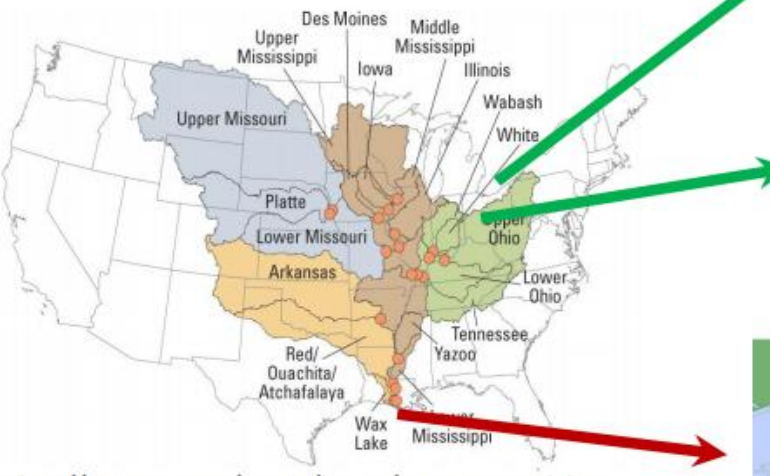
Metropolitan Water Reclamation District of Greater Chicago's (MWRDGC's) Efforts to Meet Effluent Limits for Phosphorus

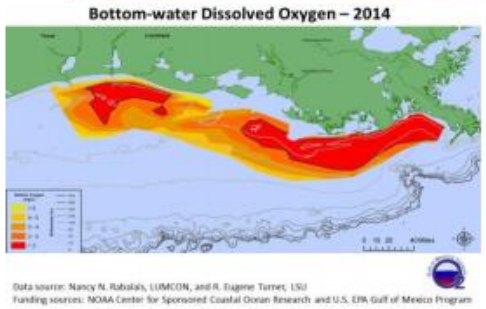
February 20, 2025

Why Remove Phosphorus?

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



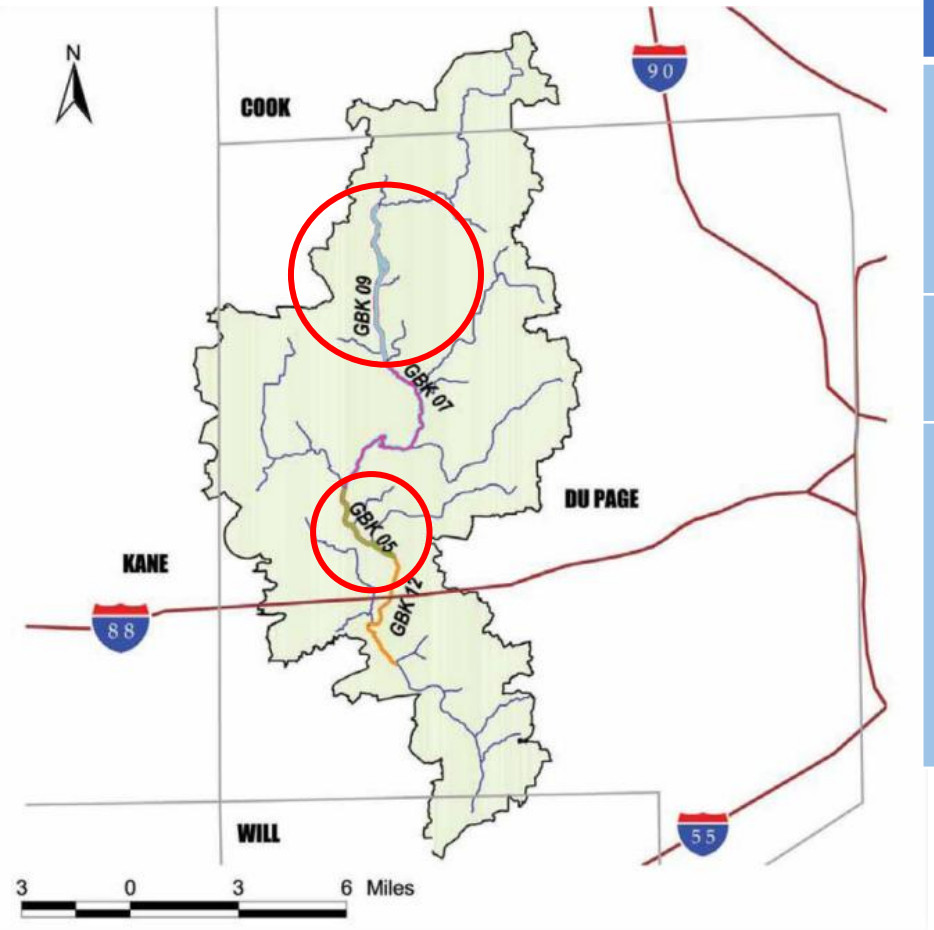
http://water.usgs.gov/nasqan/images/nasqan_ms_web.jpg



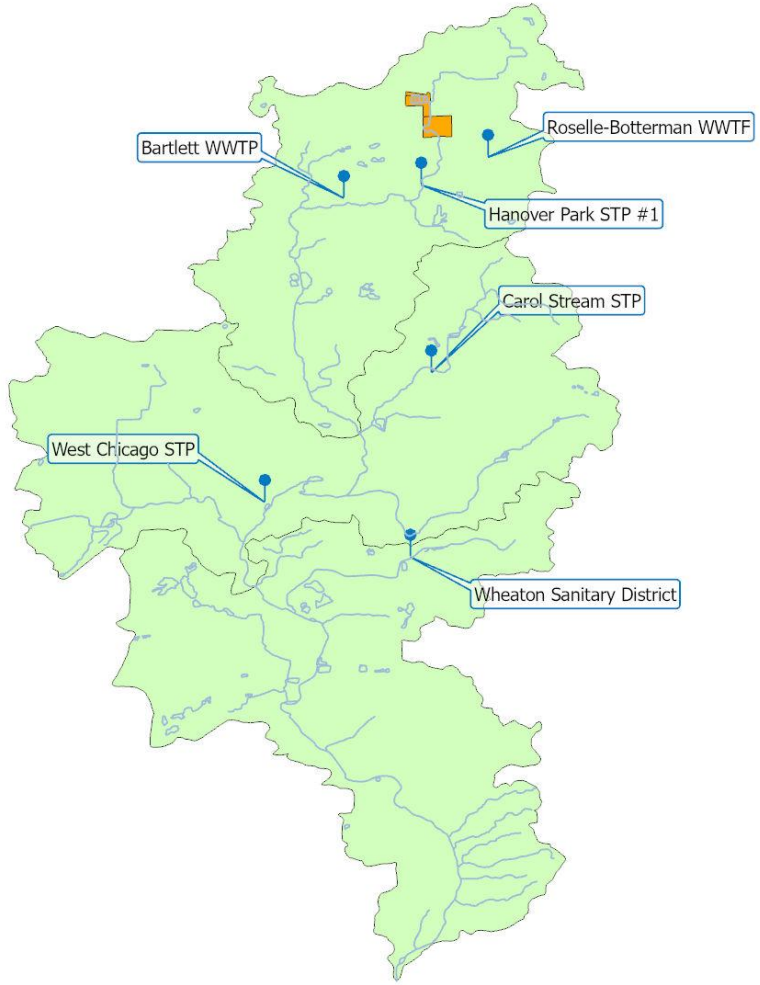
Phosphorus → freshwater harmful algal blooms (HAB)
Nitrogen → Estuary and marine eutrophication and hypoxia

- Algal blooms from eutrophication
  - Release cytotoxins
  - Cause odors
  - Prevent light penetration for other aquatic life
  - Extreme diurnal fluctuations for dissolved oxygen
  - Algae dies➔consume dissolved oxygen ➔negatively affect aquatic life

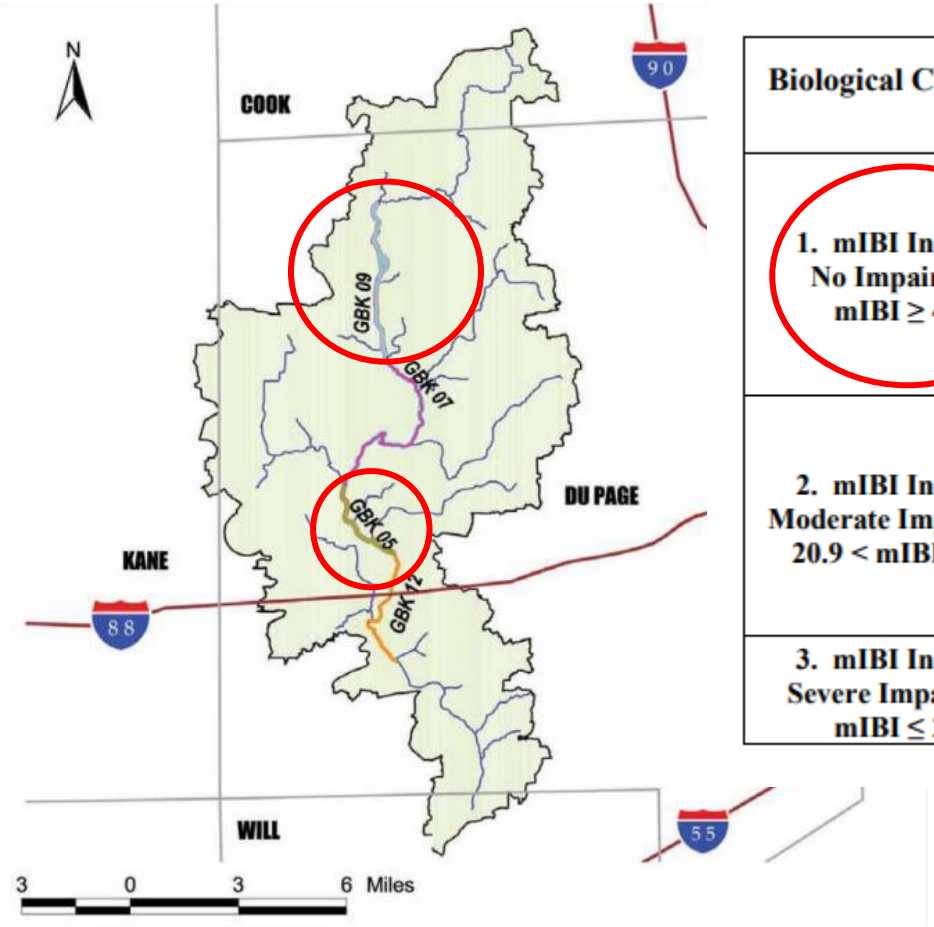
West Branch DuPage River Watershed Streams Not Supporting the Aquatic Life Use



Draft 2024 303(d) List – Aquatic Life Use	
GBK-05	Flow Regime Modification
	Phosphorus, Total
	Total Suspended Solids (TSS)
GBK-09	**Phosphorus, Total**
	Sedimentation/Siltation
GBK-14	Alteration in Stream- Side or Littoral Vegetative Covers
	Chloride
	Dissolved Oxygen
	Flow Alteration- Changes in Depth and Flow Velocity



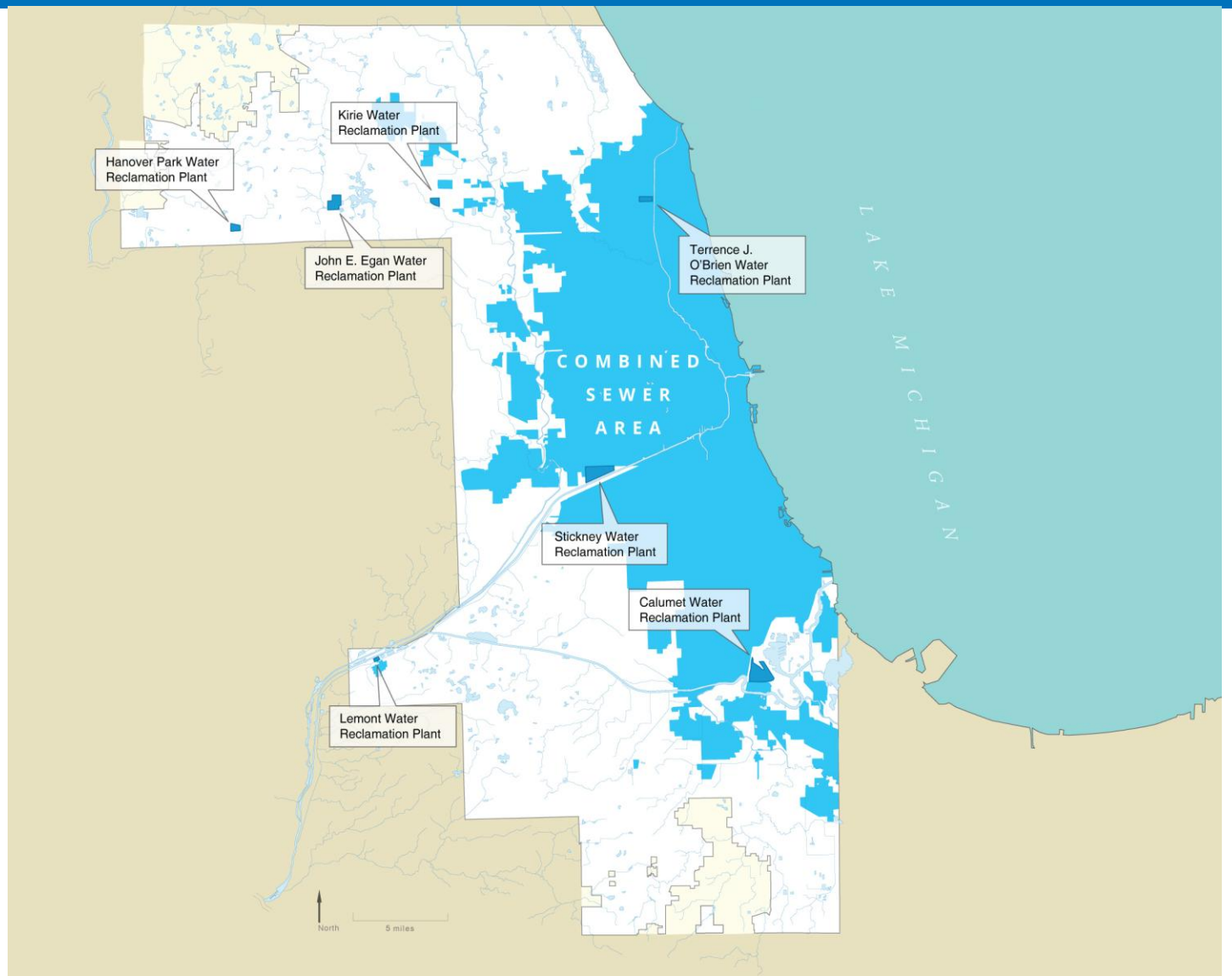
Decision Table to Assess Aquatic Life Use in Streams



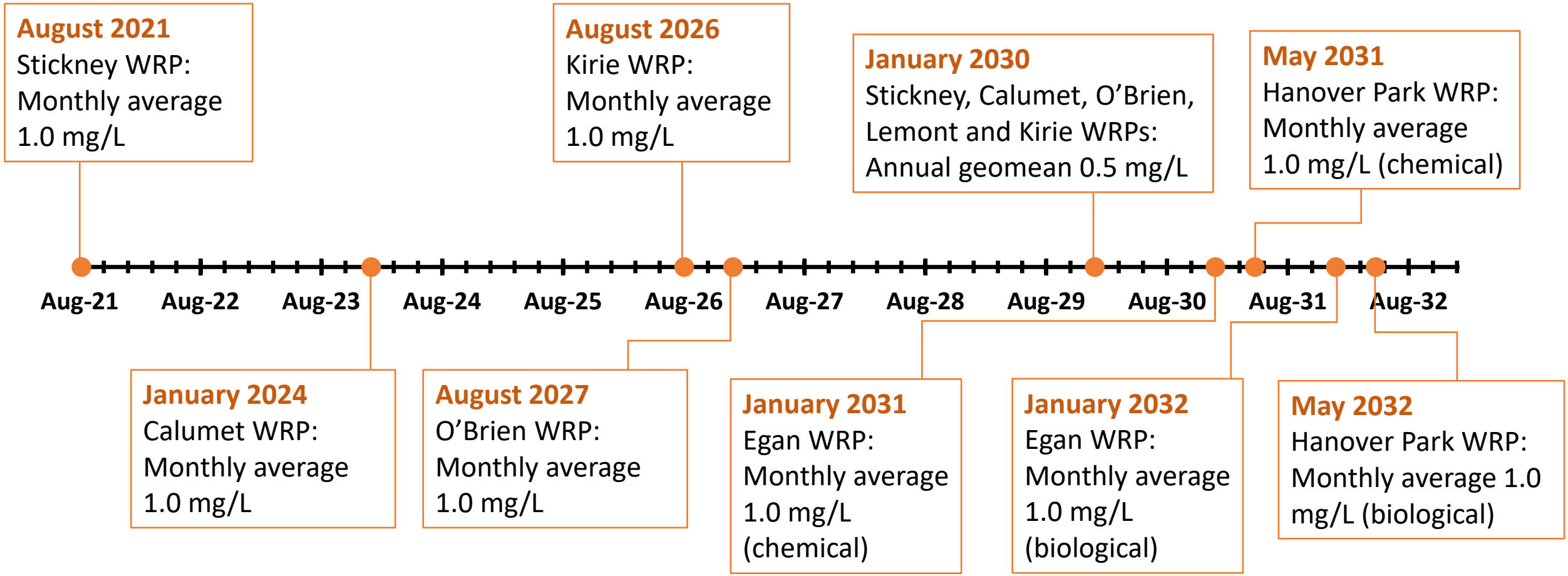
Biological Condition	A. fIBI Indicates No Impairment fIBI ≥ 41	B. fIBI Indicates Moderate Impairment 20 < fIBI < 41	C. fIBI Indicates Severe Impairment fIBI ≤ 20	D. fIBI is Unavailable
1. mIBI Indicates No Impairment mIBI ≥ 41.8	*Fully Supporting* (Water Chemistry and other data are considered during final review) (See cell 8 below).	If water chemistry data or habitat data indicate a potential for impairment, then *Not Supporting*. Otherwise, *Fully Supporting*.	*Not Supporting*	If water chemistry data indicate a potential for severe impairment, then *Not Supporting*. Otherwise, *Fully Supporting*.
2. mIBI Indicates Moderate Impairment 20.9 < mIBI < 41.8	If water chemistry data or habitat data indicate a potential for impairment, then *Not Supporting*. Otherwise, *Fully Supporting*.	*Not Supporting*	*Not Supporting*	*Not Supporting*
3. mIBI Indicates Severe Impairment mIBI ≤ 20.9	*Not Supporting*	*Not Supporting*	*Not Supporting*	*Not Supporting*

Metropolitan Water Reclamation District of Greater Chicago (MWRDGC)

- Serve 5.19 million people
- Operate 7 water reclamation plants
  - 1.2 BGD average in 2024
- DesPlaines River ->
  Illinois River ->
  Mississippi River



NPDES Permit Schedule

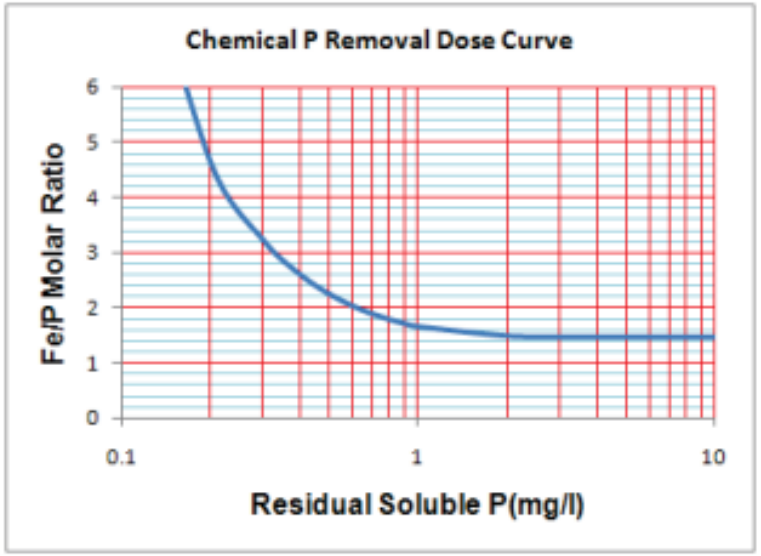


Chemical Phosphorus Removal

$$y = \frac{a}{(1 + b \times e^{-cx})}$$

Where:
y = mole iron required per mole soluble phosphate removed
x = residual soluble phosphate(mg/l P)
a = 1.48
b = -1.07
c = 2.25

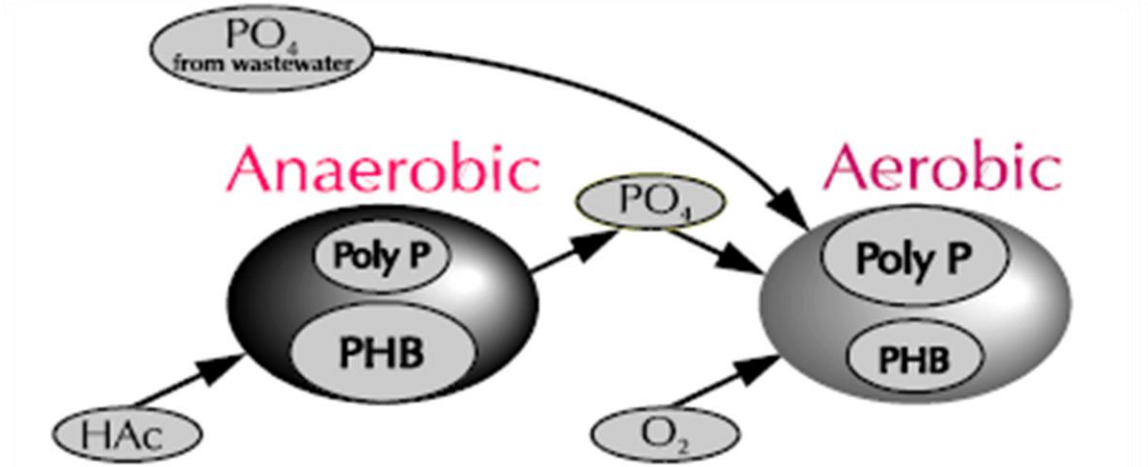
The molar dose for phosphorus precipitation is based on the desired final effluent soluble phosphorus concentration rather than the starting phosphorus concentration



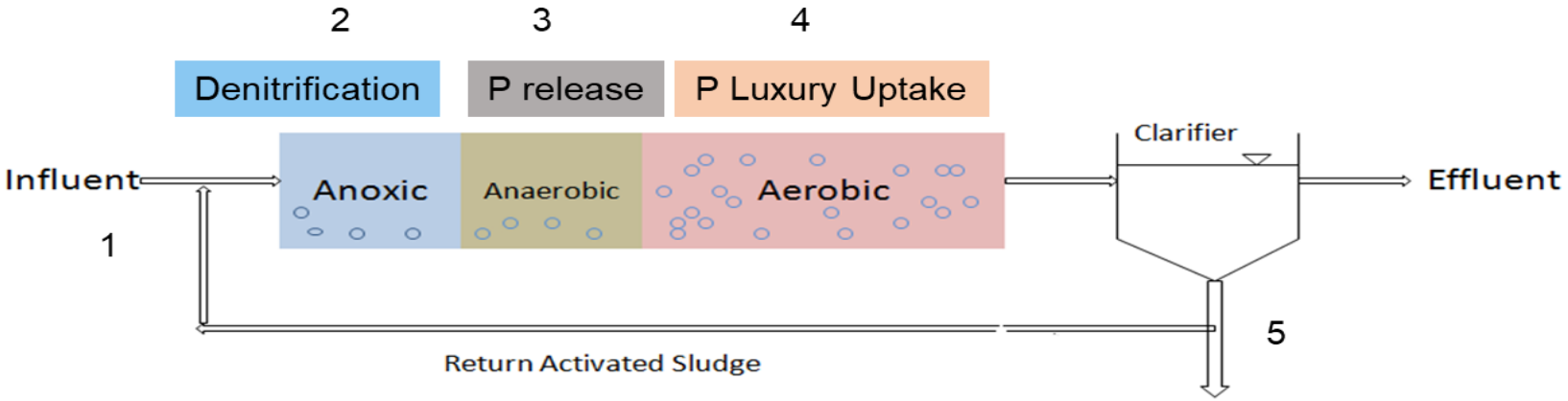
- For target concentrations above 2 mg/L, a 1:1 molar ratio of iron (from ferric chloride) to phosphorus is often sufficient
- For lower phosphorus levels (e.g., 0.3 – 1.0 mg/L), a higher iron-to-phosphorus ratio (1.2 to 4.0 moles of iron per mole of phosphorus) might be needed

Enhanced Biological Phosphorus Removal (EBPR)

- Phosphate accumulating organisms (PAOs) release phosphate in anaerobic conditions, then uptake in excess once oxygen is present

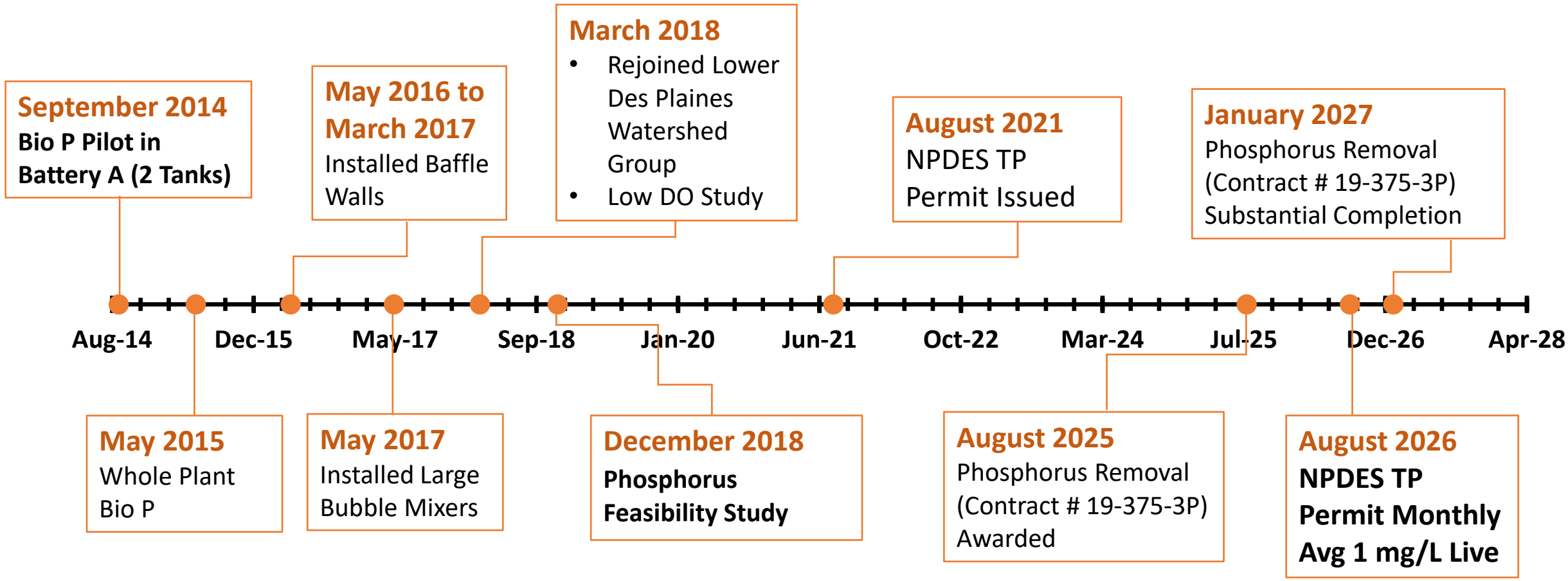


acetic acid = bioavailable carbon



Minimum ratios for achieving TP effluent concentrations <1.0 mg/L	
COD : TP	40 – 45
BOD : TP	**20**
rbCOD : TP	10 – 16
VFA : TP	4 – 16

Kirie WRP Phosphorus Removal Timeline

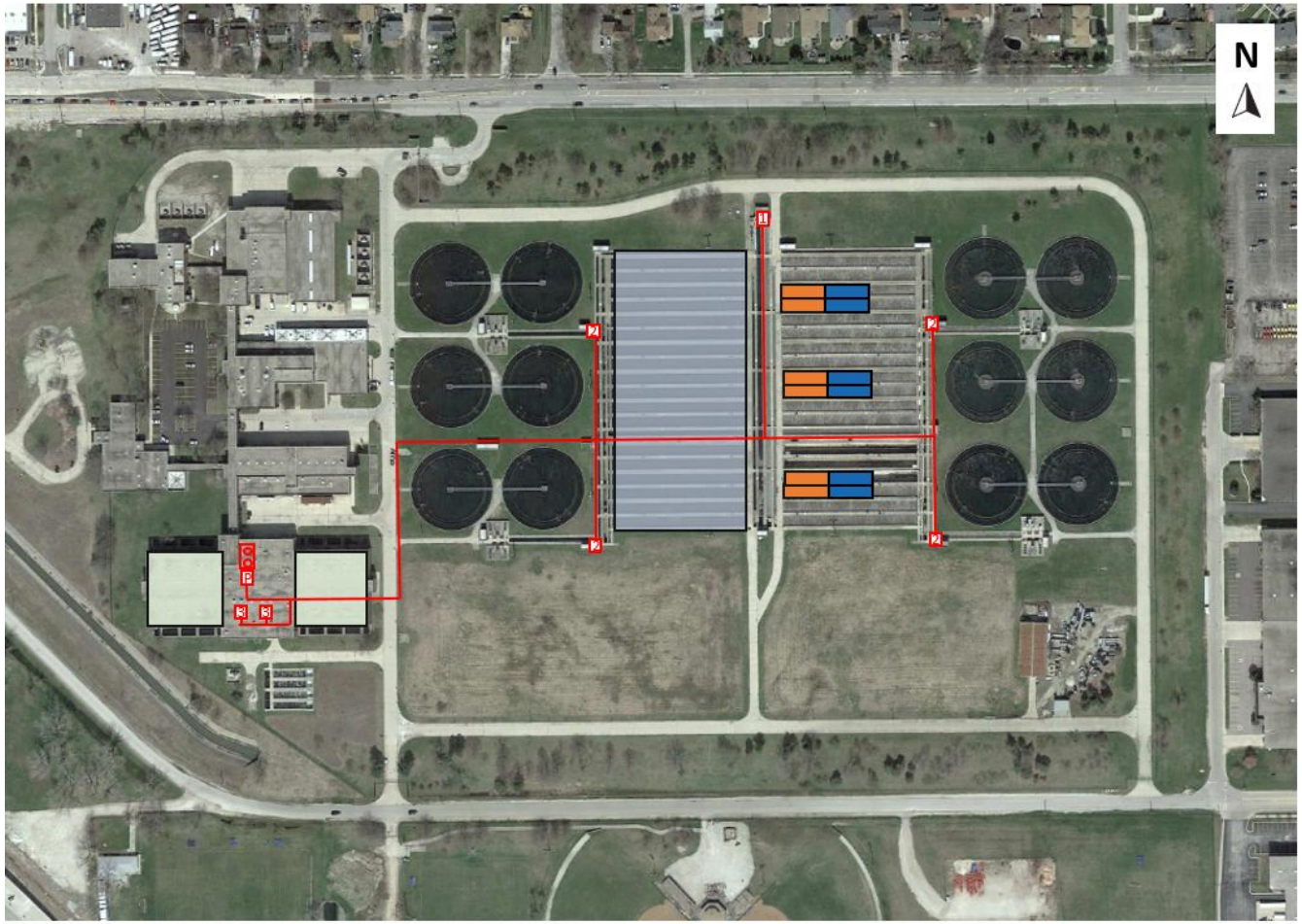


James C. Kirie Water Reclamation Plant

- ❑ Serves 264,000 people
- ❑ Flows:
  - Avg Design Capacity: 52 MGD
  - Max Design Capacity: 110 MGD
  - 2024 Average: 31 MGD

- ❑ 2 aeration batteries
  - 6 tanks/battery
  - 3 passes/tank
  - 6 circular secondary clarifiers/battery

Phosphorus Feasibility Study Recommendations for Kirie WRP



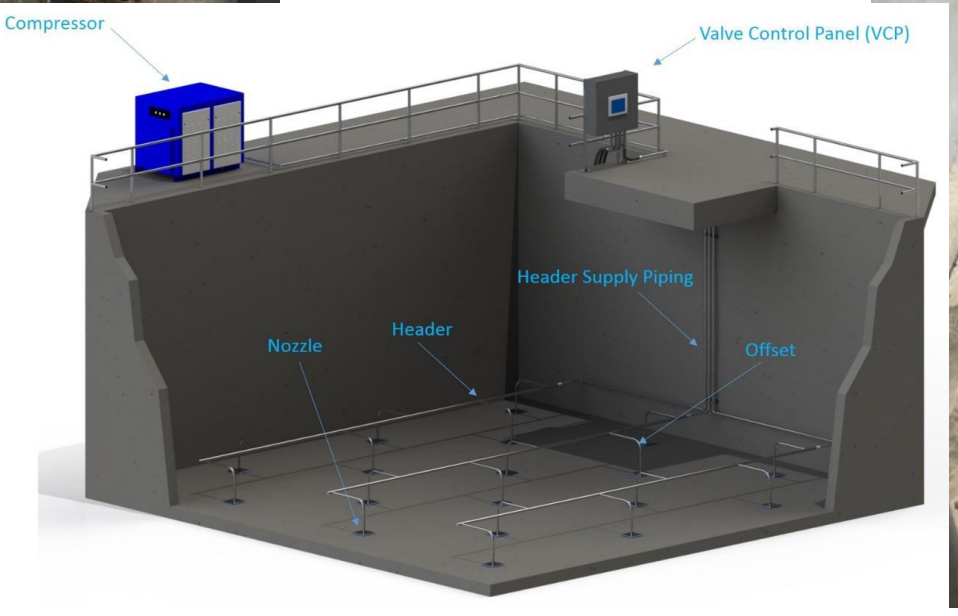
Scenario To Meet Tier 1 and Tier 2 Effluent TP Limits at Current Flows at Kirie WRP

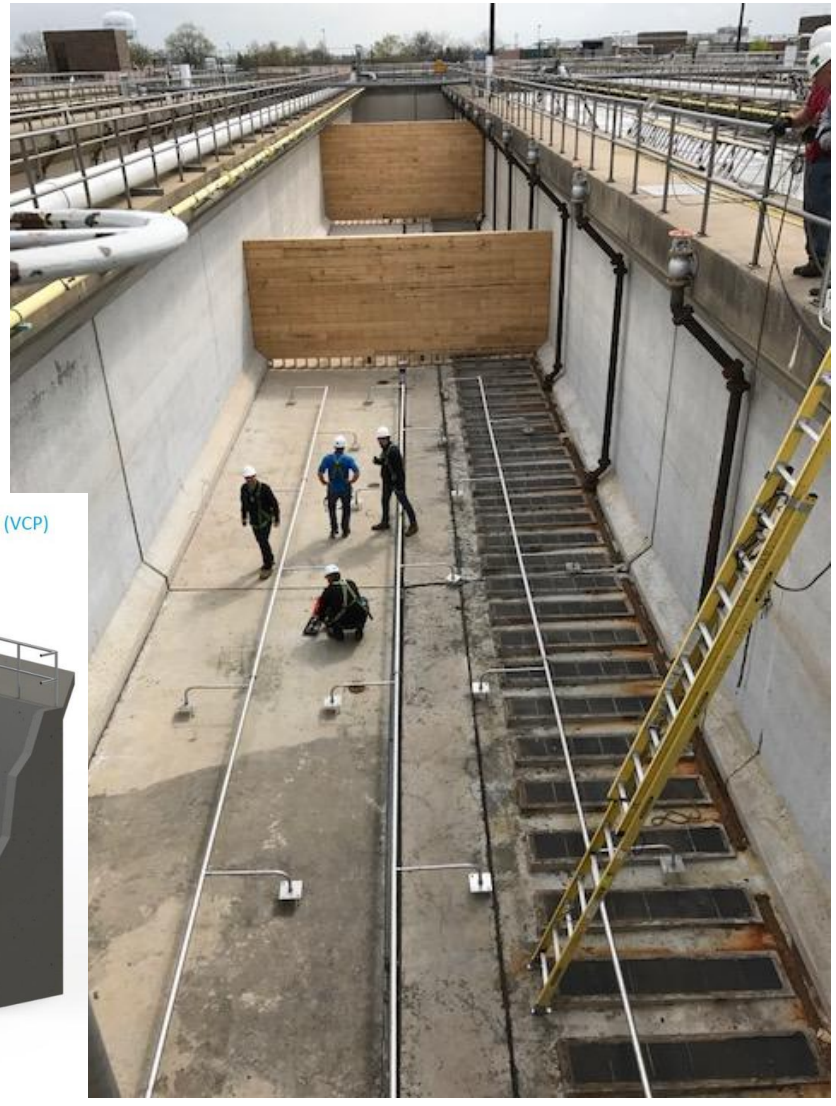
Legend:

- 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

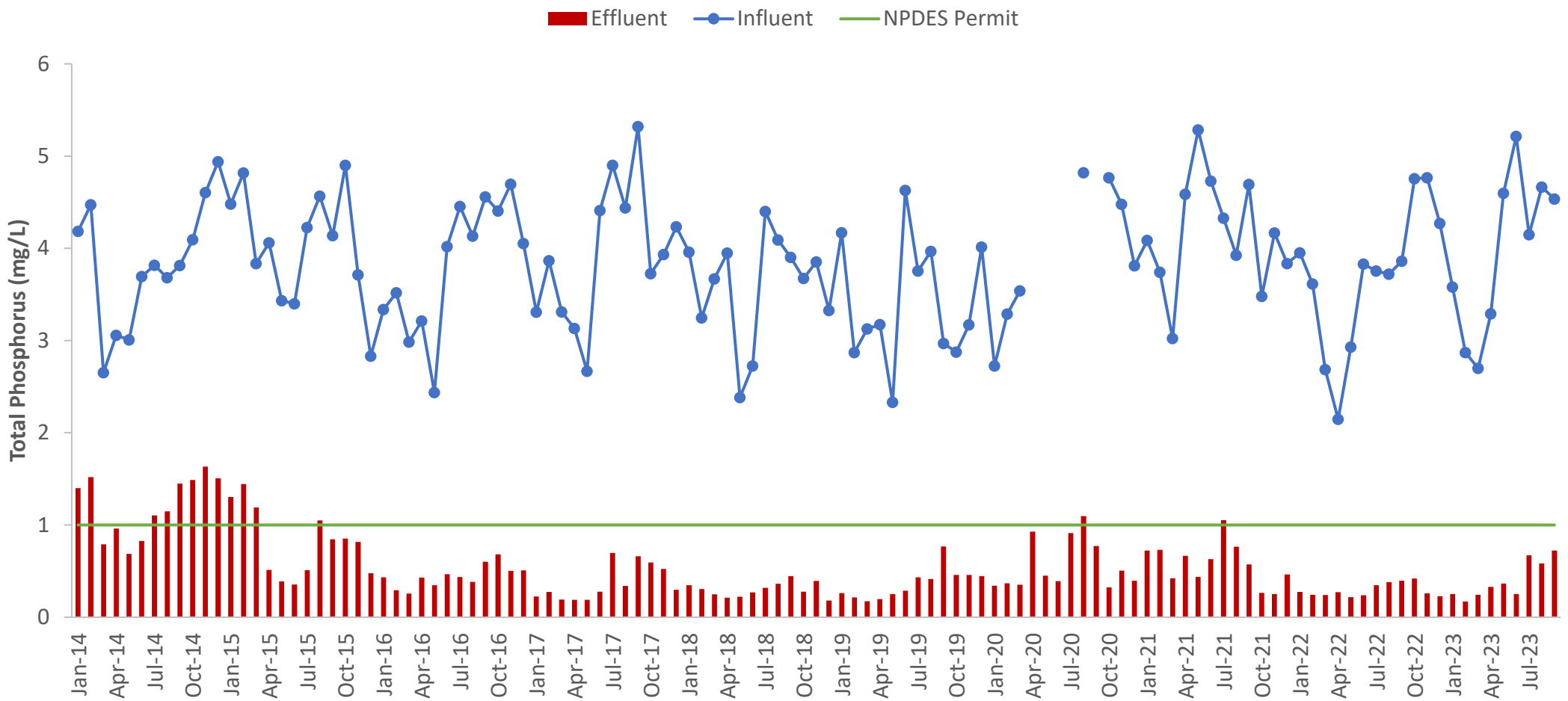
- Existing A/O process with large bubble mixers, baffles, and 2/3rd volume of the first pass for anaerobic zone for compliance with 1 mg/L and 0.5 mg/L effluent TP limits at current flows
- Chemical addition was recommended for all effluent TP limits to supplement EBPR and provide protection against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

Kirie WRP EBPR Conversion

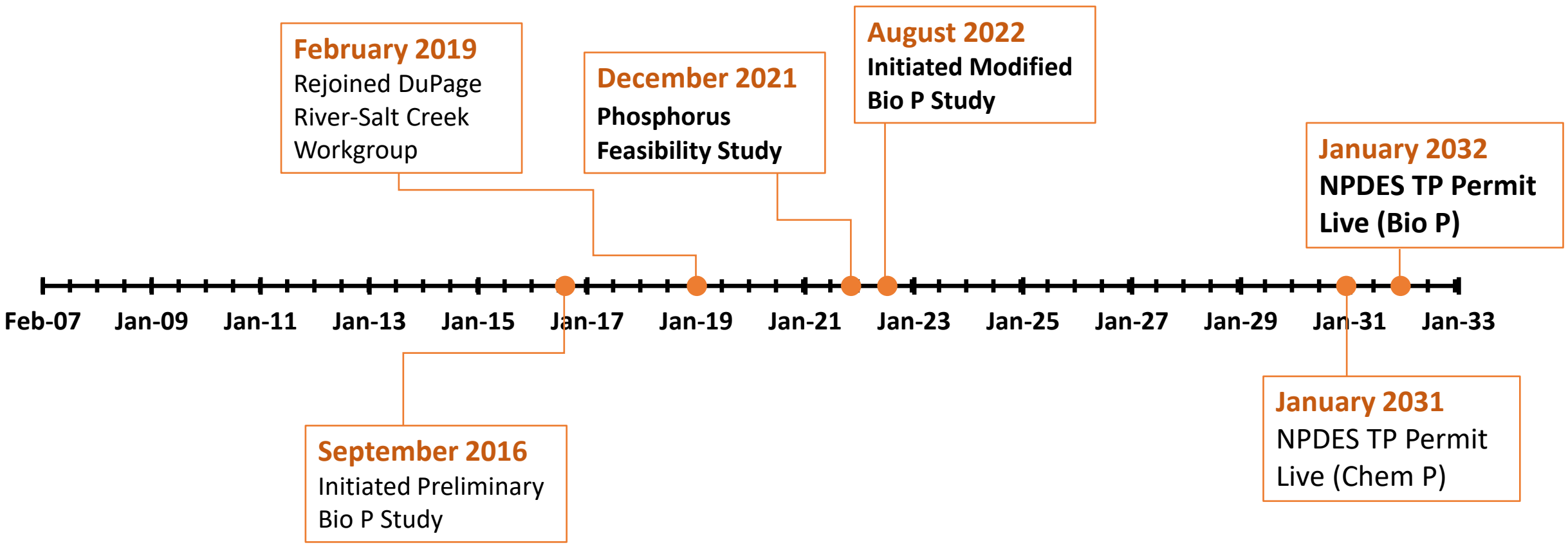




Historical Influent and Effluent Monthly Average Total Phosphorus Concentrations at Kirie WRP



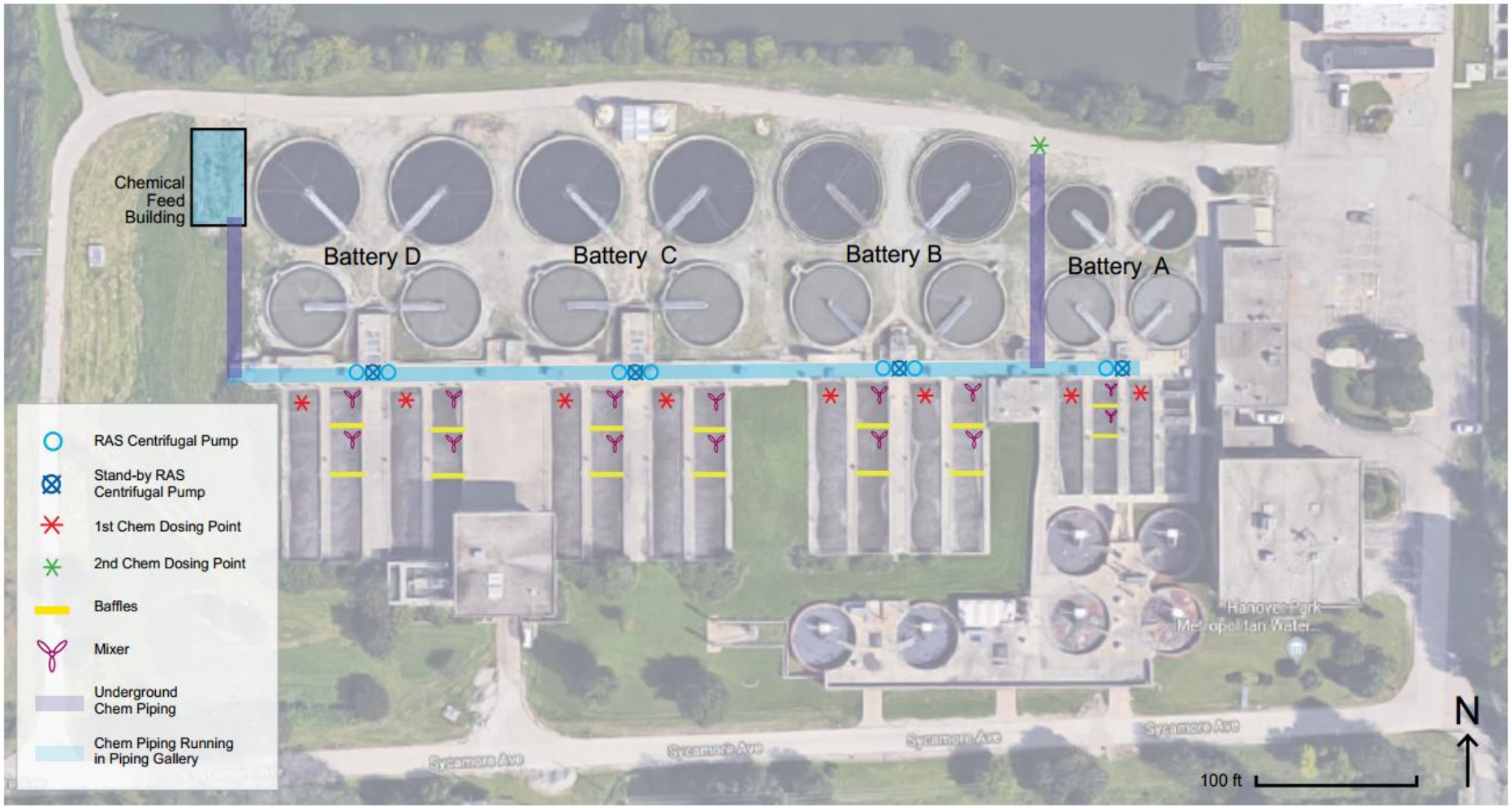
Hanover Park WRP Phosphorus Removal Timeline



Hanover Park Water Reclamation Plant

- Serves 125,568 people
- Flows:
  - Avg Design Capacity: 12 MGD
  - Max Design Capacity: 22 MGD
  - 2024 Average: 7 MGD
- 4 aeration batteries
  - 2 tanks/battery
  - 2 passes/tank
  - 2 circular secondary clarifiers/battery
- Anaerobic digesters
  - 6 Mesophilic, floating cover

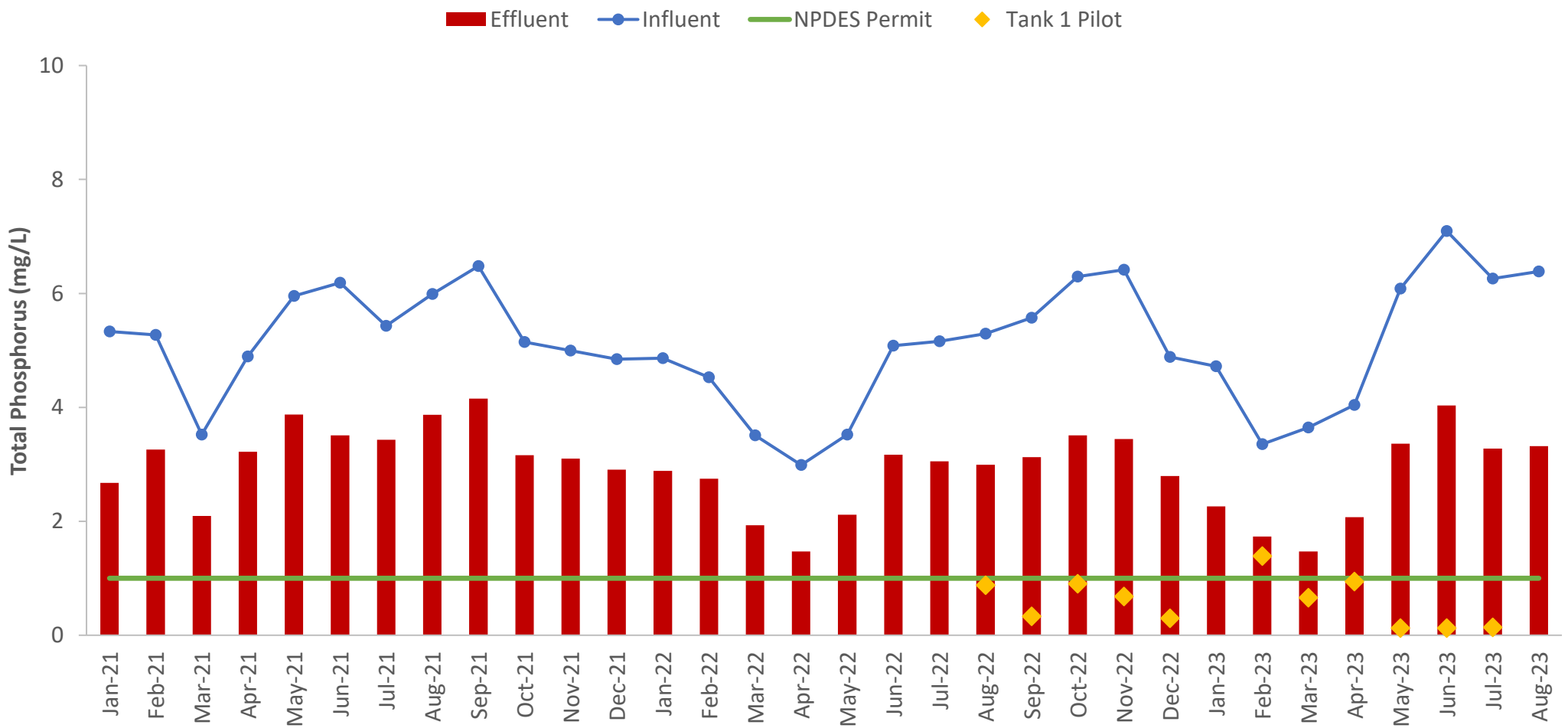
Phosphorus Feasibility Study Recommendations for Hanover Park WRP



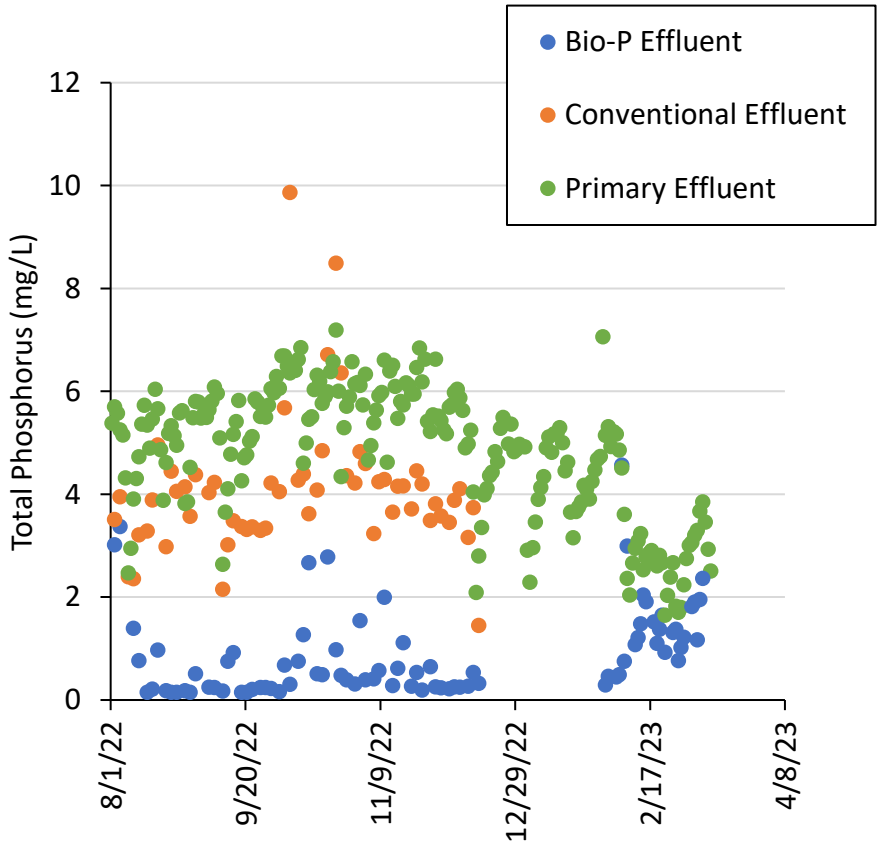
Scenario to Meet Tier 1 and Tier 2 Effluent TP Limits at Current Flows at Hanover Park WRP

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

Historical Influent and Effluent Monthly Average Total Phosphorus Concentrations at Hanover Park WRP

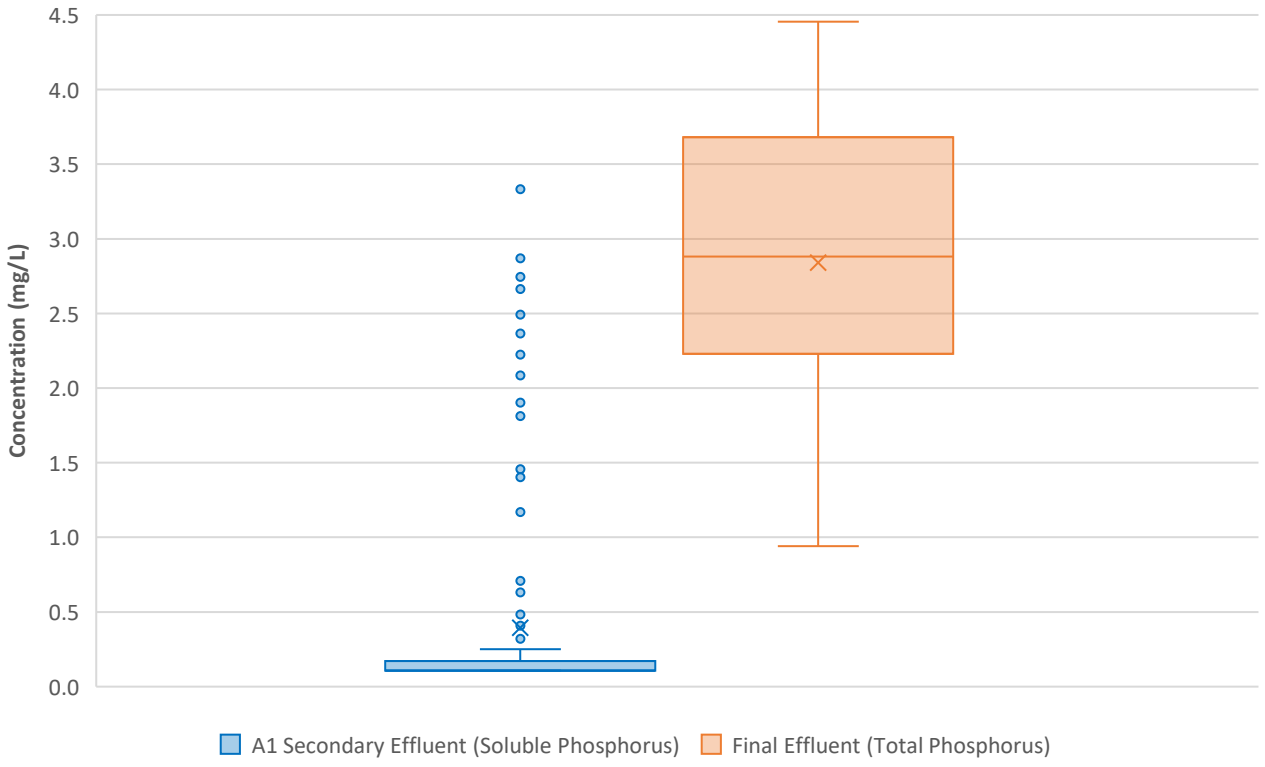


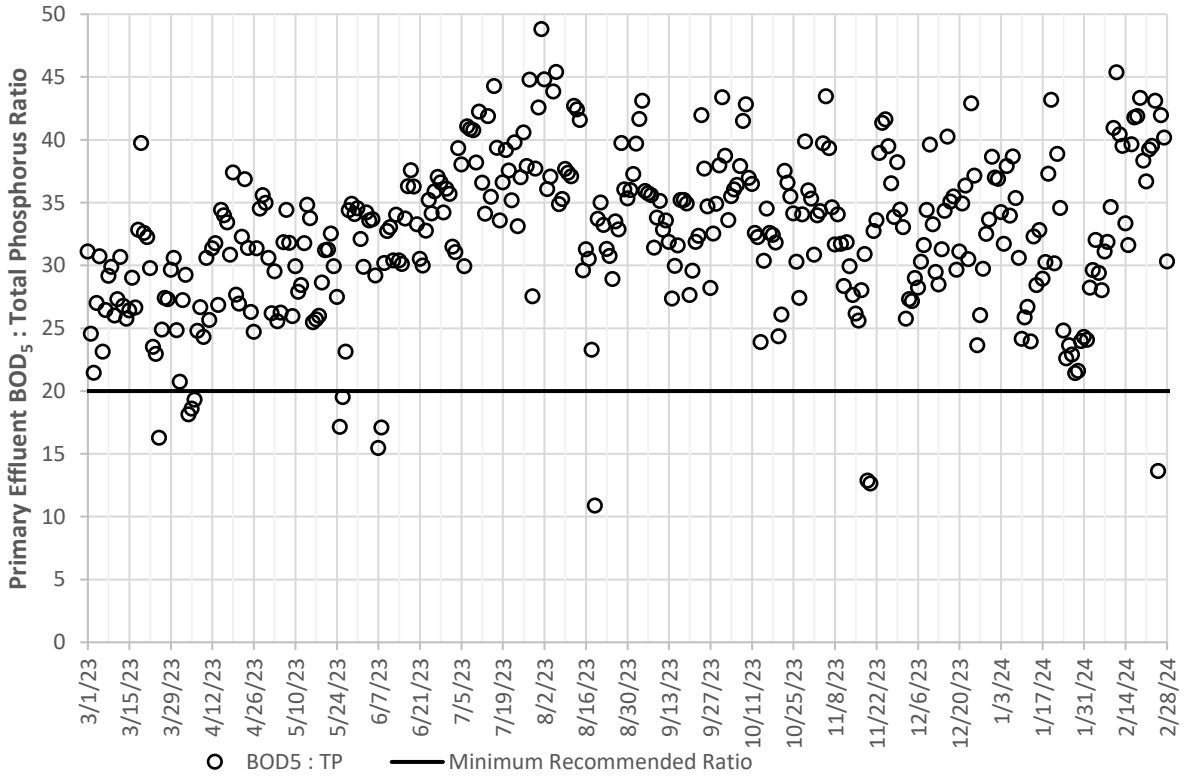
Hanover Park WRP EBPR Pilot



- 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
  - Dissolved oxygen concentrations as high as 21.6 mg/L were observed in retention pond #4 in 2023

Comparison between EBPR and Existing Conditions



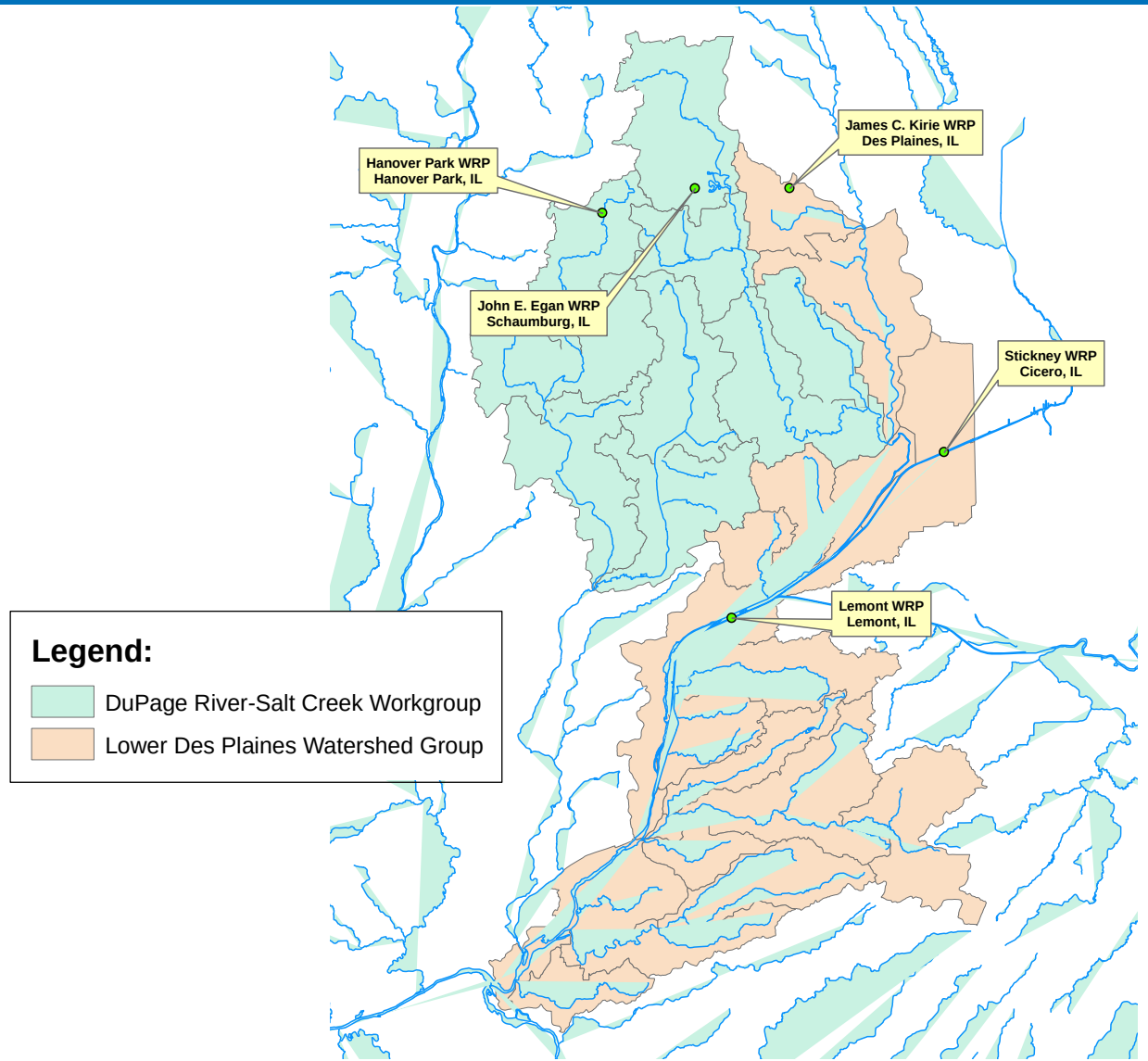


- Test Tank Secondary Effluent: Mean value of 0.39 mg/L
- Hanover Park WRP Final Effluent: Mean value of 2.84 mg/L

Watershed Group Partnerships

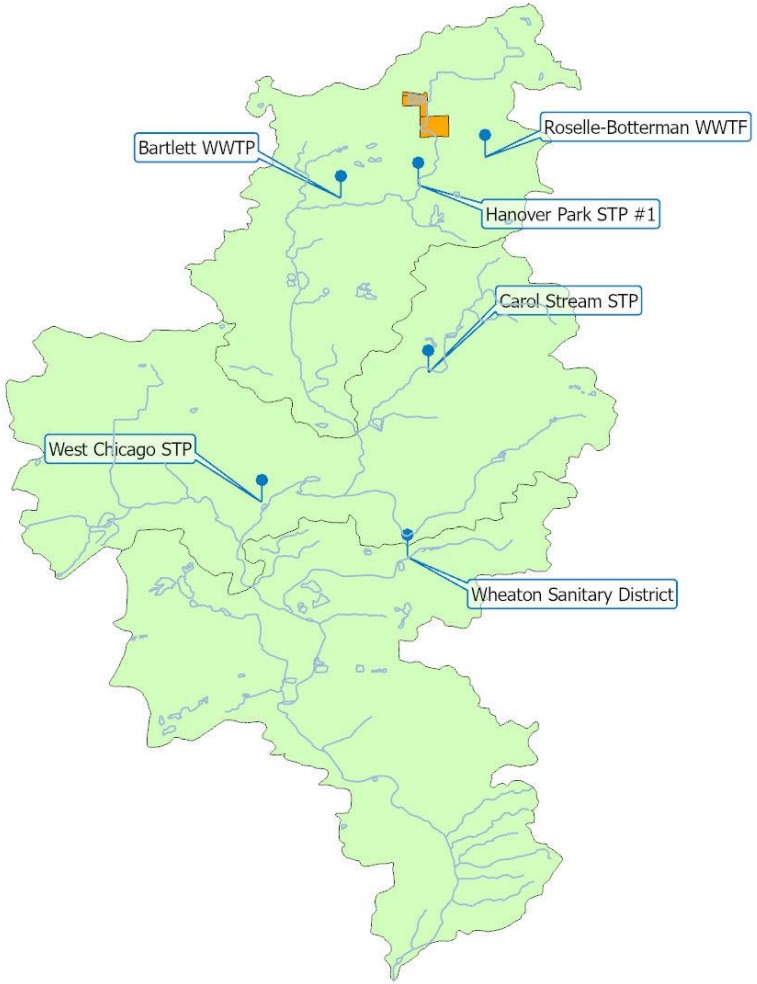
- Composed of representatives from local communities, wastewater and stormwater agencies, environmental organizations, and other interested parties
- Conduct bioassessment monitoring programs
- Identify and address nonpoint sources of nutrient pollution
- Develop joint Nutrient Assessment and Reduction 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

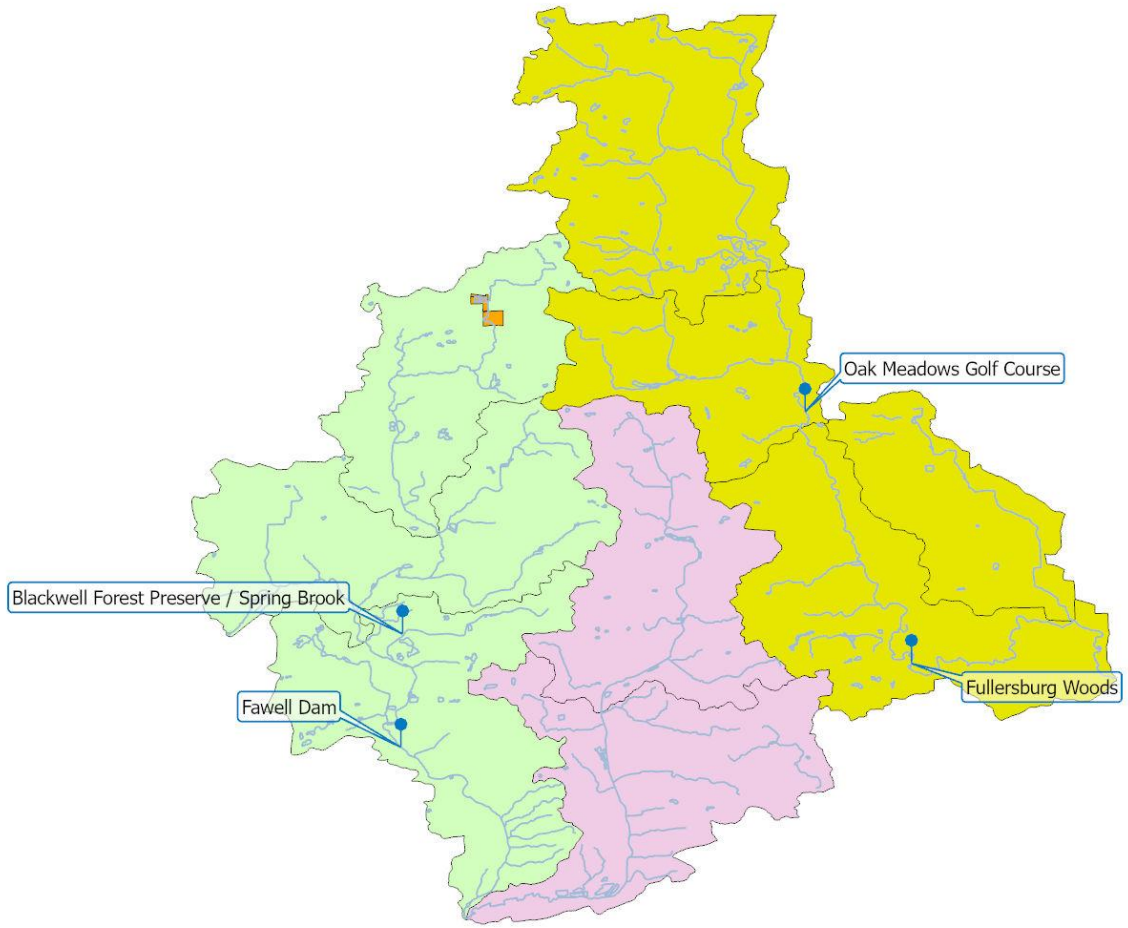


Phosphorus Removal Timeline

- The NPDES permit for the Hanover Park WRP, effective May 1, 2021, includes a special condition where the permittee will achieve a total phosphorus effluent limit of 1.0 mg/L on a monthly average basis:
  - 10 years after the effective date of the permit if chemical precipitation is used or
  - 11 years after the effective date of the permit if utilizing biological phosphorus removal

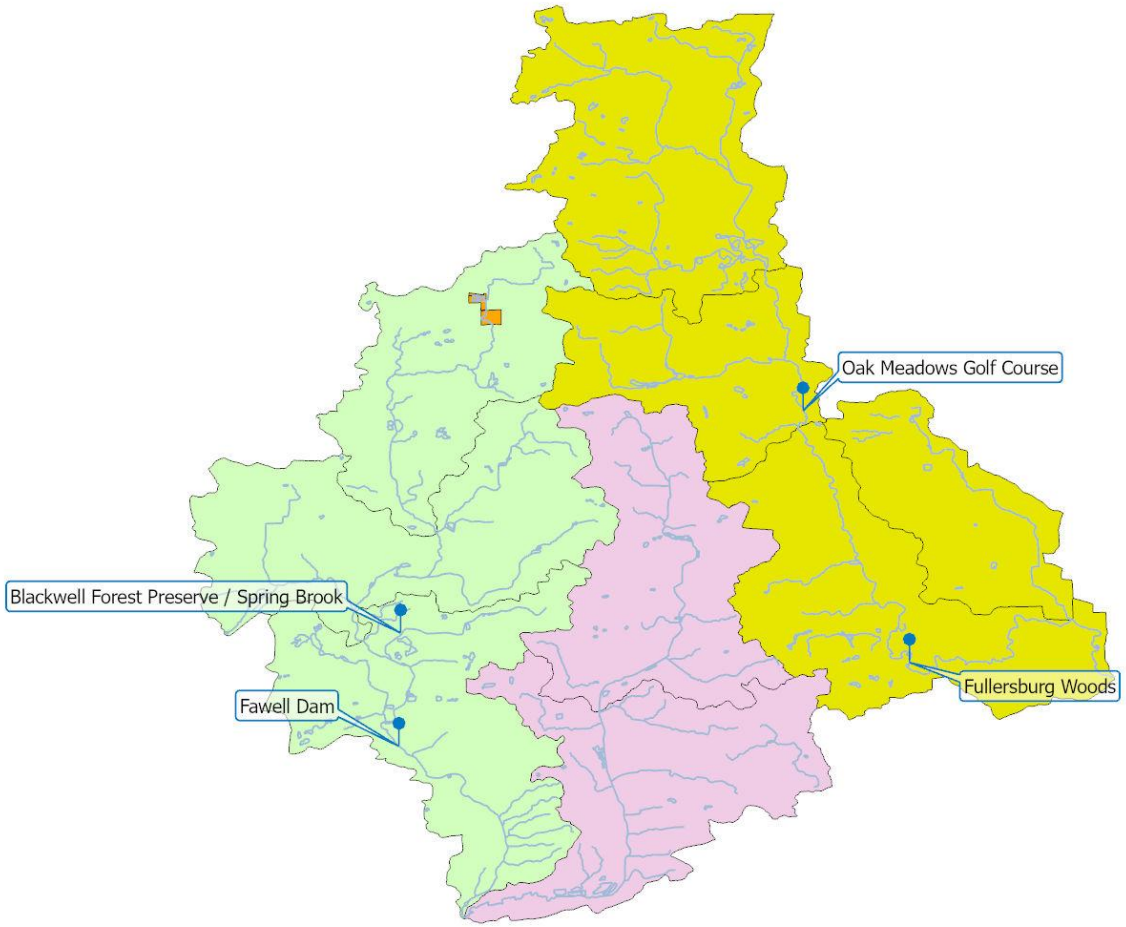


NPDES Permit Special Condition 19

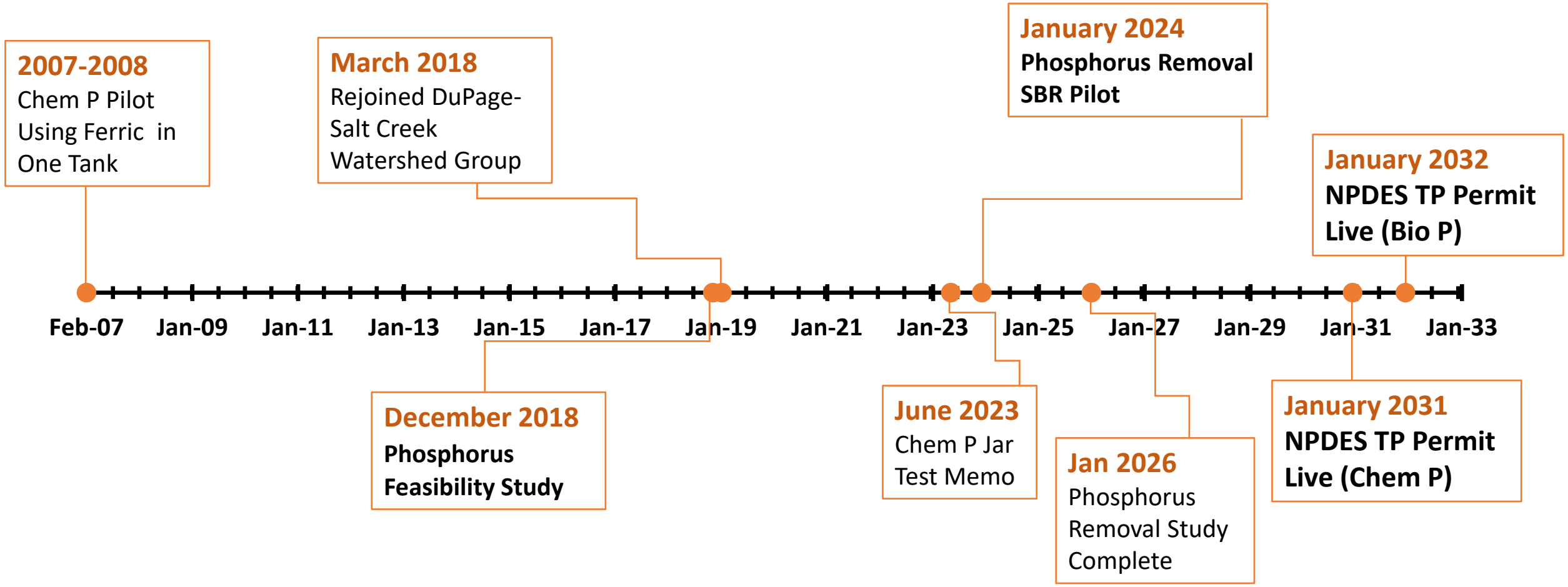


Location	Short Term Objective	Long Term Objective
Fawell Dam Modification	Modify dam to allow fish passage	Raise fIBI upstream of structure
Fullersburg Woods Dam Modification and Stream Restoration	Improve dissolved oxygen and aquatic habitat (QHEI), Reduce inputs of nutrients and sediment	Raise mIBI and fIBI
Oak Meadows Golf Course Dam Removal and Stream Restoration	Improve dissolved oxygen and aquatic habitat (QHEI), Reduce inputs of nutrients and sediment	Improve fish passage and raise mIBI
Spring Brook Restoration and Dam Removal	Improve aquatic habitat (QHEI), Reduce inputs of nutrients and sediment	Raise mIBI and fIBI
Southern East Branch Stream Enhancement	Improve aquatic habitat (QHEI), Reduce inputs of nutrients and sediment	Raise mIBI and fIBI
Southern West Branch Physical Enhancement	Improve aquatic habitat	Raise mIBI and fIBI

Stream Restoration at Fullersburg Woods along Salt Creek



Egan WRP Phosphorus Removal Timeline

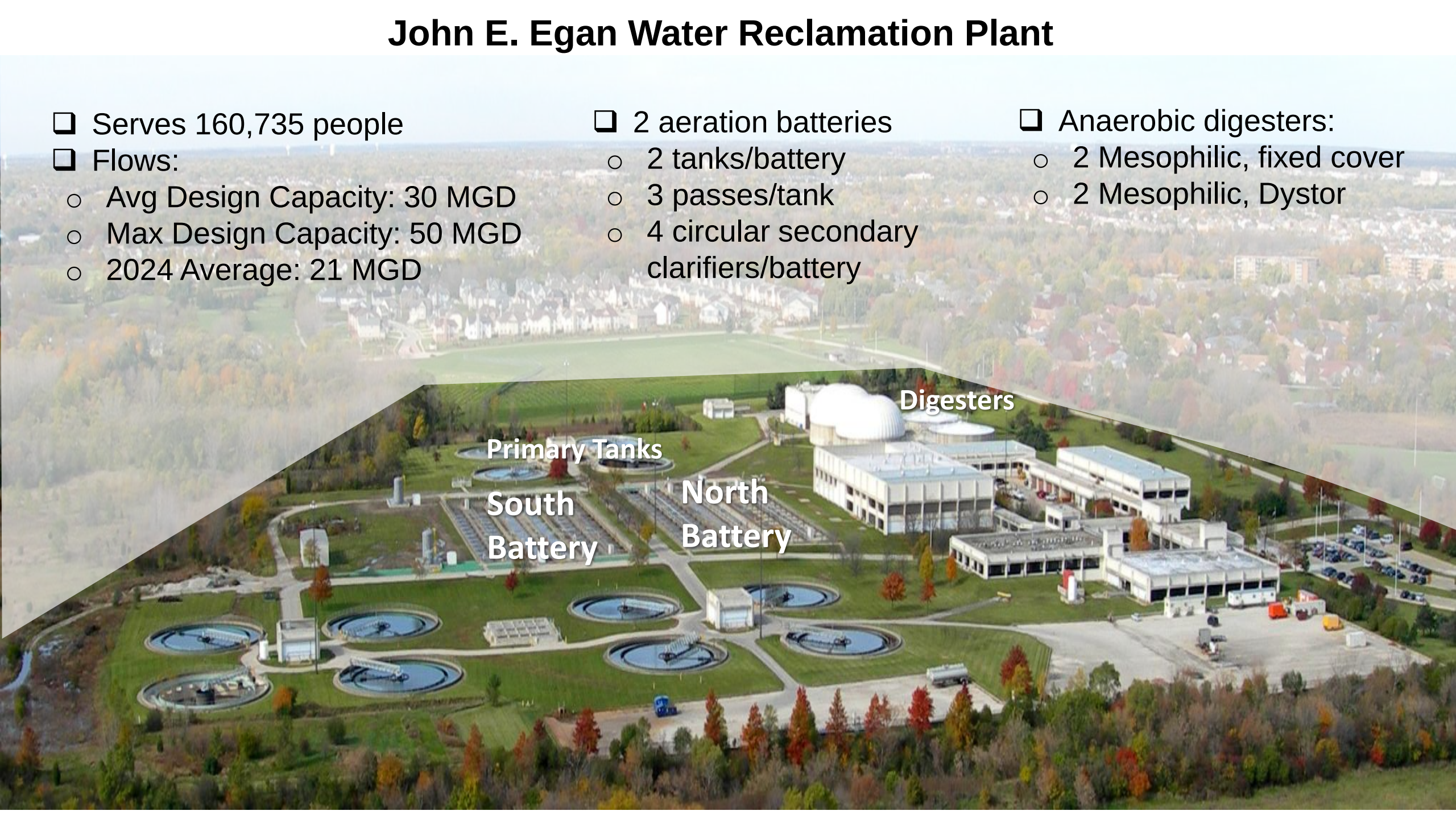


John E. Egan Water Reclamation Plant

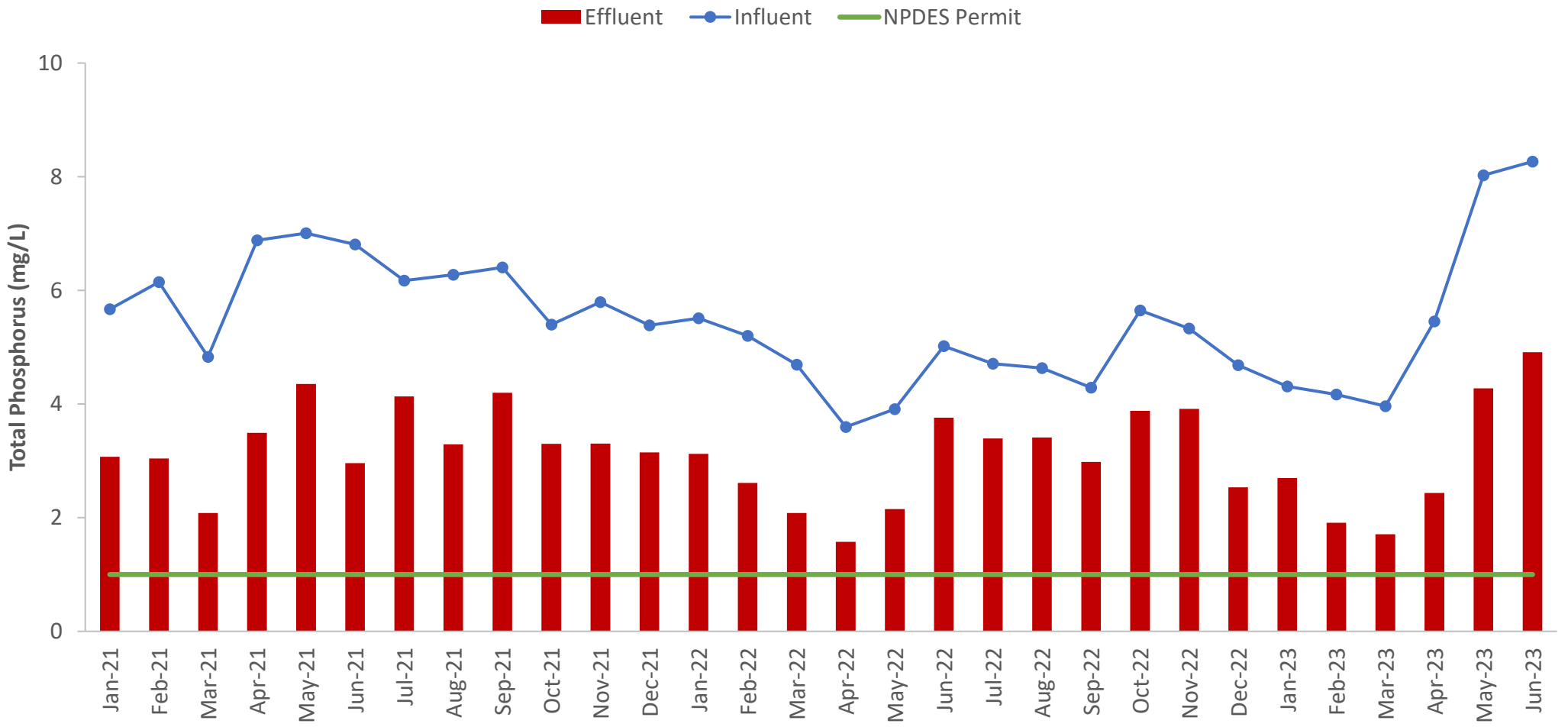
- Serves 160,735 people
- Flows:
  - Avg Design Capacity: 30 MGD
  - Max Design Capacity: 50 MGD
  - 2024 Average: 21 MGD

- 2 aeration batteries
  - 2 tanks/battery
  - 3 passes/tank
  - 4 circular secondary clarifiers/battery

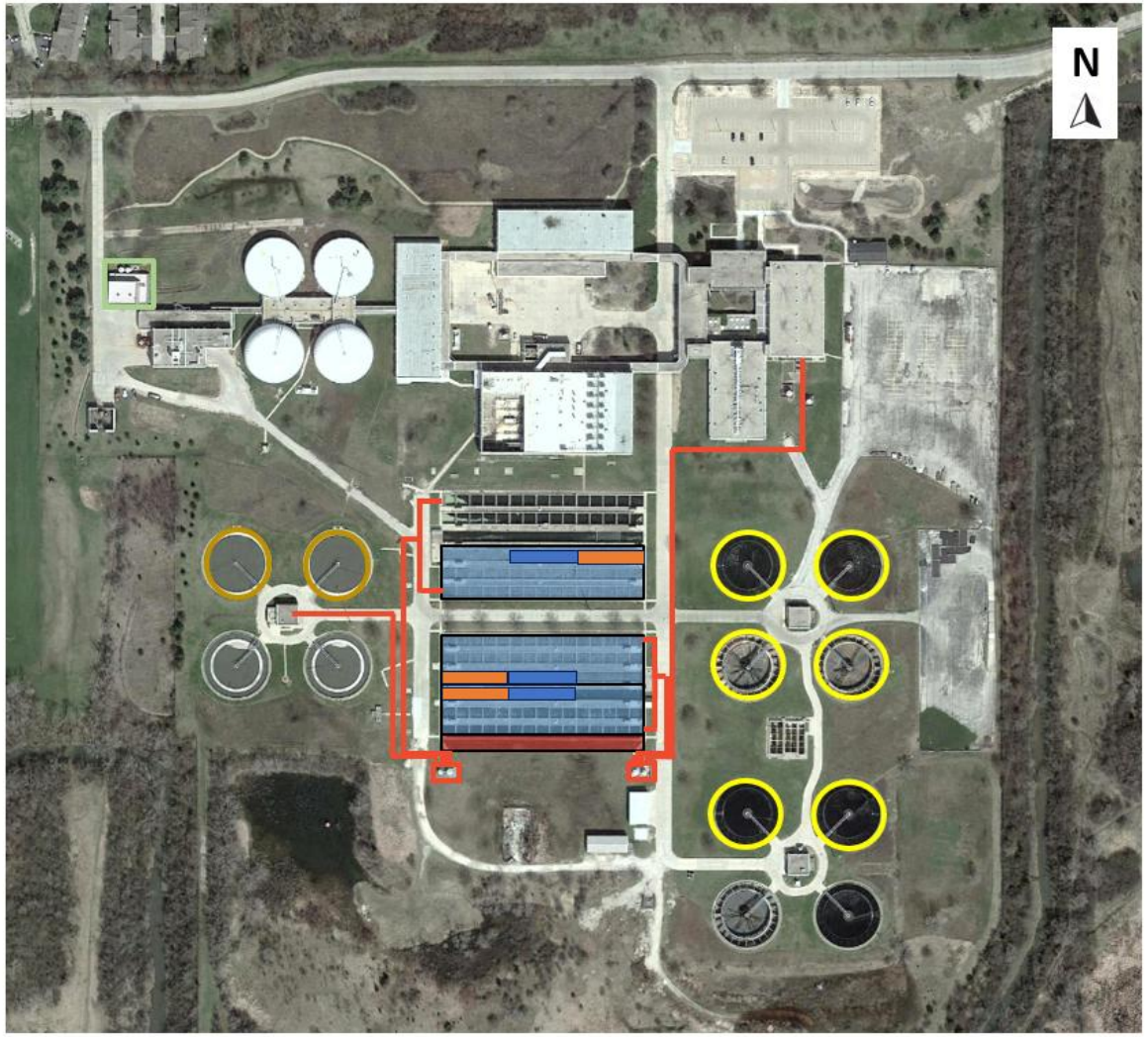
- Anaerobic digesters:
  - 2 Mesophilic, fixed cover
  - 2 Mesophilic, Dystor



Historical Influent and Effluent Monthly Average Total Phosphorus Concentrations at Egan WRP



Phosphorus Feasibility Study Recommendations for Egan WRP



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

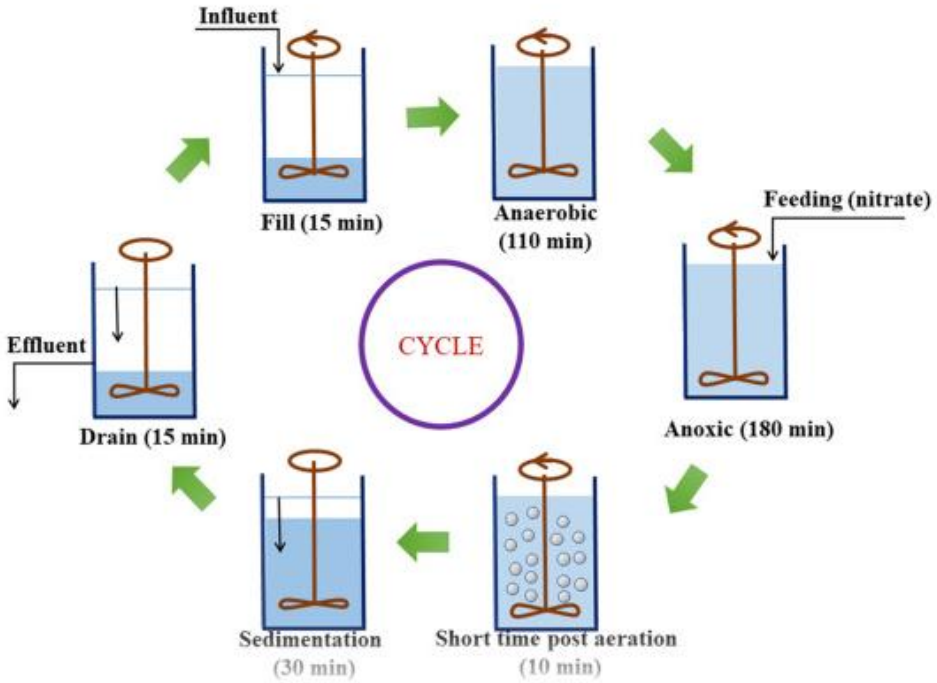
Legend:

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

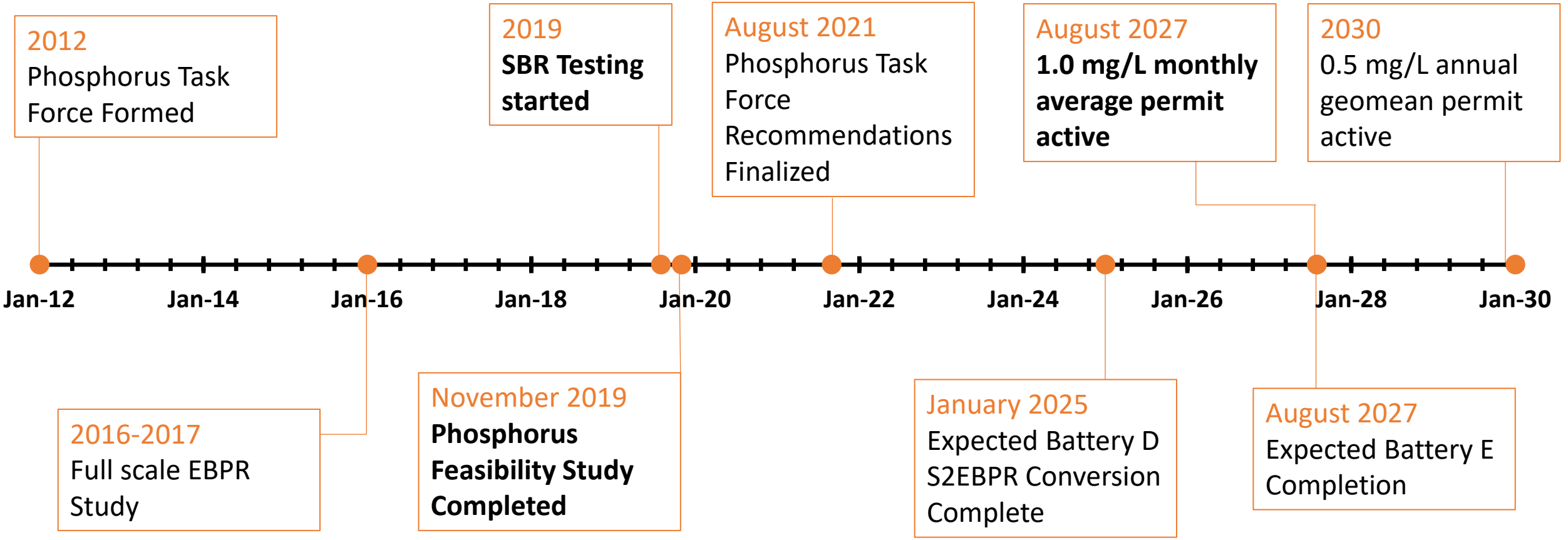
- A modified A/O process with RAS denitrification tank is recommended for EBPR
- Phosphorus sequestration is recommended
  - Estimated that approximately 45 percent of the total influent P load is from return flows
- Installation of chemical dosing system

Challenges

- Factors at Egan WRP that negatively impact EBPR:
  - Influent carbon to phosphorus ratios unfavorable
  - High phosphorus returns from GBT filtrate and centrate possible
  - Primary treatment removes some available carbon
- Currently using sequencing batch reactors (SBRs) to evaluate EBPR possibilities
  - Traditional EBPR
  - EBPR using raw influent (bypass primary treatment)
  - S2EBPR
  - S2EBPR using raw influent



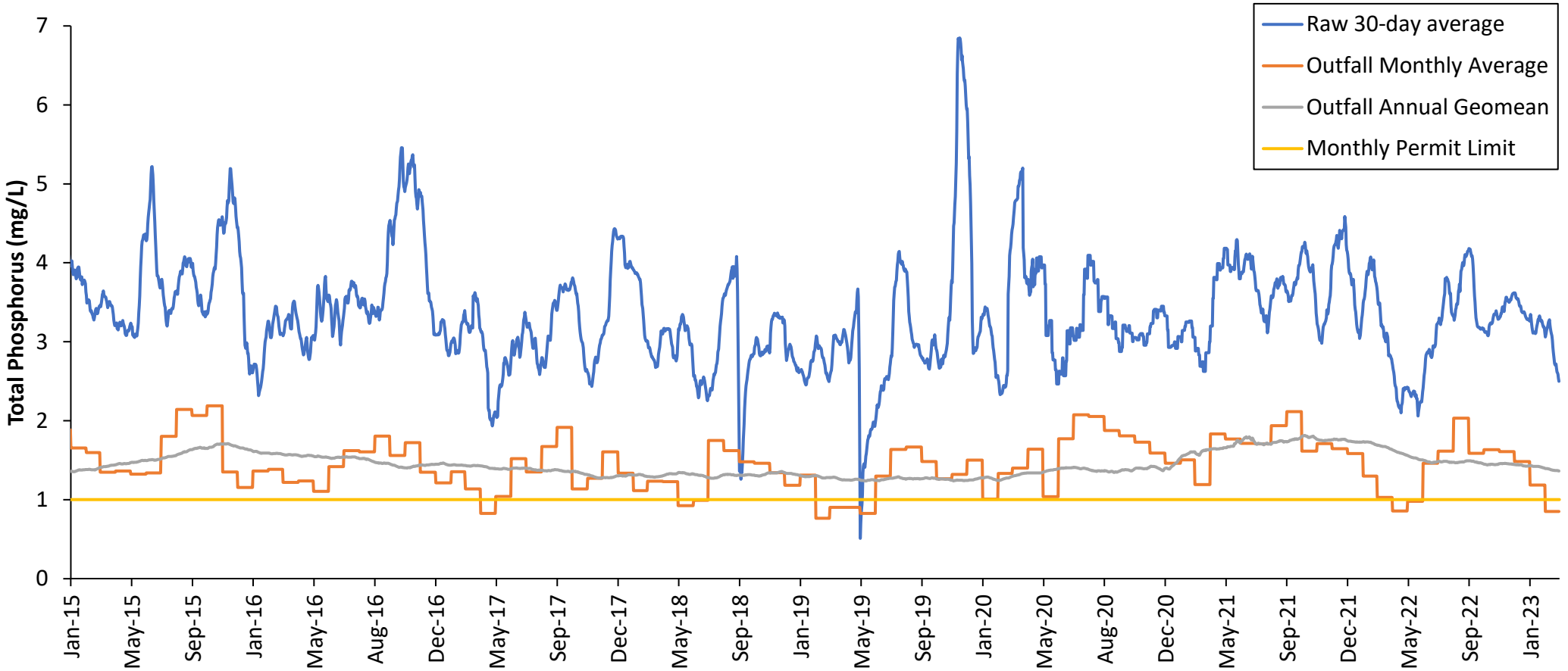
O'Brien WRP Phosphorus Removal Timeline



Terrence J. O'Brien Water Reclamation Plant

- Serves 1.3 million people
- Flows:
  - Avg. Design Capacity: 333 MGD
  - Max Design Capacity: 450 MGD
  - 2024 Average: 201 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

Historical Effluent Monthly Average Total Phosphorus Concentrations at O'Brien WRP

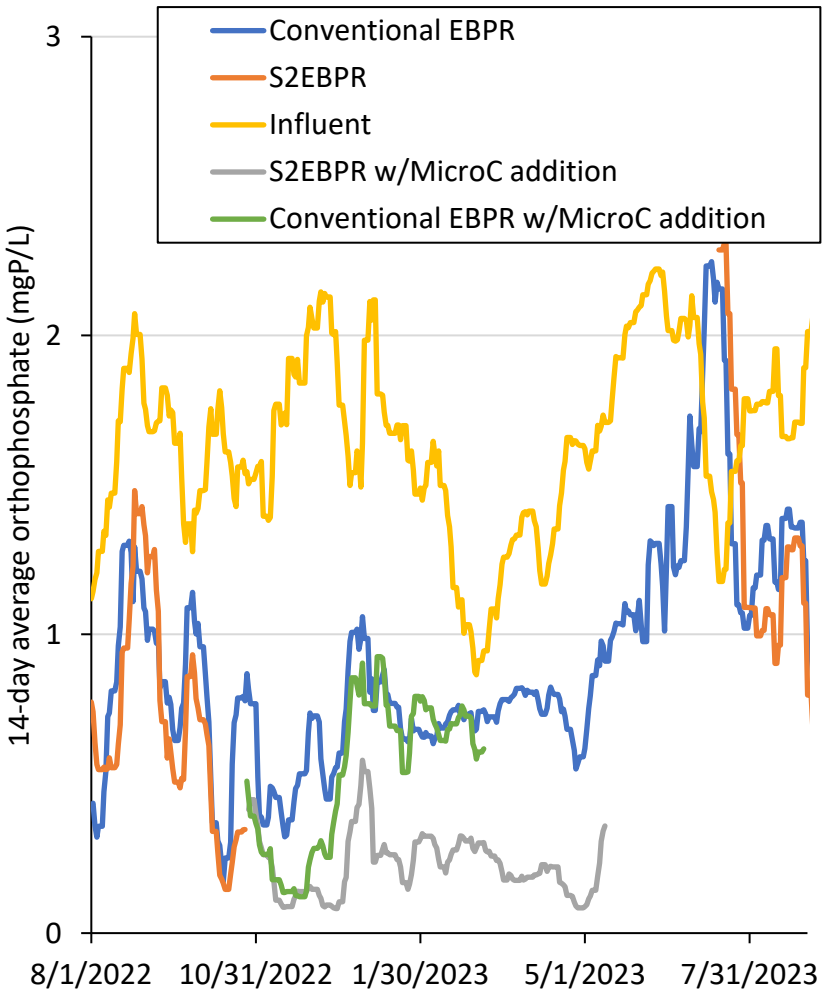


Phosphorus Feasibility Study Recommendations for O'Brien WRP

- ❑ Converting to EBPR 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
  - Utilize Side-Stream Enhanced Biological Phosphorus Removal (S2EBPR)

S2EBPR: Return activated sludge (RAS) diverted through a separate reactor to foster production of additional bioavailable carbon

Pilot Sequencing Batch Reactors (2022-23)



- EBPR met 1 mg/L most of the time, but not all the time
- S2EBPR performed comparably to conventional EBPR
- Supplemental carbon with S2EBPR worked very well

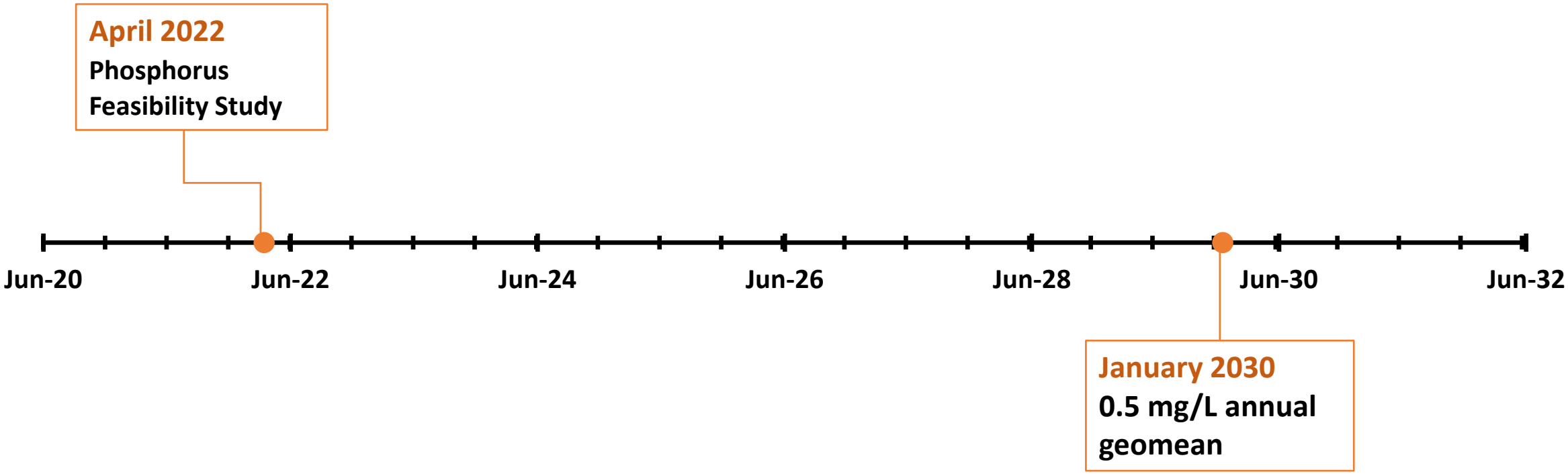
O’Brien WRP Capital Improvements Underway

- ❑ 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 EBPR 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 scheduled to be completed in late 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)

Lemont WRP Phosphorus Removal Timeline



Lemont Water Reclamation Plant

- Serves nearly 20,000 people

- Flows:
  - Avg Design Capacity: 2.3 MGD
  - Max Design Capacity: 4 MGD
  - 2024 Average: 2.7 MGD

- 1 aeration batteries
  - 3 tanks
  - 1 passes/tank
  - 4 circular secondary clarifiers/battery

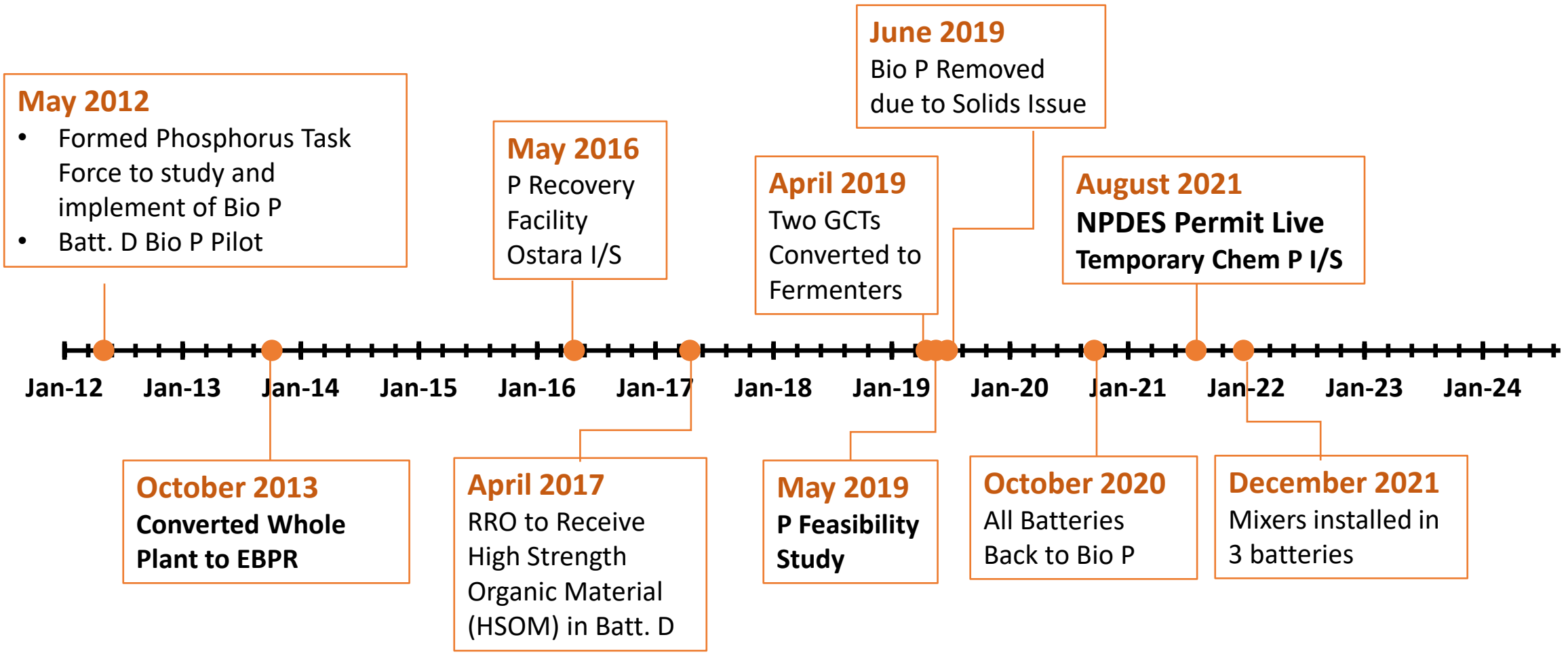
Phosphorus Feasibility Study Recommendations for Lemont WRP

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

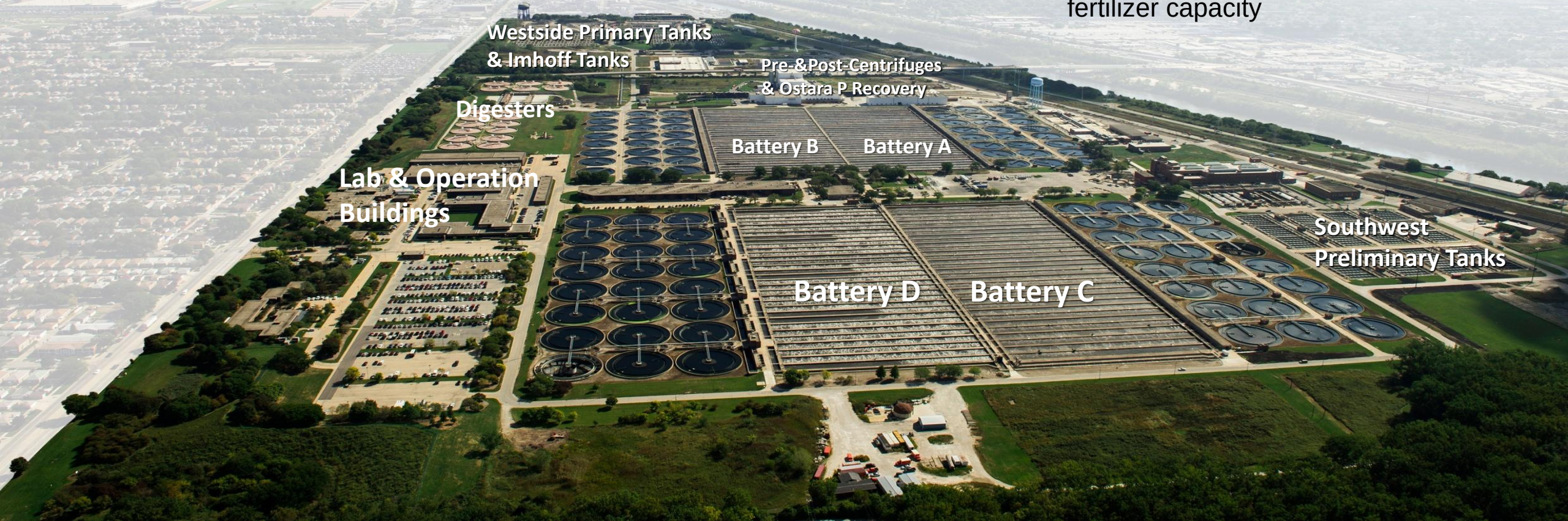
Stickney WRP Phosphorus Removal Timeline



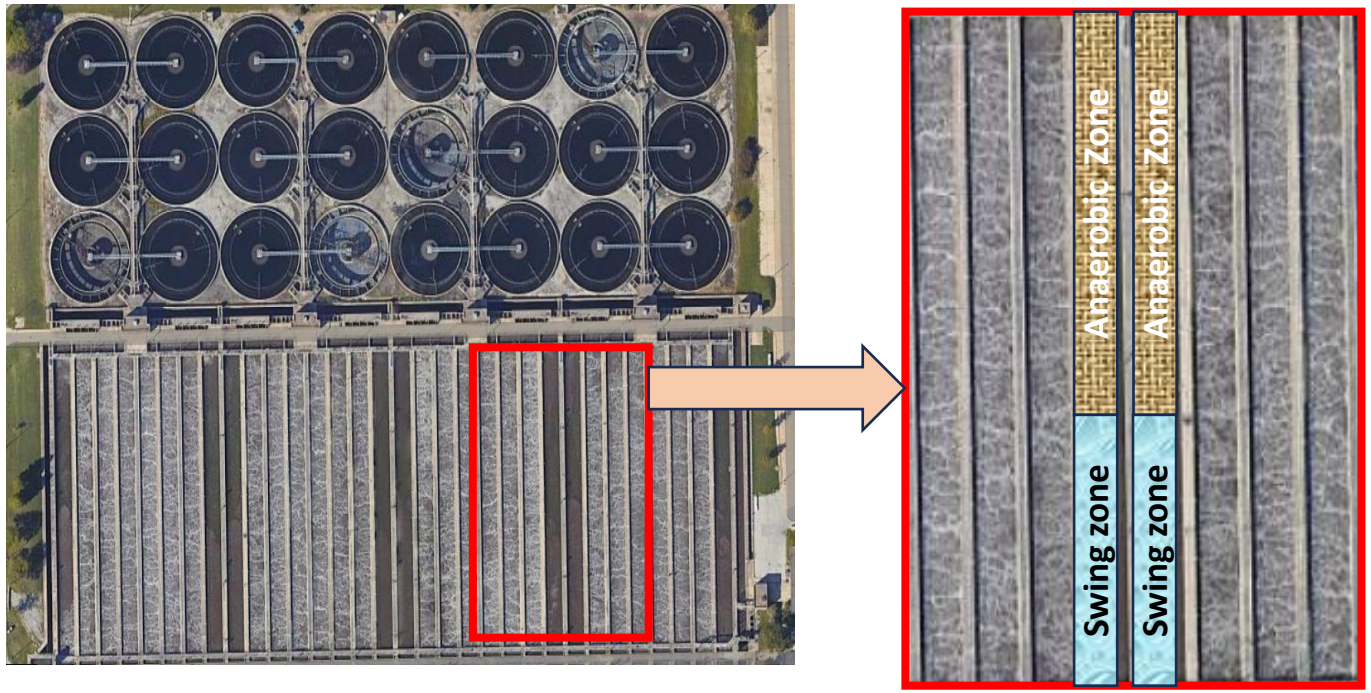
Stickney Water Reclamation Plant

- Serves 2.3 million people
- Flows:
  - Avg. Design Capacity: 1,200 MGD
  - Max Design Capacity: 1,440 MGD
  - 2024 Average: 706 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



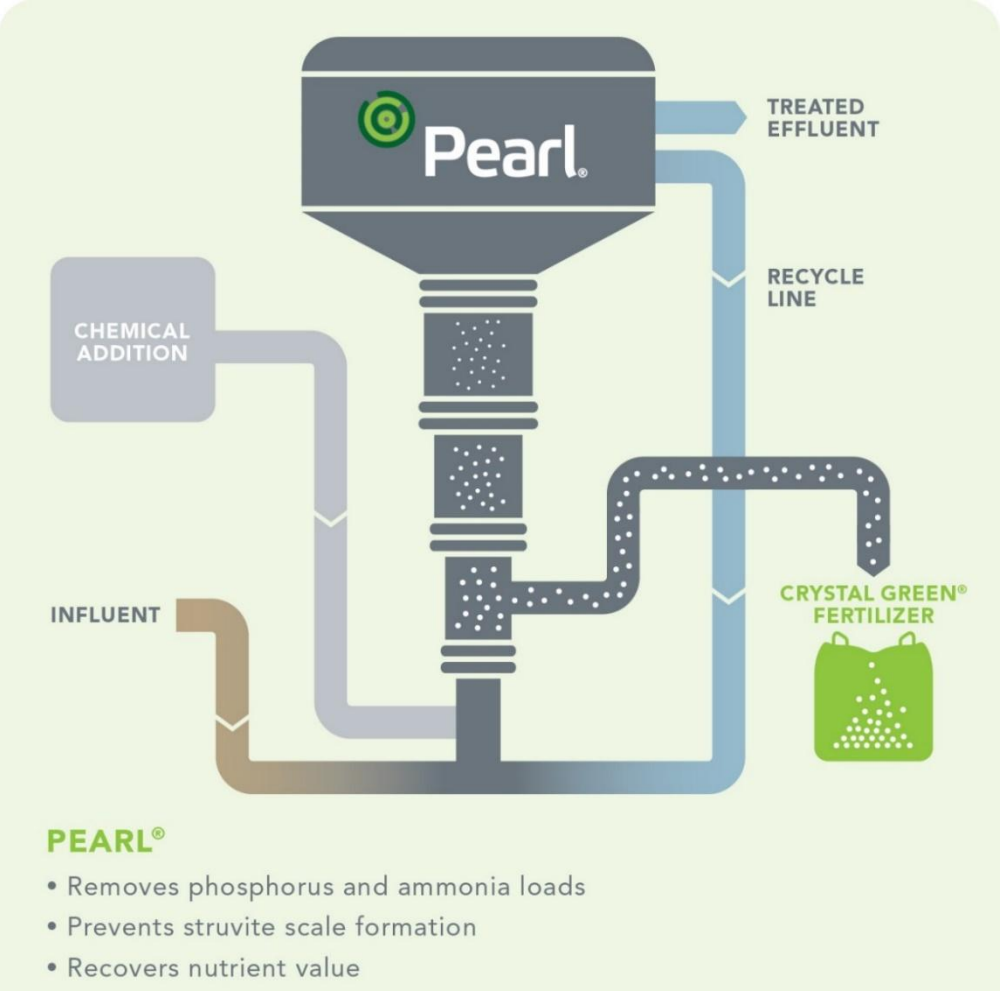
Temporary and Permanent Chemical Phosphorus Removal Facilities



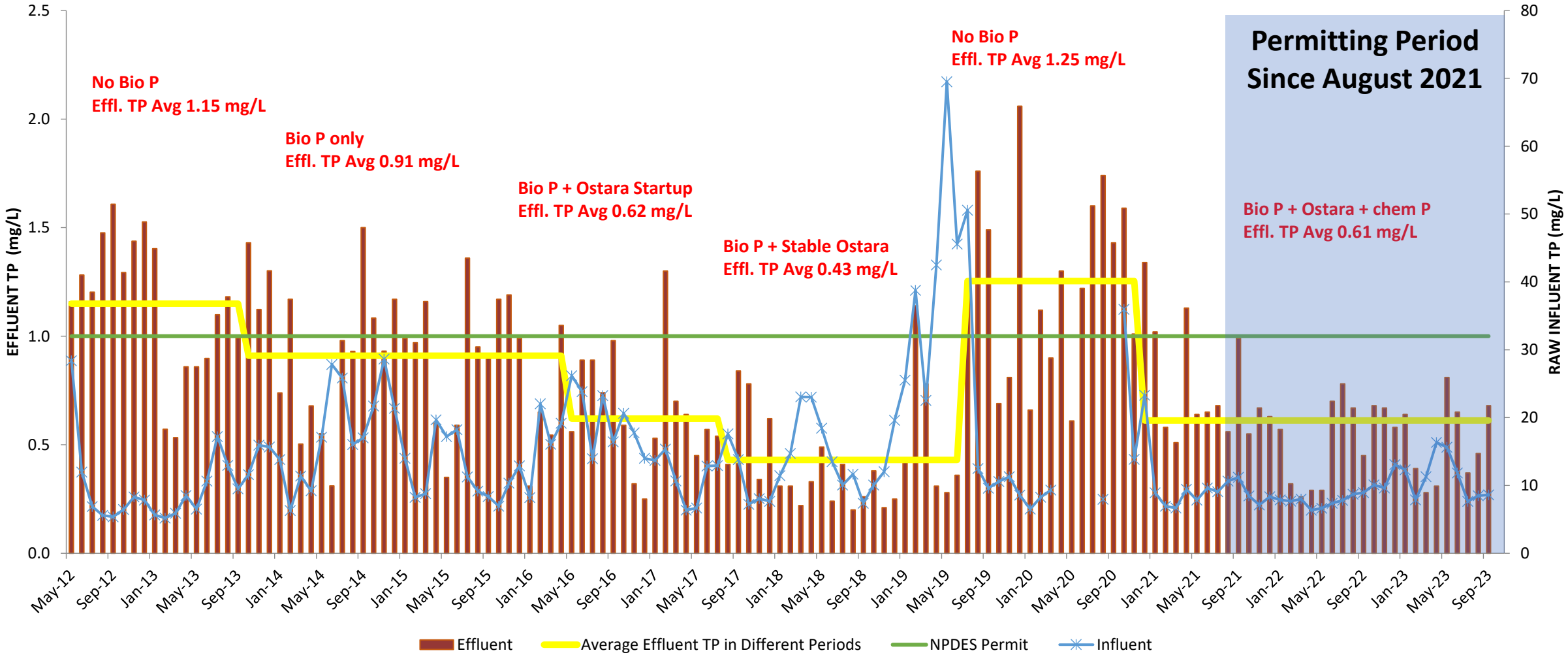
- ❑ Dosing starts if outfall ortho P goes above target (0.7 mg/L)
- ❑ Permanent chemical dosing systems expected completion in late 2025

Ostara® Post-Centrate Treatment

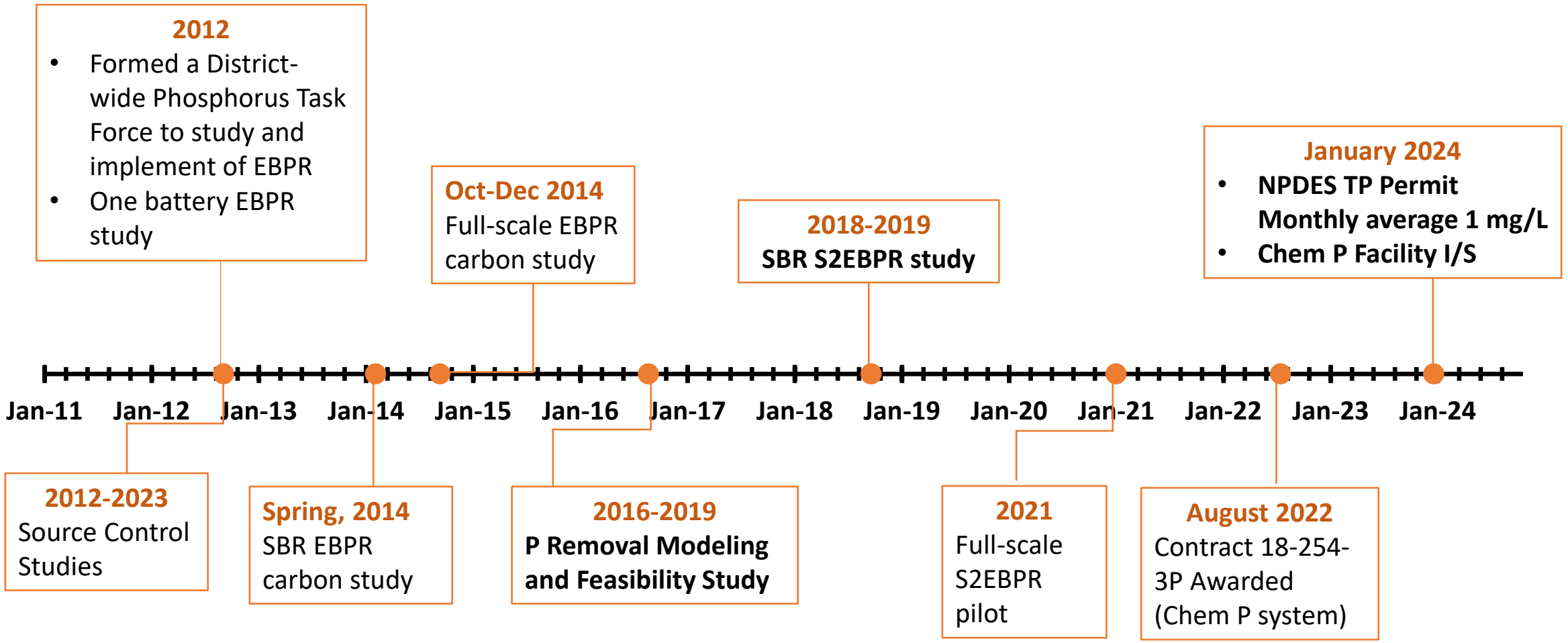
- Fluidized bed reactor
- Crystallization of struvite
  - Inject NaOH to raise pH to 7.7/7.8
  - Inject $MgCl_2$ at a molar ratio of 1.1 to 1 (Mg to P)
- Crystals grow to pellets and then harvested



Influent and Effluent Monthly Average Total Phosphorus Concentrations at Stickney WRP



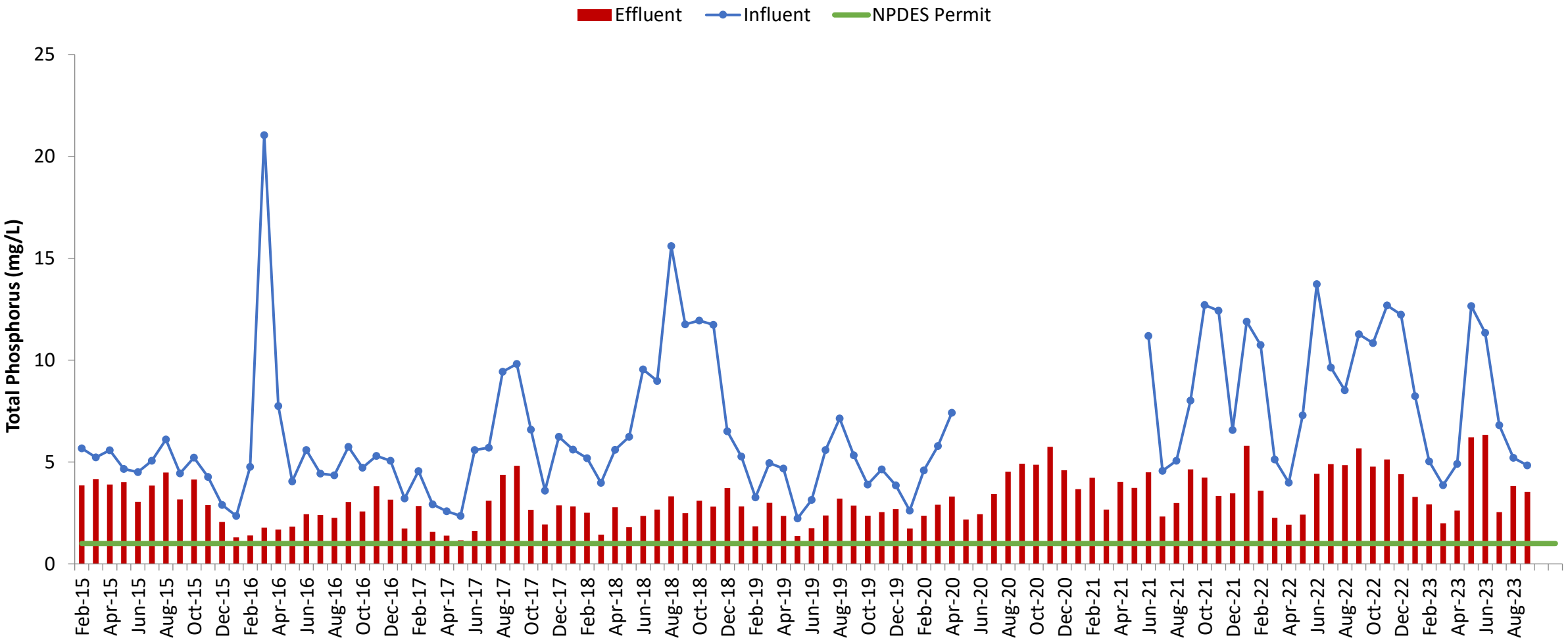
Calumet WRP Phosphorus Removal Timeline



Calumet Water Reclamation Plant

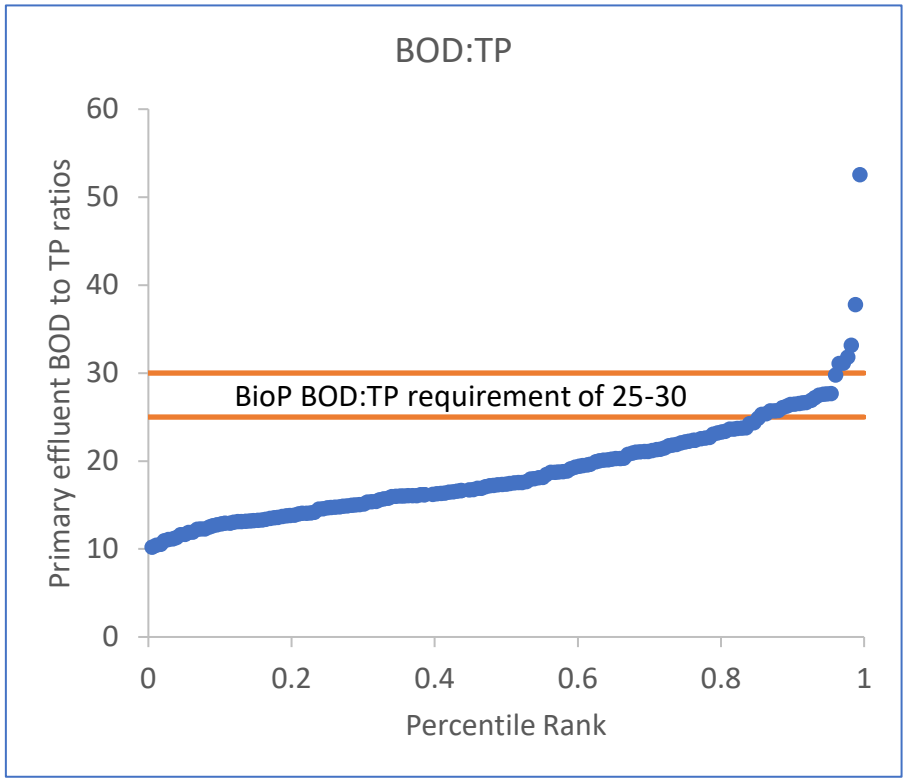
- Serves over 1 million people
- Flows:
  - Avg Design Capacity: 354 MGD
  - Max Design Capacity: 430 MGD
  - 2024 Average: 244 MGD
- 5 aeration batteries
  - 48 aeration tanks
  - Conventional one or two passes/tank
  - 52 circular secondary clarifiers
- Anaerobic Digester
  - 12 Mesophilic, floating cover

Historical Influent and Effluent Monthly Average Total Phosphorus Concentrations at Calumet WRP



2012-2020 SBR and Pilot Testing Outcomes

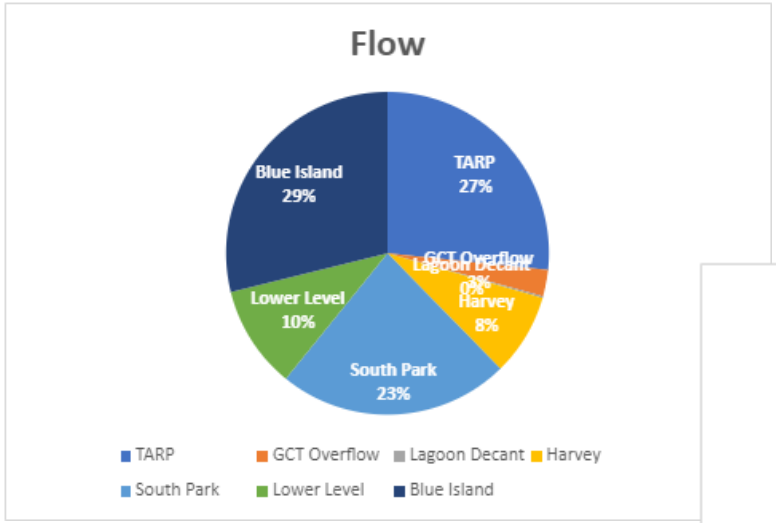
- Is EBPR Possible?
  - Low C/P ratios of influent
  - High industrial P loading that causes variable influent P and spikes

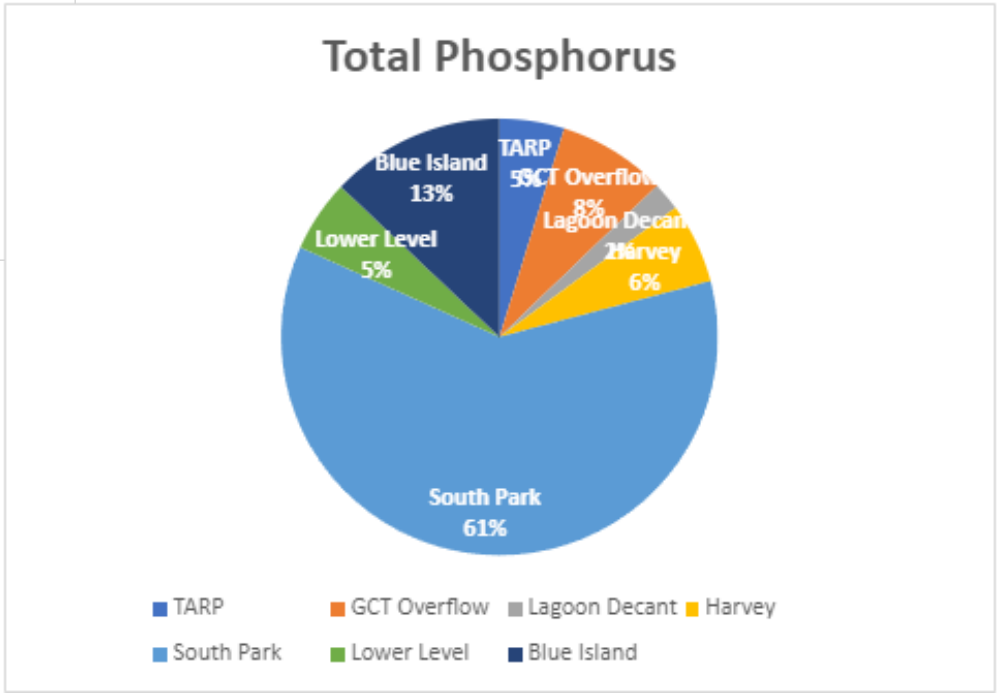


- Chemical P removal suggested by the Feasibility Study but recommended further look into S2EBPR
- 2012: Full-scale EBPR pilots in Batteries A and E1 failed due to low C/P
- 2014: SBR EBPR pilot worked with carbon dosing
- 2014: Full-scale EBPR pilot in Battery A worked with carbon dosing but not enough 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

Permanent Chemical Dosing Facility

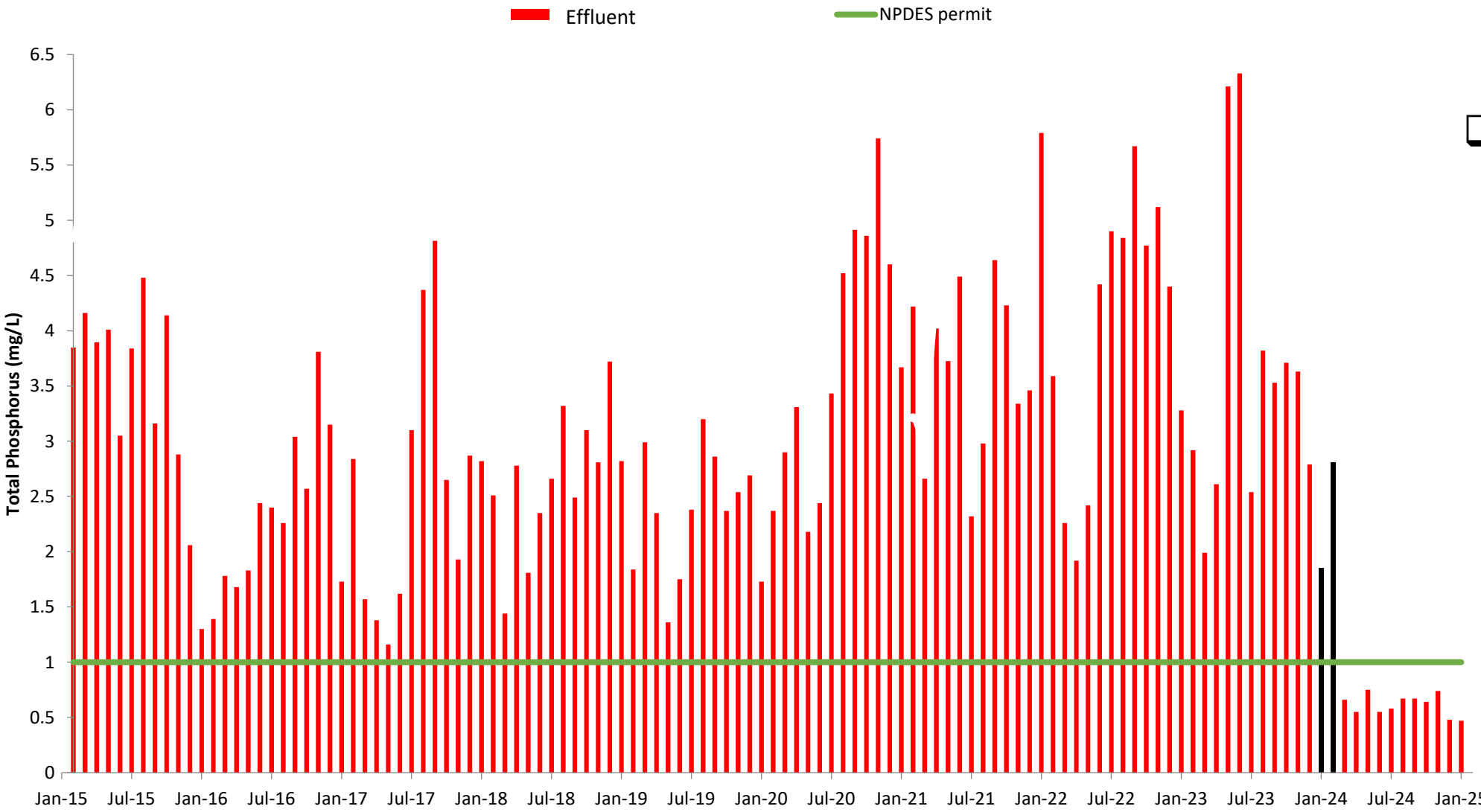
Source Investigation for High Influent Phosphorus Concentrations





- 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

Current Effluent Monthly Average Total Phosphorus Concentrations at Calumet WRP



- Calumet WRP has met the NPDES TP permit of 1 mg/L with a monthly average of 0.47 mg/L in January 2025

Summary

- The District utilizes ferric chloride dosing and EBPR, when possible, to comply with current total phosphorus permit limits
  - Bioavailable carbon is often a limitation for effective and consistent biological phosphorus removal
  - S2EBPR has been explored as an option to supplement bioavailable carbon
  - Infrastructure costs associated with tank modification, piping, and pumps are limitations for biological removal
  - Chemical dosing is commonly viewed as a stable and comfortable alternative
- The District engages in watershed partnerships to facilitate changes in riverine systems
  - Goal of improving macroinvertebrate and fish populations
  - Acknowledge that a reduction in phosphorus loads alone will not achieve this goal

Questions?

Robert Swanson
Senior Environmental Research Scientist
Metropolitan Water Reclamation District of Greater Chicago
SwansonR@mwrd.org
708.588.4146