGD
  - 2022 Average: 208 MGD
- 4 aeration batteries
  - Batteries A, B, and C: 12 tanks/battery – single pass
  - Battery D: 8 tanks – two-pass
  - 64 circular and converted square secondary clarifiers

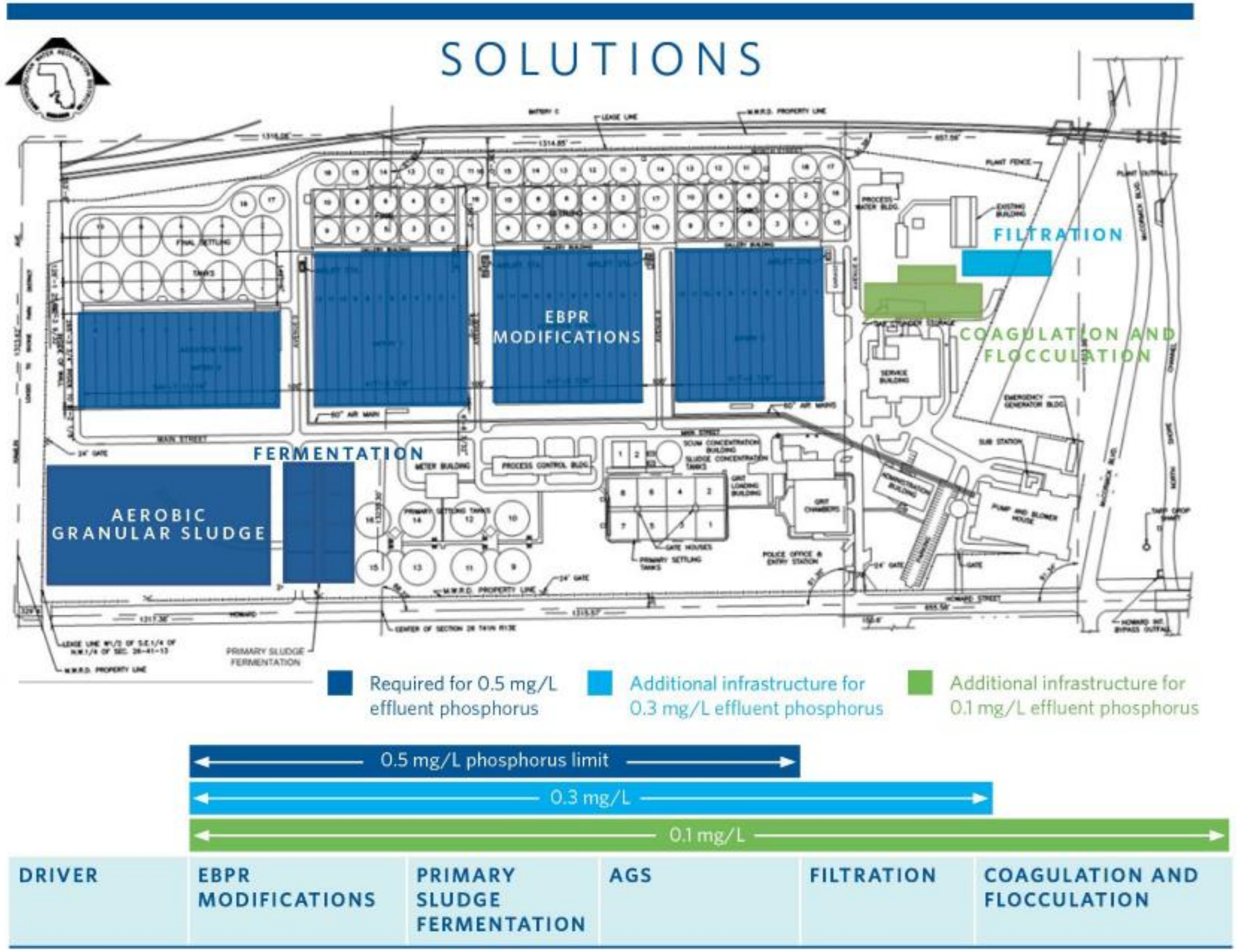
O’Brien WRP Phosphorus Removal Timeline



Current Outfall Monthly Average TPs at O'Brien WRP

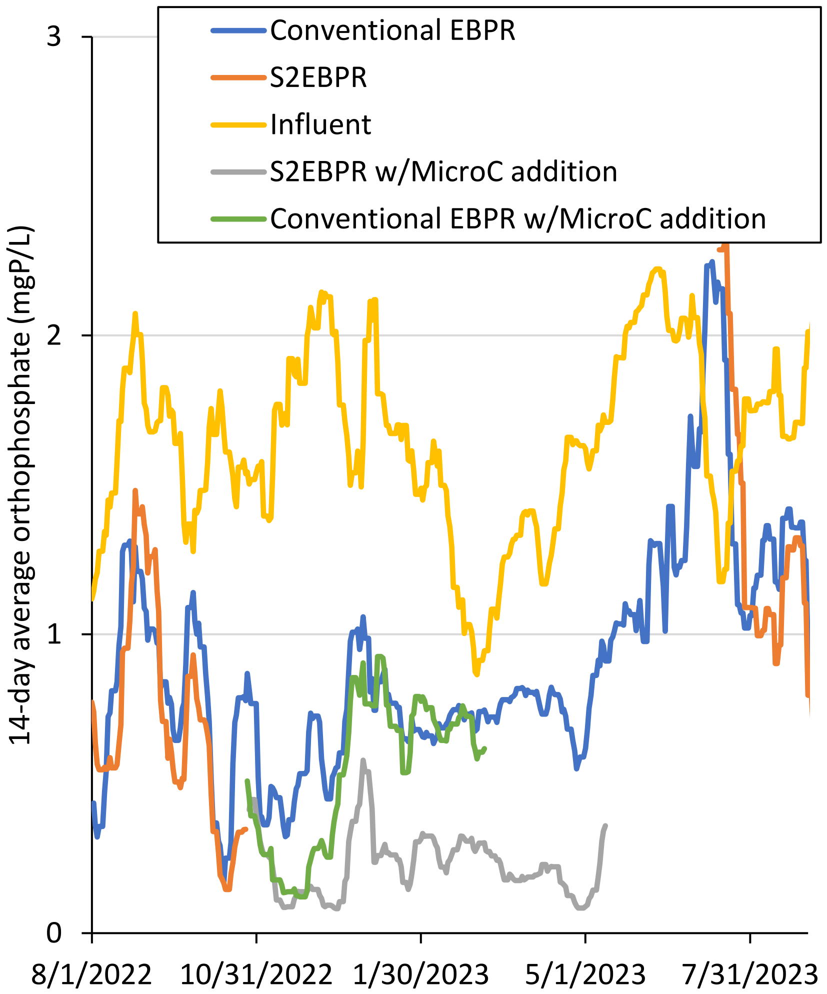


Phosphorus Removal Feasibility Study, 2019



- Converting to bio-P removes too much aeration capacity so needs more treatment capacity.
- Supplemental carbon is needed to meet the 1.0 mg/L monthly permit limit some of the time.

Pilot Sequencing Batch Reactors 2022-2023



- In agreement with the B&V report, bio-P met 1 mg/L most of the time, but not all the time
- S2EBPR performed comparably to conventional EBPR, maybe slightly better
- Supplemental carbon with S2EBPR worked very well

O’Brien WRP Capital Improvements Underway

- Chemical Phosphorus Removal Polishing System
  - Designed for chem-P treatment of Batteries A, B, and C, and polishing for Battery D
  - Chem-P will be scaled back with the completion of more bio-P capacity
- Battery D conversion to S2EBPR
  - Selector zones added to the beginning of each aeration tank and one tank (of eight) converted to a RAS fermenter
  - Construction July 2023 to January 2025
  - This will be the full-scale demonstration before converting Batteries A, B, and C to S2EBPR
- Battery E
  - Full greenfield S2EBPR battery
  - 80 MGD average flow, 125 MGD max flow
  - Expected construction August 2024 to August 2027

Future Challenges

- Learn to operate S2EBPR in Batteries D and E
- Odor problems from RAS fermentation
- Potential struvite problems in the sludge line to Stickney
- Converting Batteries A, B, and C to EBPR or S2EBPR?
  - Concrete repair; nearly 100 years old
  - Improve aeration efficiency
  - Flow distribution improvements
  - Add airlifts to final tanks (RAS return is currently by gravity)

Other nutrient removal approaches under investigation

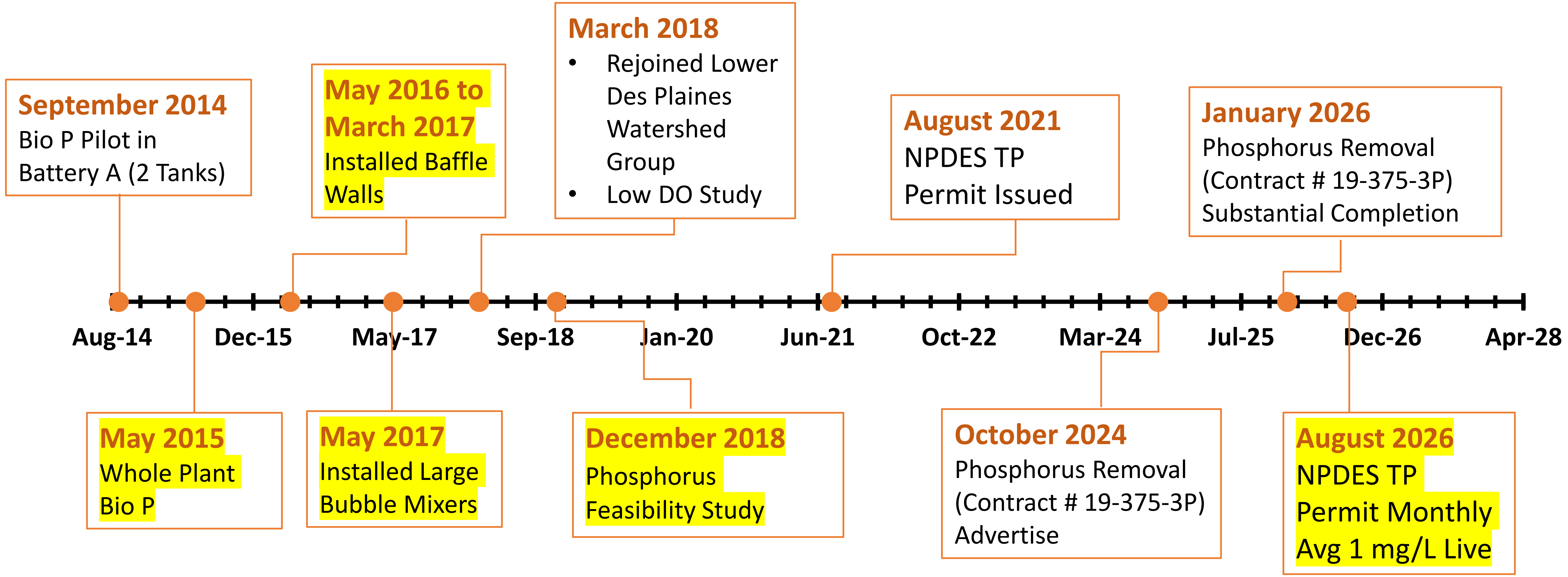
(from left to right)

- Rotating Algal Biofilm Reactor
- Artificial Floating Islands
- Duckweed

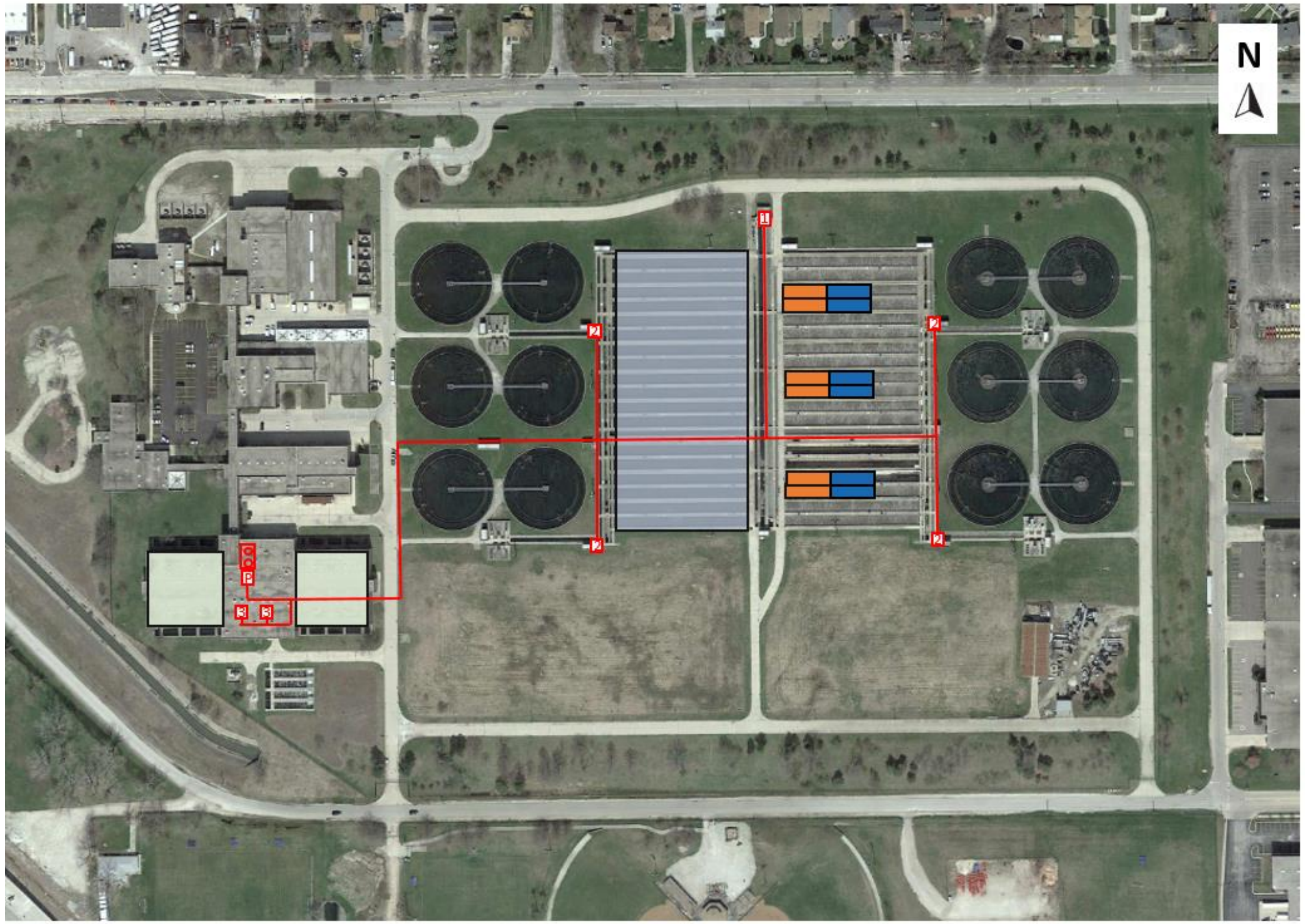
James C. Kirie Water Reclamation Plant

- Serves 264,000 people
- Flows:
  - Avg Design Capacity: 52 MGD
  - Max Design Capacity: 110 MGD
  - 2022 Average: 32 MGD
- 2 aeration batteries
  - 6 tanks/battery
  - 3 passes/tank
  - 6 circular secondary clarifiers/battery

James C. Kirie Phosphorus Removal Timeline



Phosphorus Feasibility Study Recommendations

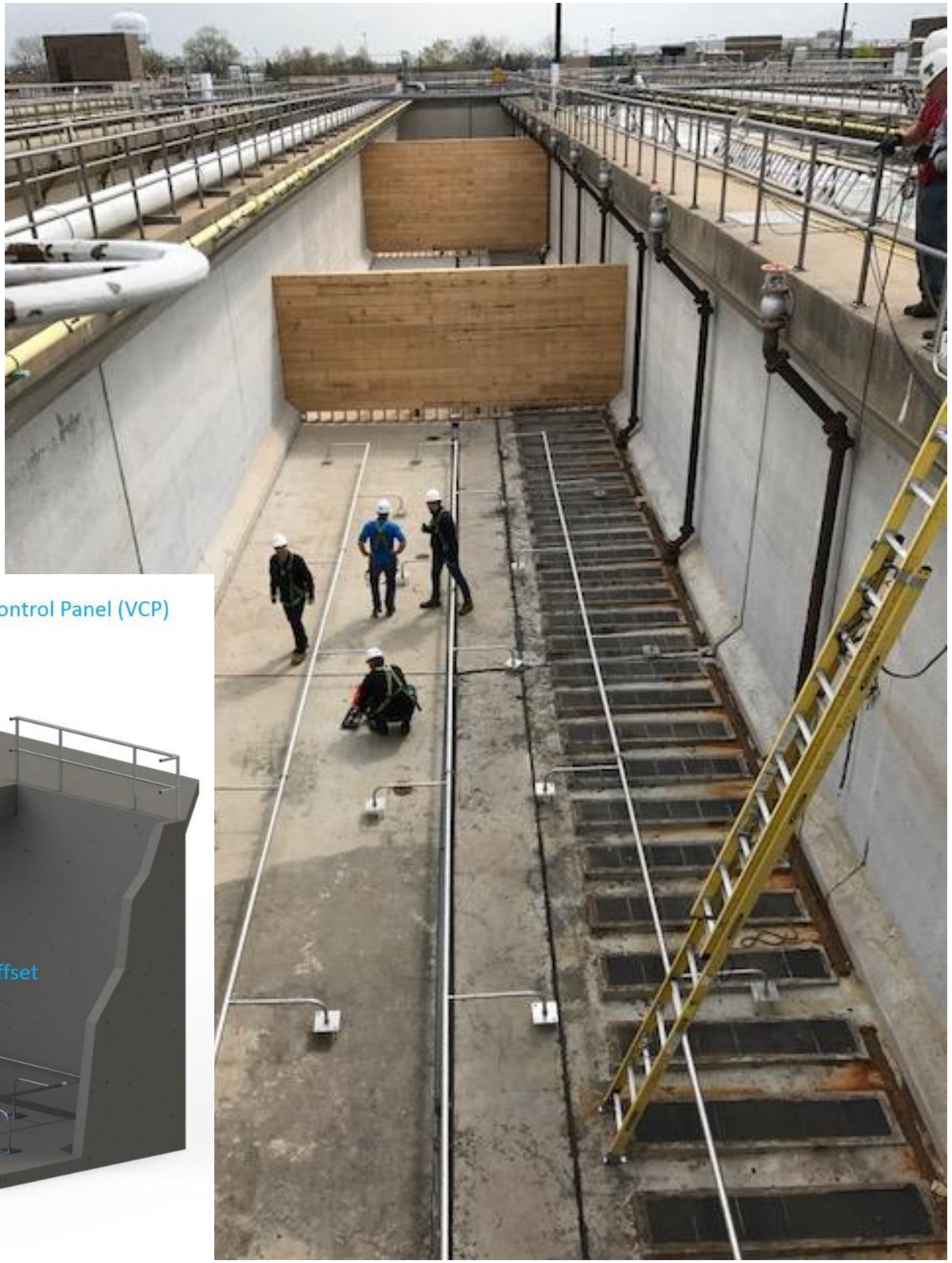


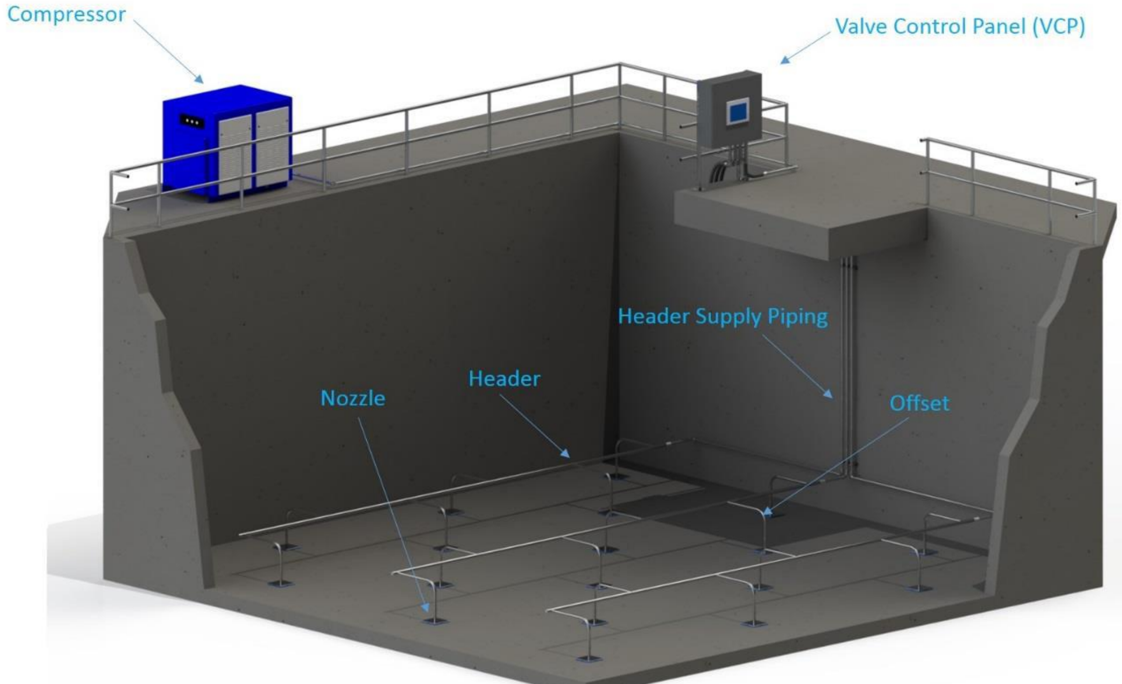
Scenario To Meet Tier 1 and Tier 2 Effluent TP Limits at Current Flows at Kirie WRP

Legend:
- Anaerobic Zone
- Swing Zone (Operated as Anaerobic)
- Aeration Capacity Not In Use
- Dual Media Filters Not In Use (Anthracite and Sand)
- Chemical Feed Line
- Ferric Chloride Storage Tanks
- 1 Raw Sewage Junction Box
- 2 Aeration Tank Discharge
- 3 Feed to Filters
- P Chemical Storage Room

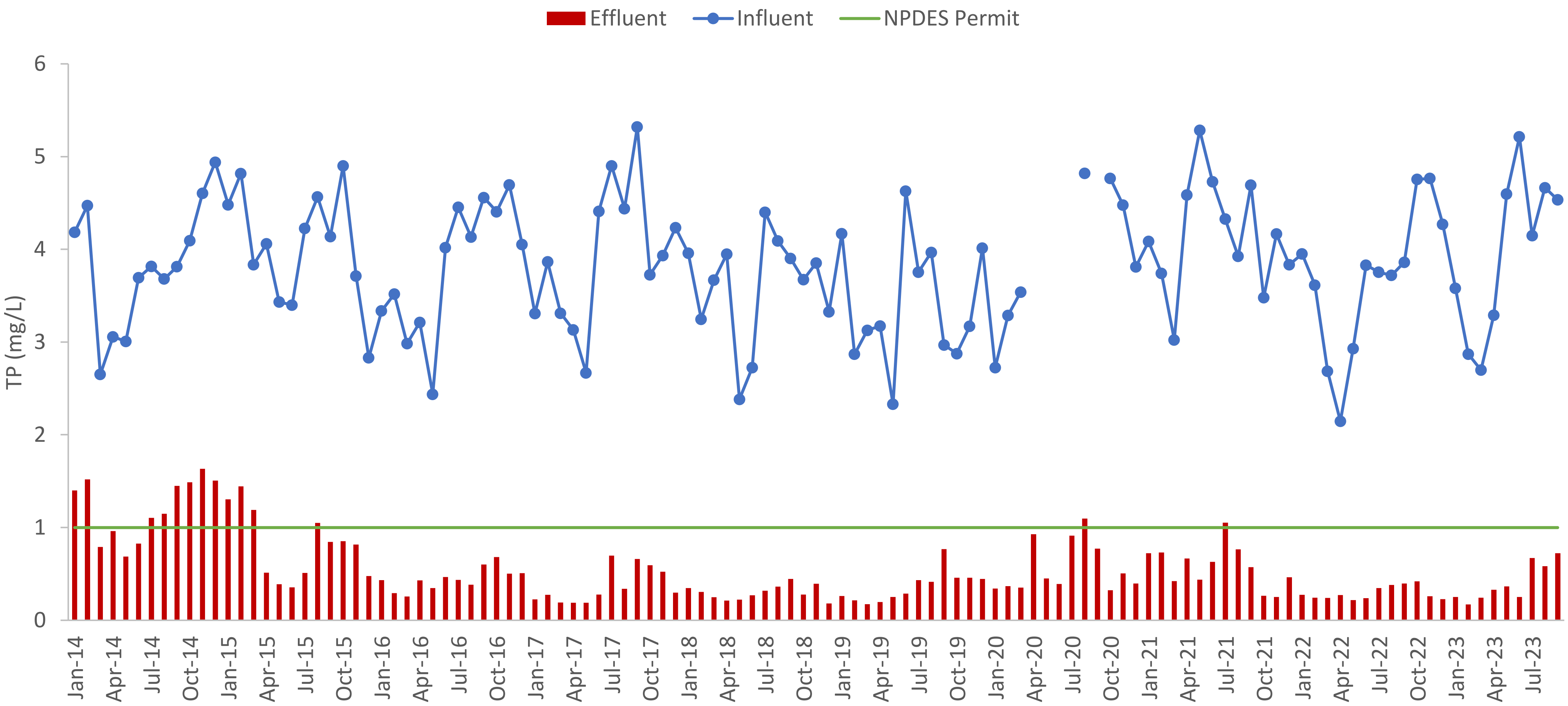
- Existing A/O process with large bubble mixers, baffles, and 2/3rd volume of the first pass for anaerobic zone for compliance with 1 mg/L and 0.5 mg/L effluent TP limits at current flows.
- Chem P was recommended for all effluent TP limits in order to supplement Bio P and provide protection against TP excursions.

Kirie WRP EBPR Conversion





Current Influent and Effluent Monthly Average TPs at James C. Kirie WRP



Challenges

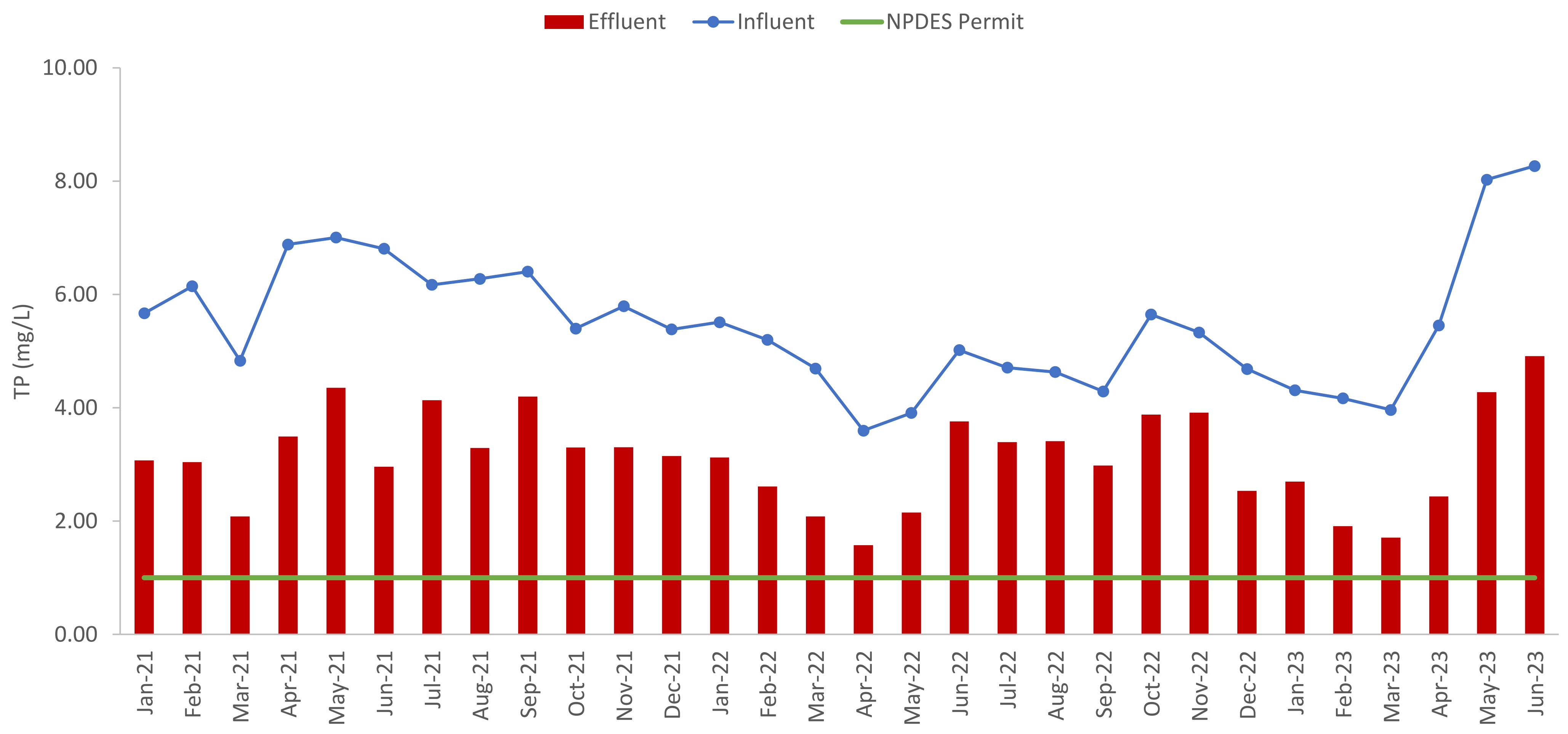
- Lack VFA/rbCOD sometimes
  - Seasonal deteriorated P removal performance in late Summer/early Fall
- No primary clarifiers
  - Annual RAS channel maintenance
- Large influent flow variation
  - Plant shutdown during night shift in low flows
- Only half of the plant secondary treatment is available – nitrification completed near the end of the aeration tank
- Limitation to increase MLSS due to the RAS channel capacity and risk of solids overload to the secondary clarifiers

John E. Egan Water Reclamation Plant

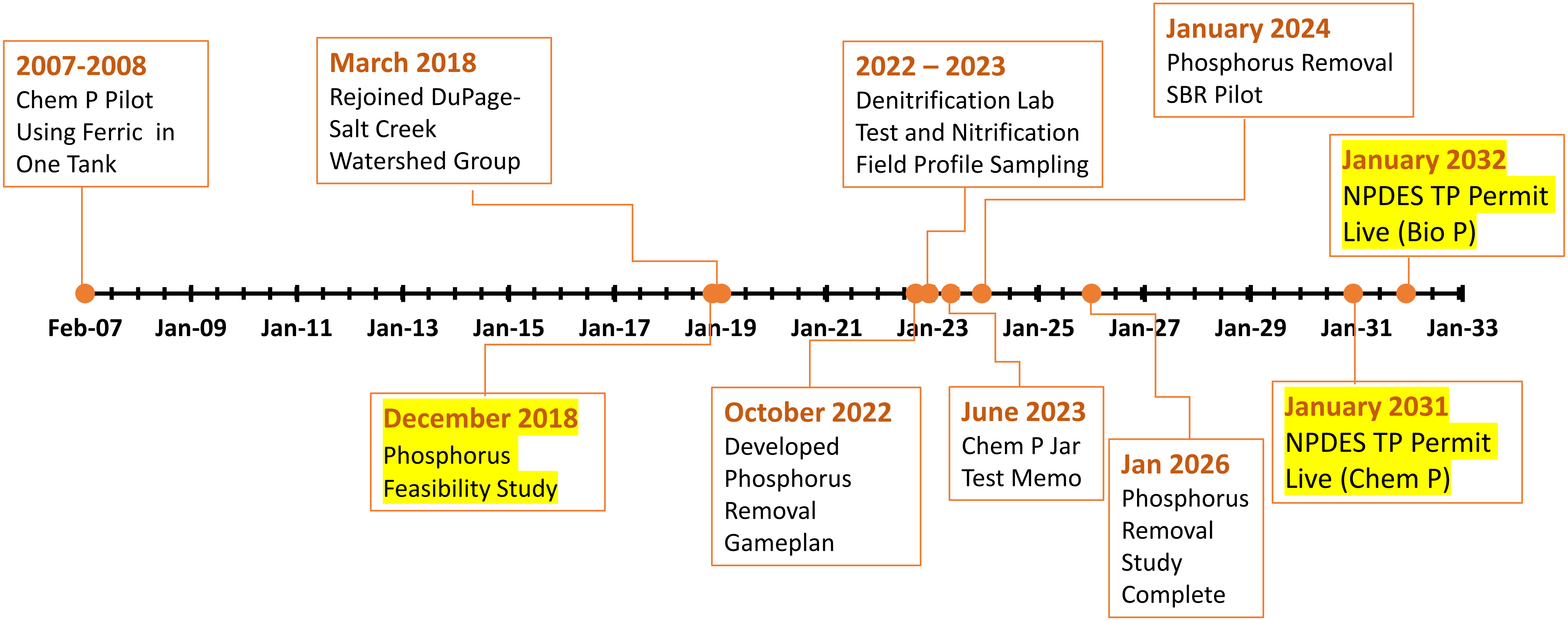
- Serves 160,735 people
- Flows:
  - Avg Design Capacity: 30 MGD
  - Max Design Capacity: 50 MGD
  - 2022 Average: 23 MGD
- 2 aeration batteries
  - 2 tanks/battery
  - 3 passes/tank
  - 4 circular secondary clarifiers/battery

- Anaerobic digesters:
  - 2 Mesophilic, fixed cover
  - 2 Mesophilic, Dystor

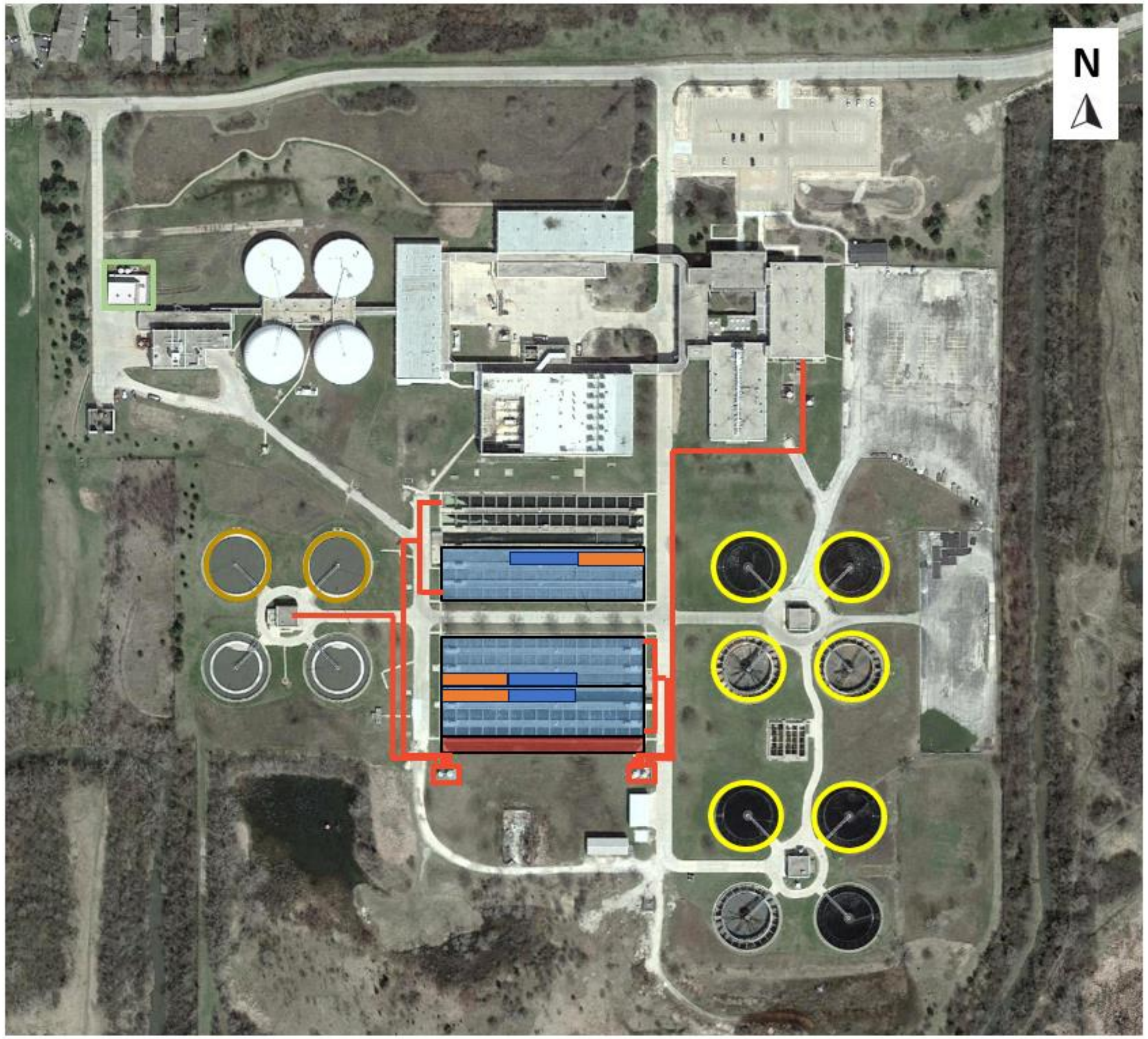
Current Influent and Effluent Monthly Average TPs at John E. Egan WRP



John E. Egan Phosphorus Removal Timeline



Phosphorus Feasibility Study Recommendations



Scenario To Meet Tier 1 and Tier 2 Effluent TP Limits at Current Flows at Egan WRP

Legend:

- Primary Clarifiers Online
- Aeration Basins Online
- Secondary Clarifiers Online
- Phosphorus Sequestration
- Anaerobic Zone
- Swing Zone (Operated as Anaerobic)
- RAS Denitrification Basin
- Chem P System

- A modified A/O process with RAS denitrification tank is recommended to provide Bio P performance.
- P sequestration is recommended at the Egan WRP. It is estimated that approximately 45 percent of the total influent P load is from return flows.
- Installation of Chem P system

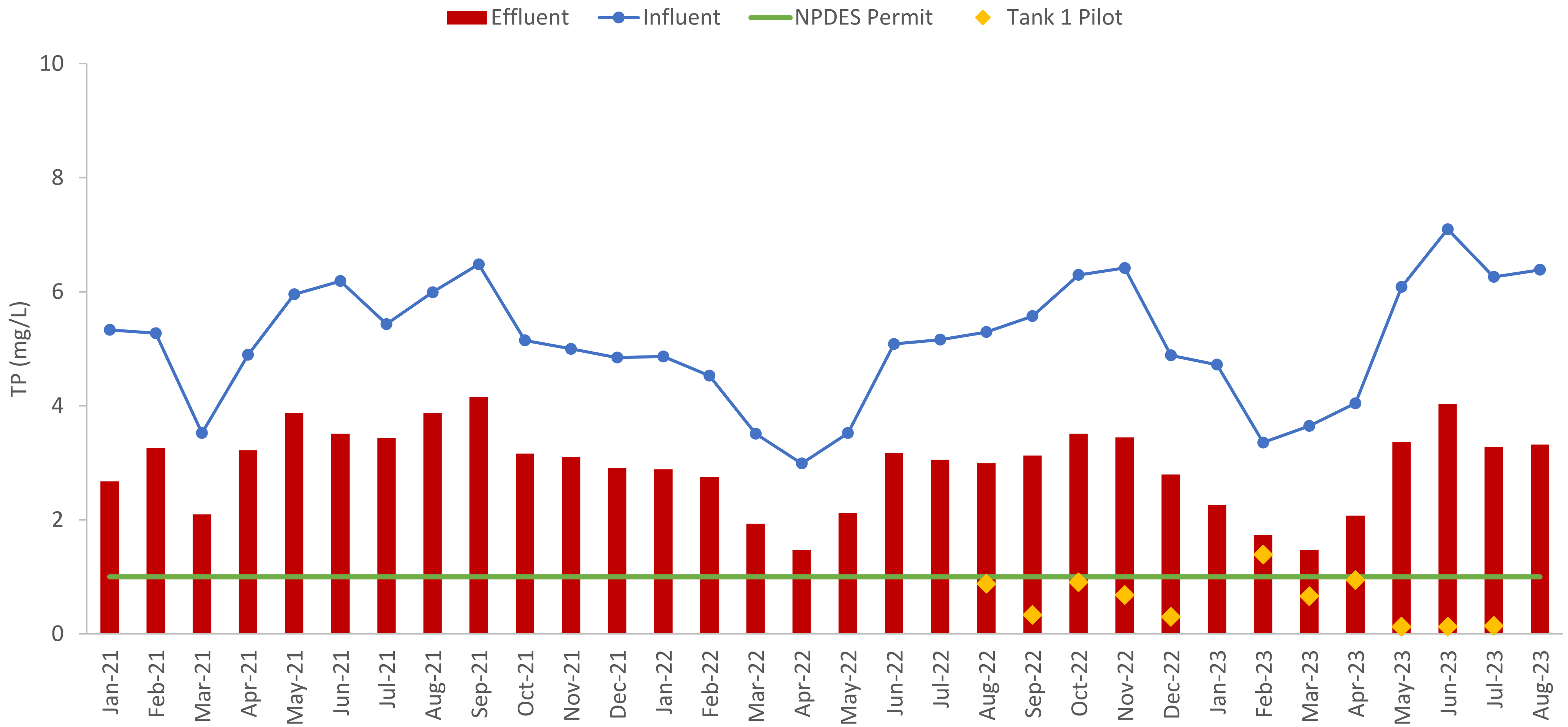
Challenges

- More aeration tanks required to run Bio P due to reduced nitrification capacity
  - Normally two tanks in operation
  - With Bio P more tanks which would require more air/energy
- Factors at the Egan WRP negatively impact Bio P:
  - Influent carbon to P ratio unfavorable to Bio P
  - Handling solids from both Egan and Kirie WRPs, including GBT filtrate return and centrate return as applicable
  - P release in anaerobic digesters
  - Primary treatment removes some available carbon

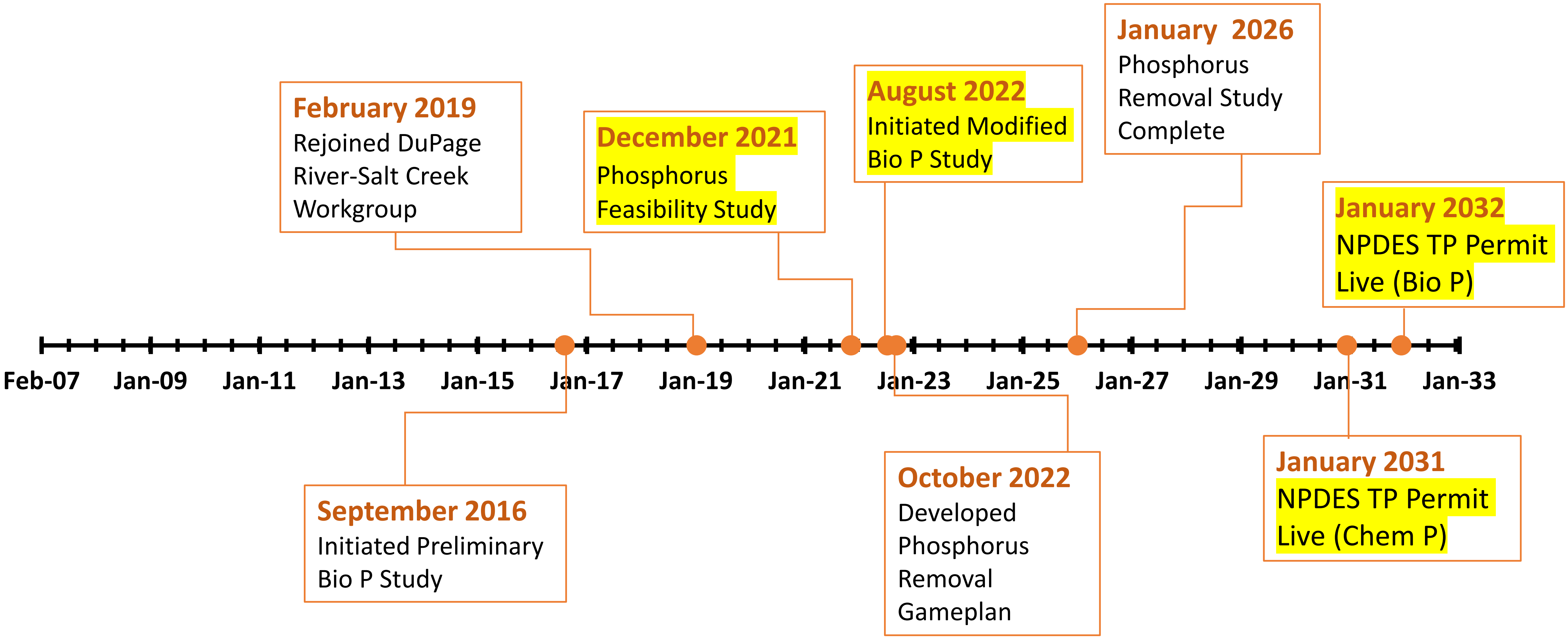
Hanover Park Water Reclamation Plant

- Serves 125,568 people
- Flows:
  - Avg Design Capacity: 12 MGD
  - Max Design Capacity: 22 MGD
  - 2022 Average: 7.5 MGD
- 4 aeration batteries
  - 2 tanks/battery
  - 2 passes/tank
  - 2 circular secondary clarifiers/battery
- Anaerobic digesters
  - 6 Mesophilic, floating cover

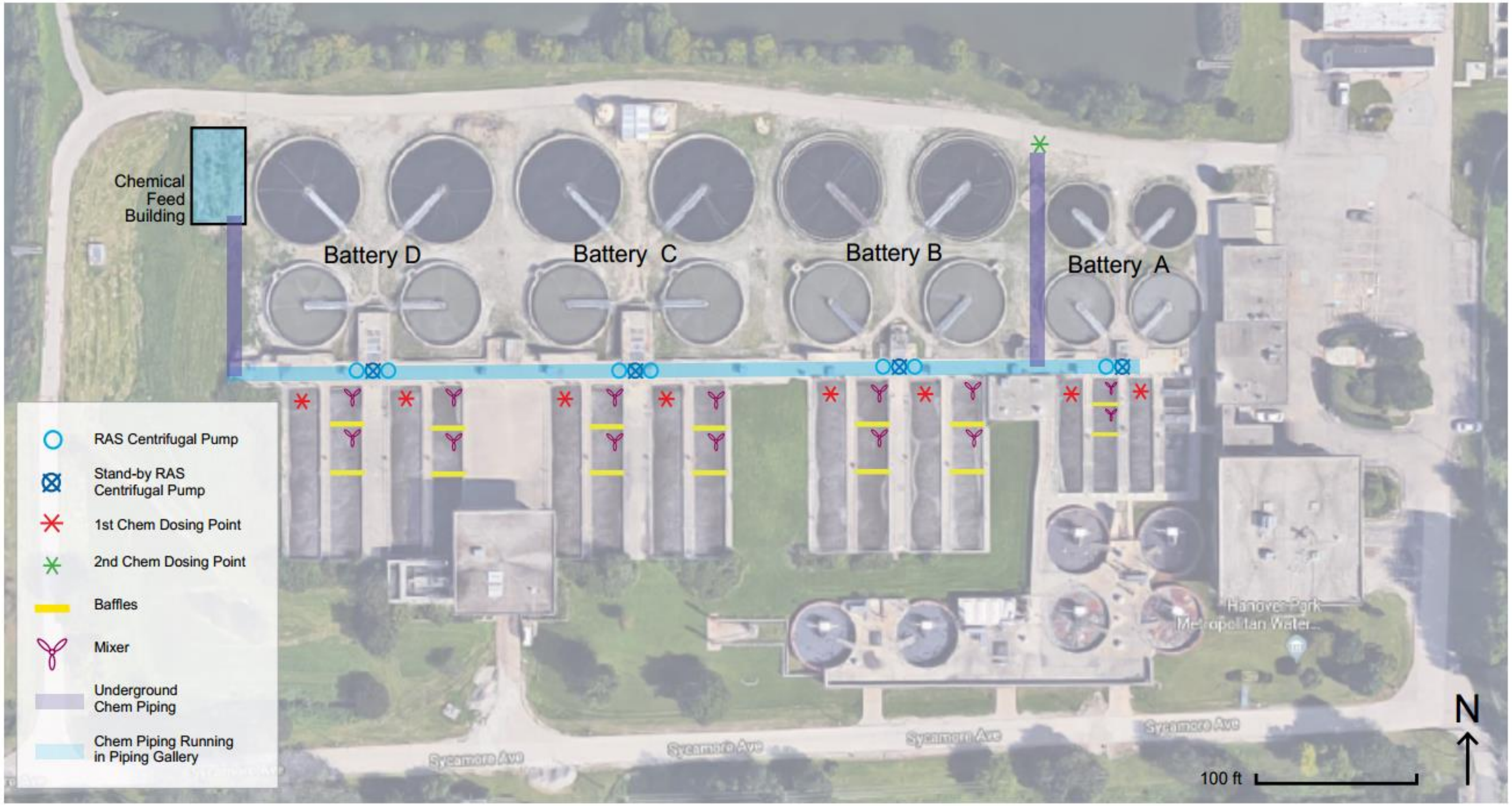
Current Influent and Effluent Monthly Average TPs at Hanover Park WRP



Hanover Park WRP Phosphorus Removal Timeline



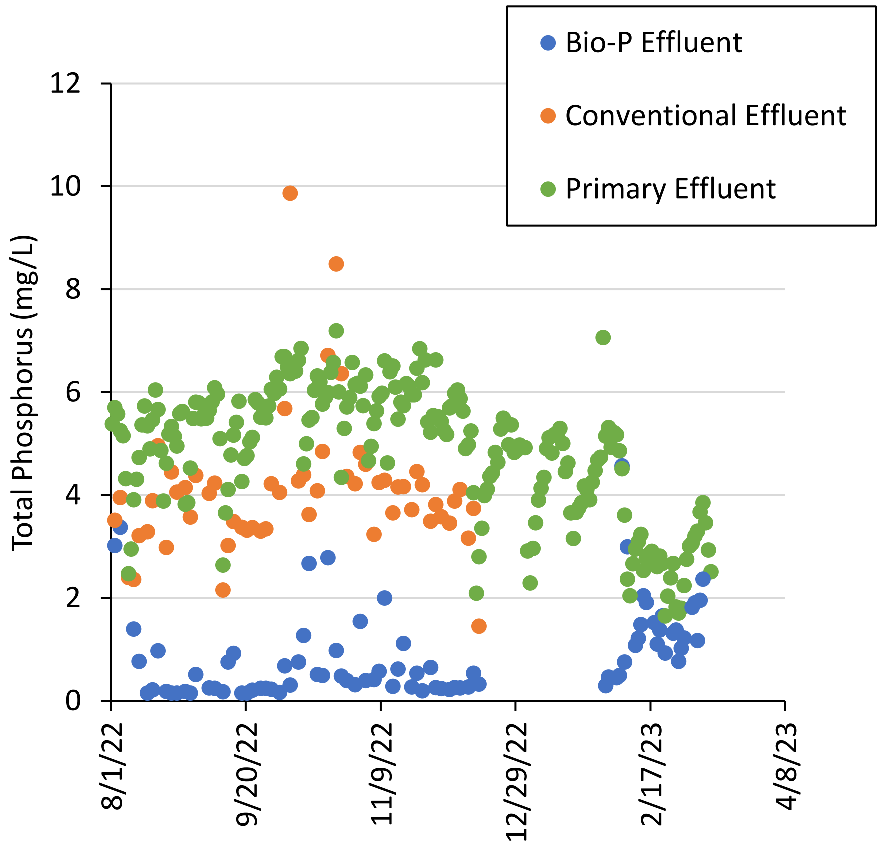
Phosphorus Feasibility Study Recommendations



Scenario to Meet Tier 1 and Tier 2 Effluent TP Limits at Current Flows at Hanover Park WRP

- Anoxic / Anaerobic / Oxic zones in each of the eight aeration tanks
- Ferric Chloride Dosing for Removal Optimization
- Utilize Existing Cloth Media Filters

Hanover Park EBPR Pilot



- Anoxic/Anaerobic/Aerobic bio-P process worked very well for several months
- Caused a floating sludge problem from poor baffle wall design
  - Redesigned and restarted
- Lost bio-P likely from high influent dissolved oxygen when pumping pond water (containing algae)

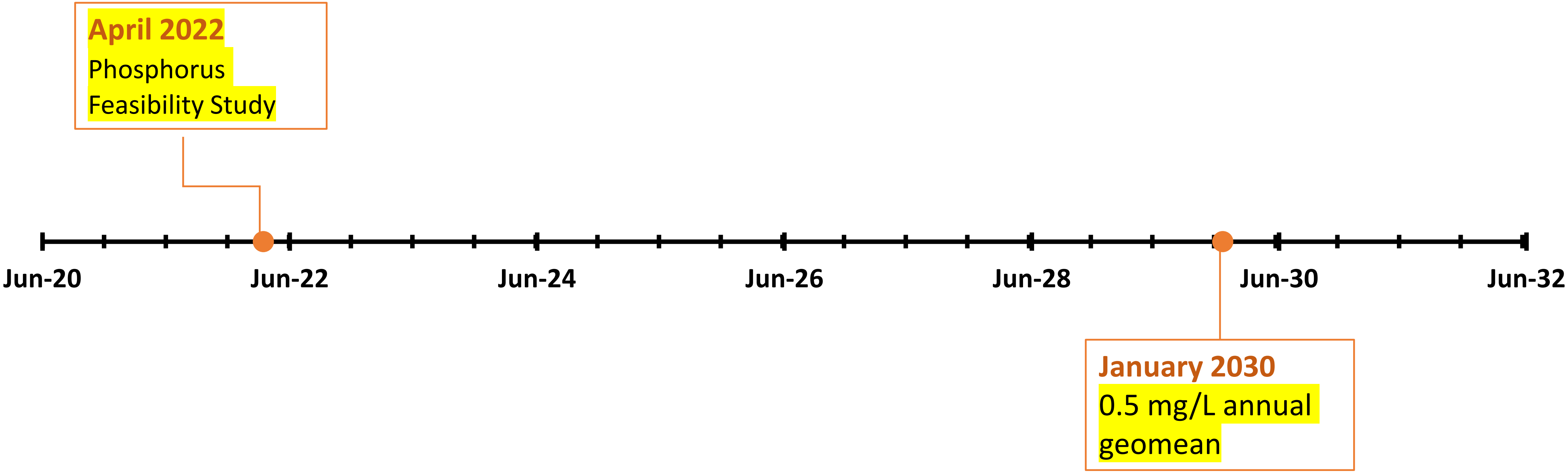
Challenges

- Eight separate treatment trains, so any needed chemical dosing would be more complex
  - However, average BOD:TP ratio of 32 exceeds recommended minimum ratio of 25-30 for Bio P, so chemical dosing may not be needed all the time
- The presence of oxygen in the retention pond pump back flow and high nitrate concentrations in return activated sludge may impact the development of anoxic/anaerobic zones
- Phosphorus removal, whether through chemical or biological means, typically results in an increased solids load

Lemont Water Reclamation Plant

- Serves nearly 20,000 people
- Flows:
  - Avg Design Capacity: 2.3 MGD
  - Max Design Capacity: 4 MGD
  - 2022 Average: 2.6 MGD
- 1 aeration batteries
  - 3 tanks
  - 1 passes/tank
  - 4 circular secondary clarifiers/battery

Lemont WRP Phosphorus Removal Timeline



Phosphorus Feasibility Study Recommendations

Draft permit suggests P trading with Stickney

Scenario to Meet Tier 1-3 Effluent TP Limits

- Ferric Chloride Dosing for Removal Optimization
- Blue PRO Filters

Summary

Plants	Status	Contracts
Stickney WRP	Implemented bio P with chemical polishing system and P recovery	• P recovery Ostara (Contract 11-195-CP) (12-RFP-20) • Mixers in Batteries A, C, & D (Contract 19-57-3P) • Conversion of Two GCTs to Fermenters (Contract 15-124-3P) • Chem P polishing system (Contract 19-159-3P) • Battery A Improvements and Battery B Installation of Mechanical Mixers (Contract 08-174-3D)
Calumet WRP	Chemical P removal facility – under construction Engineering evaluation - ongoing	• Chem P removal facility (18-254-3P)
Terrence J. O'Brien WRP	Battery D S2EBPR conversion under construction; Battery E and Chem P facility under design	• Battery D S2EBPR conversion (21-091-3) • New S2EBPR Battery E (22-RFP-06) • Chem P removal facility for Batteries A-C and polishing for D and E (internal design)
James C. Kirie WRP	Implemented designed Bio P in 2 tanks; The rest 4 tanks will get baffle walls and mixers; chem P under design	• Phosphorus Removal (Contract # 19-375-3P)
John E. Egan WRP	Under evaluation	• None
Hanover Park WRP	Under evaluation	• None
Lemont WRP	Trade w/ Stickney WRP to meet P removal needs?	• None

Acknowledgements

- Interdepartmental Phosphorus Task Force
- M&O Staff
  - TPOs – making the field adjustments
  - Trades – installing monitoring equipment and improving equipment
- Engineering Department
  - Designed and overseen constructions of major contracts
- M&R Staff
  - EM&RD for Field Sampling and Pilot Studies
  - Planning group of Engg evaluations
  - Analytical Laboratories Division for Chemical Analysis
  - Microbiological Analysis

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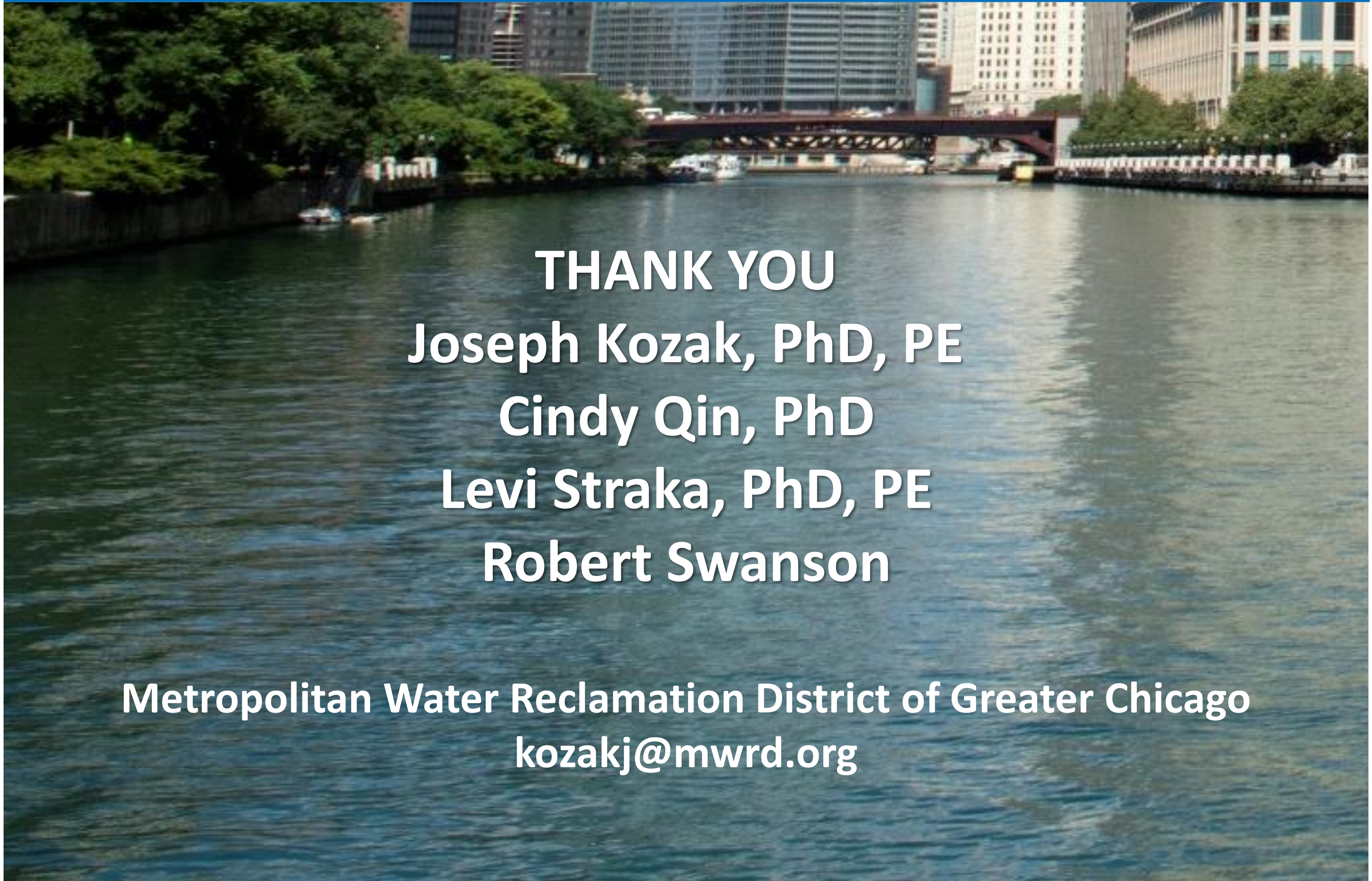

THANK YOU

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Watershed Group Partnerships

- Composed of representatives from local communities, wastewater and stormwater agencies, environmental organizations, and other interested parties
- Conduct bioassessment monitoring programs
- Identify and address nonpoint sources of nutrient pollution
- Develop joint Nutrient Assessment and Reduction Plan, which is an NPDES Wastewater Permit Special Condition requirement
- Focus nutrient reduction efforts to areas in a watershed that help improve biology rather than supporting strict, universal permit discharge limits

DuPage River Salt Creek Workgroup

Lower Des Plaines Watershed Group