Achieving Chesapeake Bay Nutrient Limits at a Large WWTP

Ohio Water Environment Association

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RK&K

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Agenda

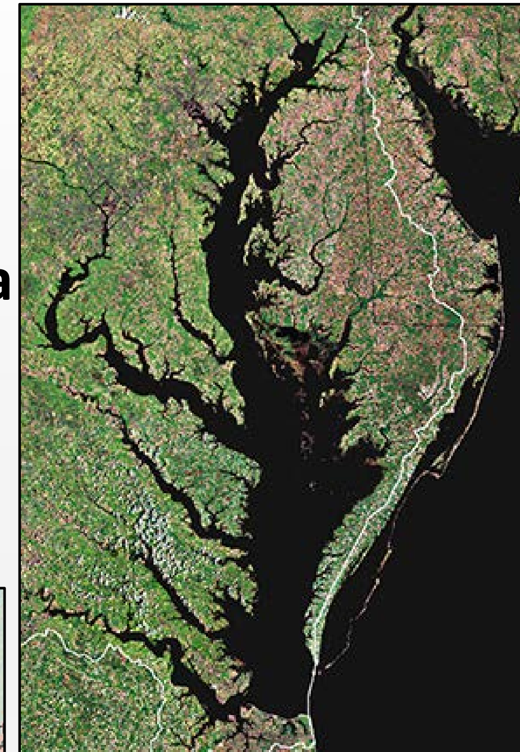
- Background – Nutrient Removal & Patapsco WWTP
- Process Performance
- Treatment Process Considerations
- Site-Specific Challenges
- Construction
- ENR Facility

Acknowledgements

- City of Baltimore – Department of Public Works
  - Office of Engineering and Construction
  - Operations Division
- RK&K Design & Construction Administration Staffs
  - Terry Zentkovich, PE – RK&K Deputy PM / Lead Engineer
  - Jerry Henger & Joe Tack – RK&K Construction Administrators
- De Nora (formerly Severn Trent Services) / KET
- Kruger / TLC Environmental
- Balfour Beatty Infrastructure, Inc. (formerly FruCon)

Restoring the Chesapeake Bay

- Largest estuary in U.S., 3rd largest in world
- Nearly 200 miles long
- Area 4,479 square miles in Maryland & Virginia
- Bay & tidal estuaries shoreline = 11,684 miles
- Watershed = 64,299 square miles
- NY, PA, WV, DE, MD, VA & DC



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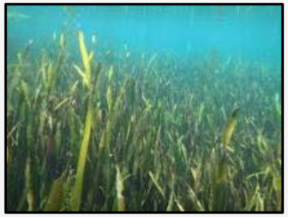
Restoring the Chesapeake Bay

- Immense ecological diversity
  - Characteristic of an estuary
- Major regional economic driver
  - Commercial shipping/Baltimore's Port
  - Commercial fishery
  - Recreational boating, fishing, crabbing
  - Valuable shoreline real estate

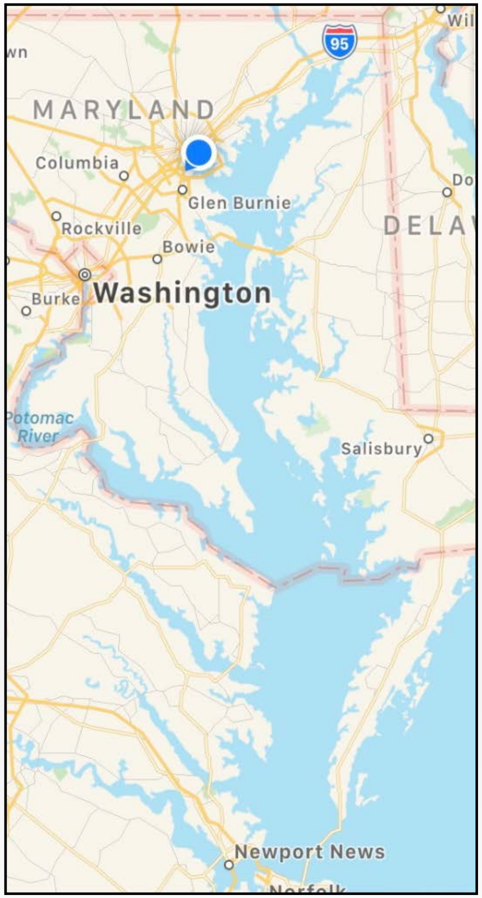




State of the Chesapeake Bay

- **Deterioration apparent in 1970s**
  - **Decreasing water clarity**
  - **Declining fisheries**
  - **Disappearing submerged vegetation**
  - **Chesapeake Bay Foundation's**
    ***2018 State of Bay Report* score = 33 out of 100**
- **Key stressors**
  - **Population in watershed =18,100,000 (2015)**
    - **Creates wastewater (sewage)**
    - **Generates urban runoff (storm water)**
  - **Overharvesting fisheries**
  - **Farming activities**
    - **Sediments, nitrogen & phosphorus**



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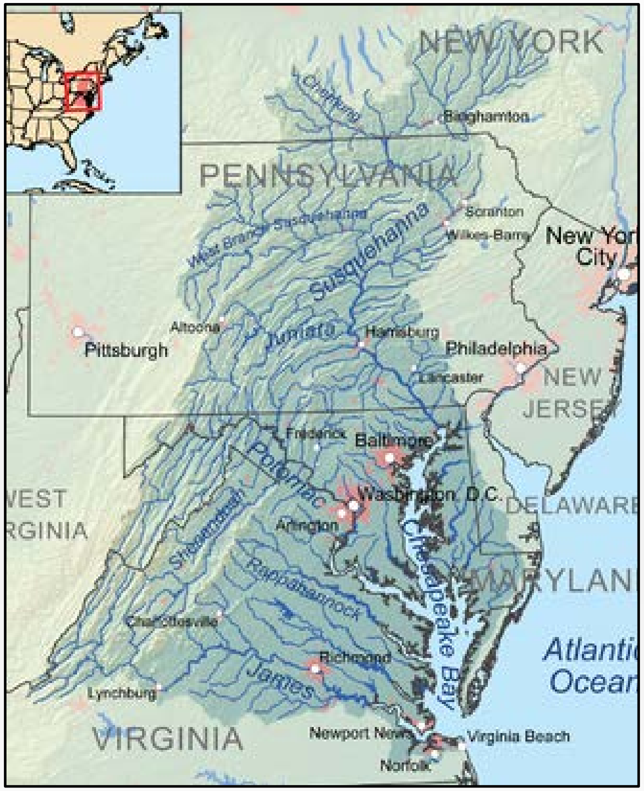
Saving the Chesapeake Bay

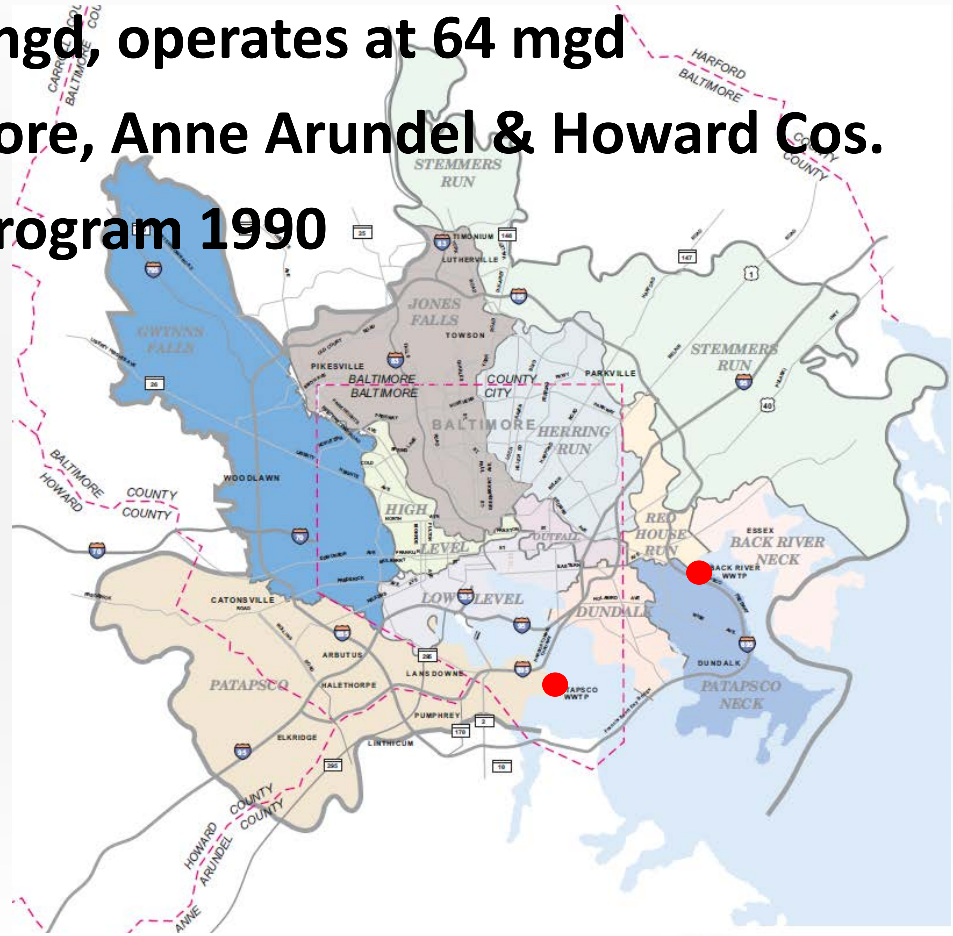
- Focus of clean up initiatives in past 35 years
  - Increase dissolved oxygen
  - Increase water clarity
  - Reduce nutrients
  - Reduce sedimentation
- Restoration goal – increase natural resources
  - Underwater grasses
  - Fish
  - Oyster
  - Blue crabs
- Billions spent to preserve & restore



Point source nutrient removal at WWTPs started in mid-1980s

Baltimore City's WWTPs

- Baltimore City owns & operates 2 WWTPs – 45% of MD capacity
- Back River WWTP – rated at 180 mgd, operates at 140 mgd
- Patapsco WWTP – rated at 81 mgd, operates at 64 mgd
- Serves City; portions of Baltimore, Anne Arundel & Howard Cos.
- City started nutrient removal program 1990
- *ENR upgrades required - 2000*
  - Annual effluent mass loadings of
    - TN = 4 mg/L
    - TP = 0.3 mg/L
  - Design for concentrations of
    - TN = 3 mg/l
    - TP = 0.3 mg/L



Patapsco Wastewater Treatment Plant

- Rated capacity 81 mgd
- Located in industrial area
- Average 64 mgd, peak > 350 mgd, significant industrial component
- NPDES MD0021601 compliant – Secondary effluent to Patapsco R.
- Features:
  - High purity oxygen biological system
  - Heat drying / pelletization of biosolids

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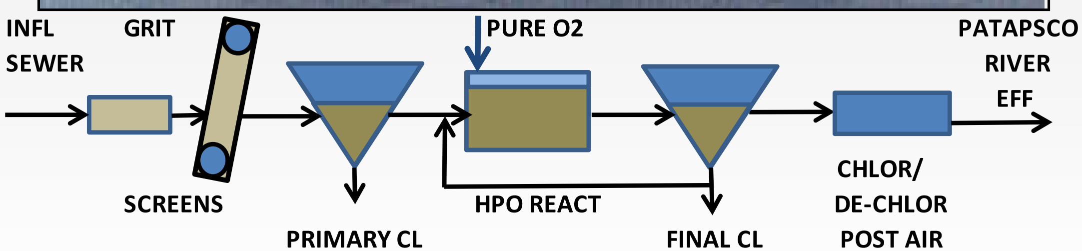
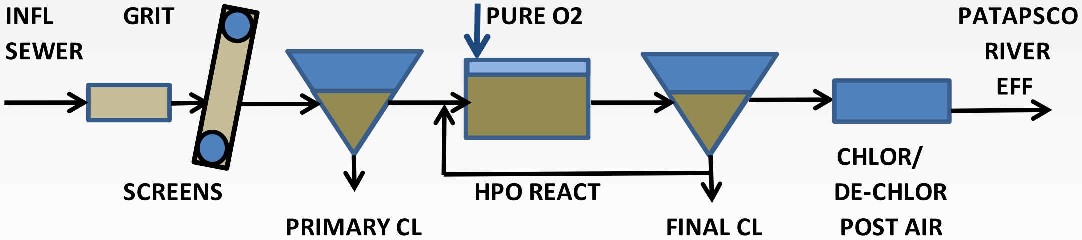
Pre-ENR Liquid Treatment Process

Grit Removal Facility



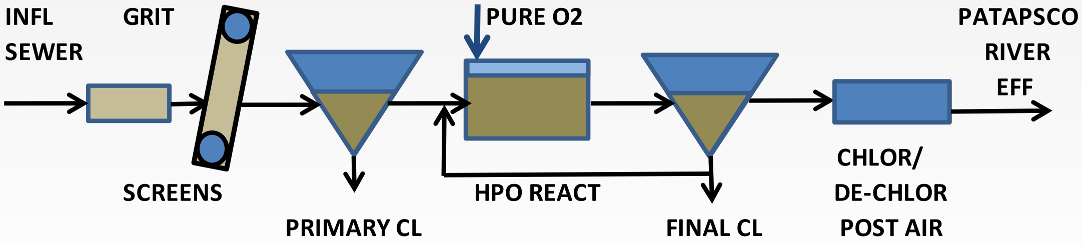
Pre-ENR Liquid Treatment Process

Screen Building



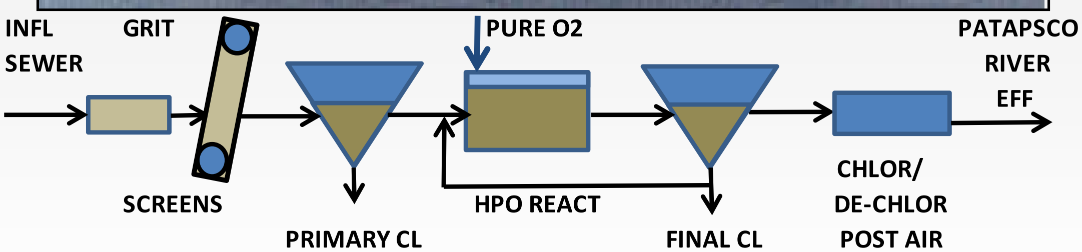
Pre-ENR Liquid Treatment Process

Primary Clarifiers



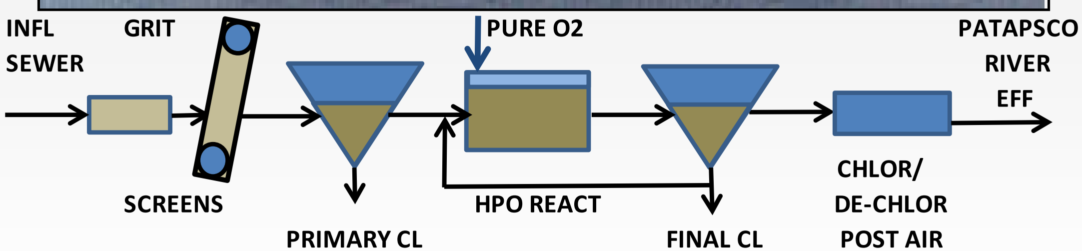
Pre-ENR Liquid Treatment Process

Biological Treatment
In High Purity
Oxygen Reactors



Pre-ENR Liquid Treatment Process

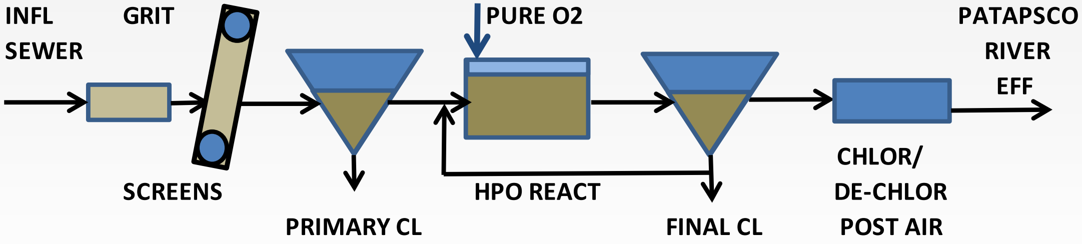
Final Clarifiers



Pre-ENR Liquid Treatment Process

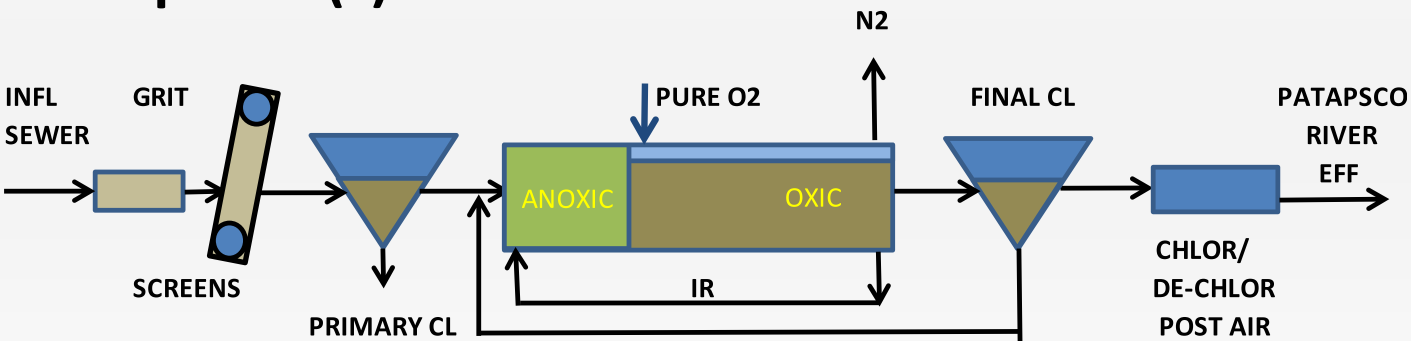
Chlorination / Dechlorination Facilities

Outfall to Patapsco River



MLE for Nutrient Removal at Patapsco

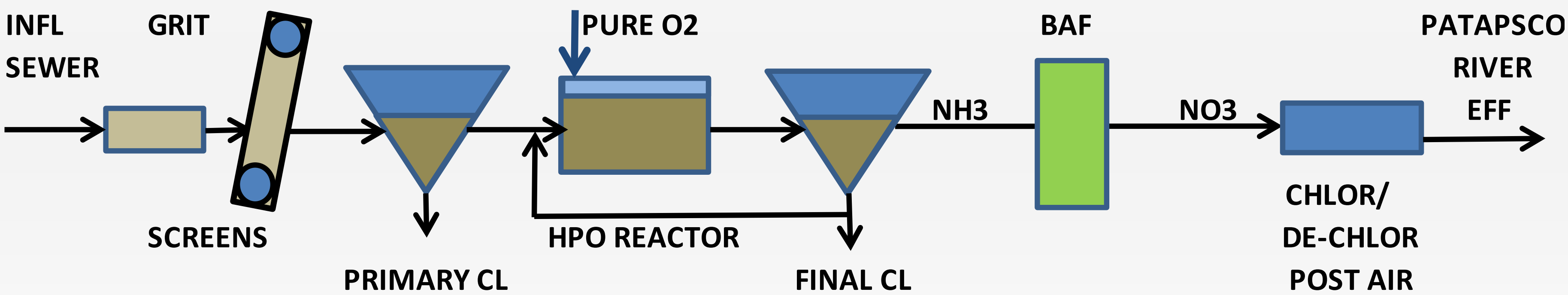
- Previous attempts at nitrogen removal were unsuccessful with a new HPO reactor configured as Modified Ludzack-Ettinger
- MLE was good idea – primary clarifier effluent BOD as carbon source for denitrification - saves costs for methanol
- Could not sustain nitrification
- Nitrification inhibition suspected as cause, but specific compound(s) were never identified



HPO REACTOR
MLE CONFIGURATION

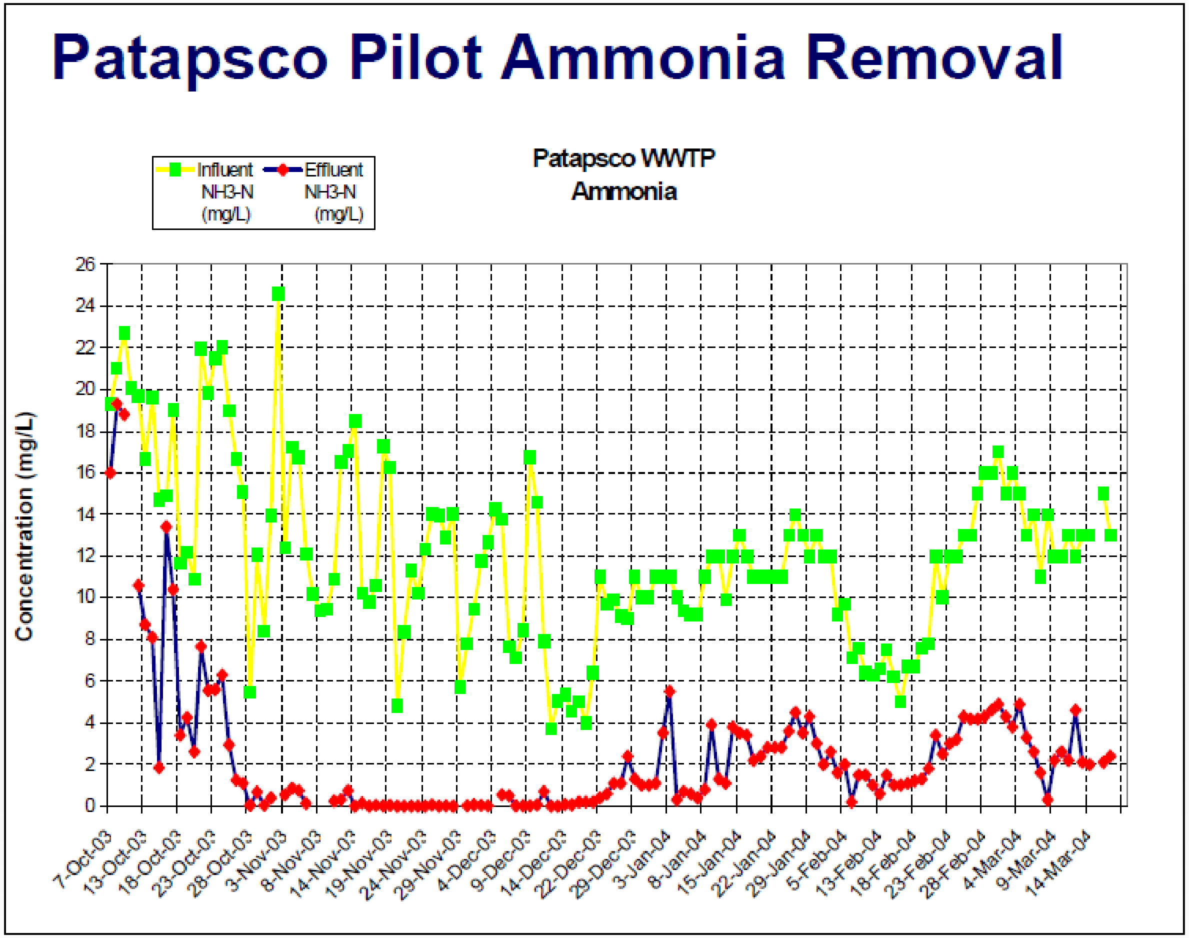
Success with Biological Aerated Filter

- ENR process selection performed in Preliminary Design
- City & JMT/KCI JV evaluated process alternatives
- Pilot testing by JMT/KCI JV demonstrated sustained cold weather nitrification of HPO effluent using a biological aerated filter (BAF)
  - BAF is an attached growth aerobic biological process
- HPO system mitigated inhibition, but mechanism not known



BAF Pilot Testing for Nitrification

- **Multiple BAF vendors were pilot tested**
  - **IDA's BIOFOR**
  - **Kruger's BIOSTYR**
  - **Severn Trent's SAF**



BIOSTYR Results

Downflow Sand Filter for Denitrification

- Proven process in U.S. for nitrogen & TSS removal
- Good nitrate removal in warm & cold weather
- Methanol used as supplemental carbon source
- No pilot testing was performed in Preliminary Design

le 1: Howard Curren AWTP – Tampa, FL (100 MGD)

Period	MGD	BOD (mg/l)	SS (mg/l)	TN (mg/l)	TKN (mg/l)	NH_3-N (mg/l)	NOx-N (mg/l)
1980-1988	51.3	3.4	2.8	2.8	1.7	0.17	1.06
1989-1998	55.5	2.4	1.6	2.4	1.56	0.18	0.87
1999	50.45	2.6	0.9	2.52	1.46	0.13	1.01
2000	48.5	3.1	0.7	2.24	1.29	0.14	0.95
2001	49.7	2.3	0.8	2.28	1.21	0.15	1.06
Average	51.0	2.76	1.4	2.4	1.5	0.15	0.99

le 2. Cold Weather Performance Data – Northeast US (Monthly Averages)

	MGD	Wastewater Temperature degrees C	Influent NO_3-N mg/l	Effluent NO_3-N mg/l
Nov 2003	1.01	14.9	11.56	0.45
Dec 2003	1.77	11.6	8.25	0.47
Jan 2004*	1.13	8.5	10.91	0.48
ADF Design	1.0	8	13	0.5
Peak-Day Design	2.36	8	11	0.5

ENR Facilities Location

- Only one location at WWTP site was available

Existing Treatment Facilities

Existing Chlorination/ Dechlorination Facilities

ENR Site Prior to Construction

Former Site & New ENR Facility

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ENR Facility

Tertiary PS

Denitrification Filter

Biological Aerated Filter

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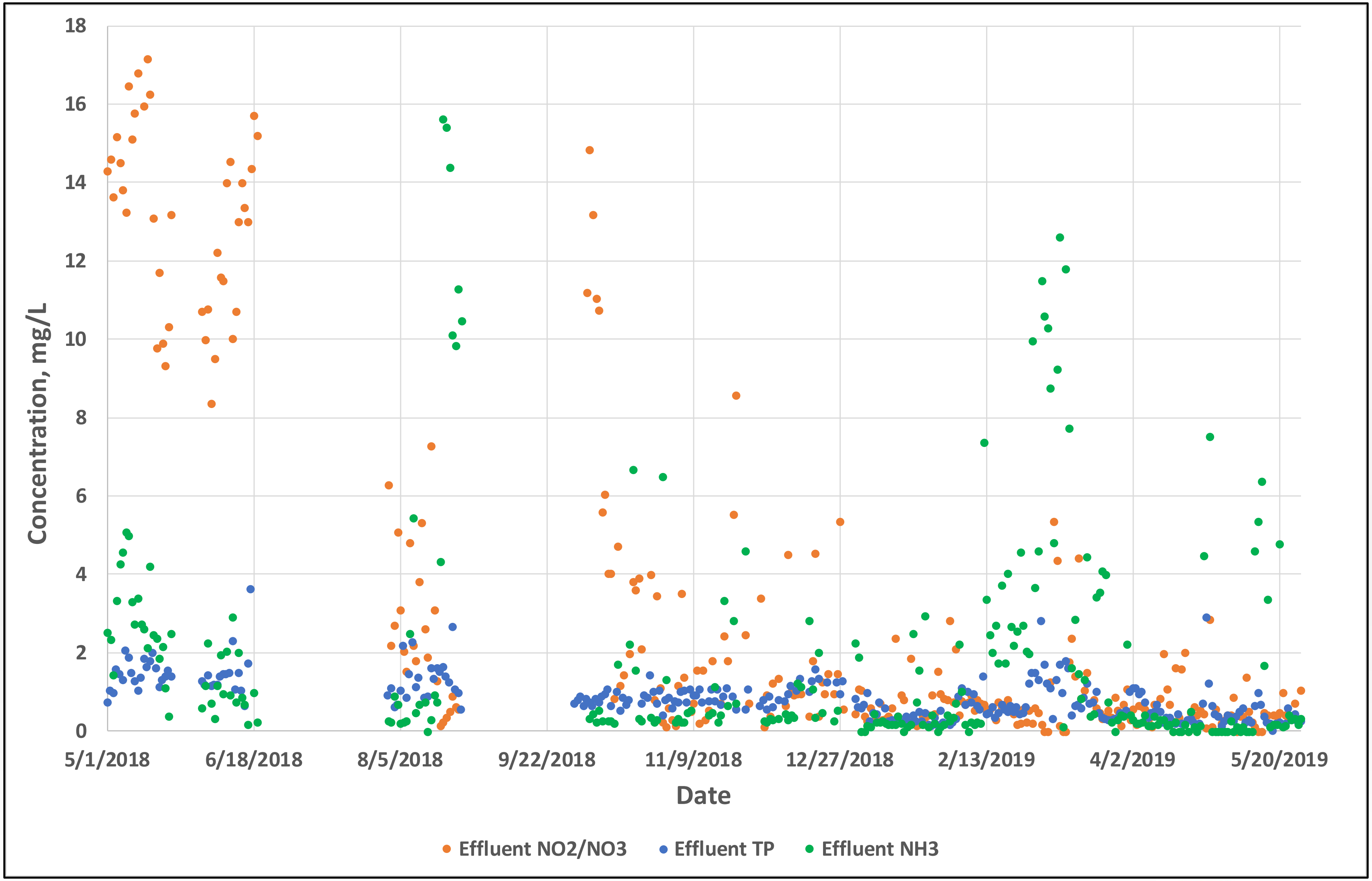
ENR Facility

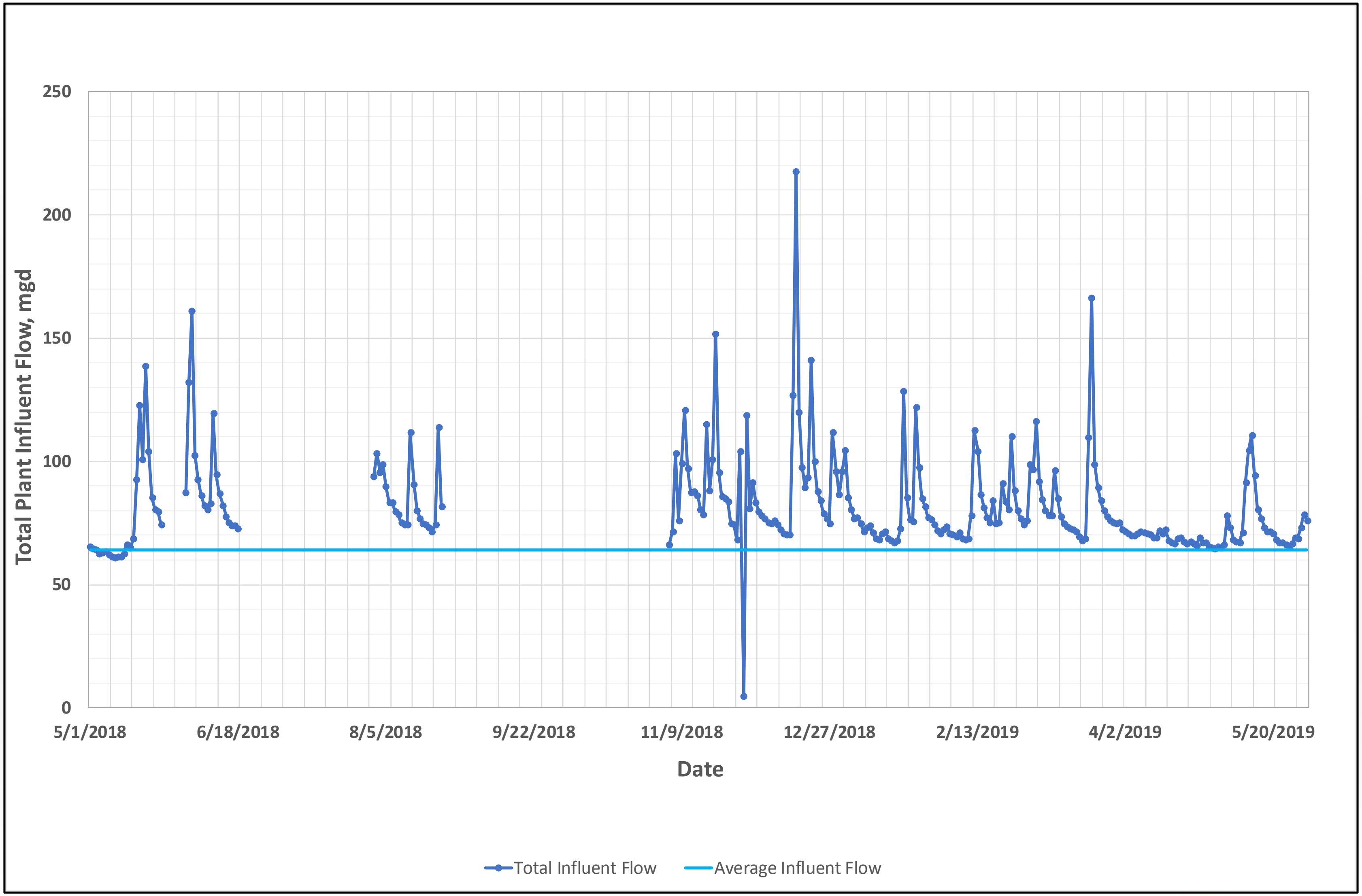
Patapsco ENR Project Statistics

- 22 BAF Cells – 28 ft x 56.67 ft
- 34 Denitrification Filter Cells – 11.5 ft x 100 ft
- 72,000 gallons methanol storage
- Tertiary PS – 150 mgd capacity
- New ENR Operations Building
- Plant-wide process control system upgrade – ABB 800xA
- ENR built in two construction contracts - $246 M – both by BBI
- Upstream improvements in companion project
- Construction started – Ground-breaking Spring 2010
- Equipment testing - Late 2017 / Early 2018

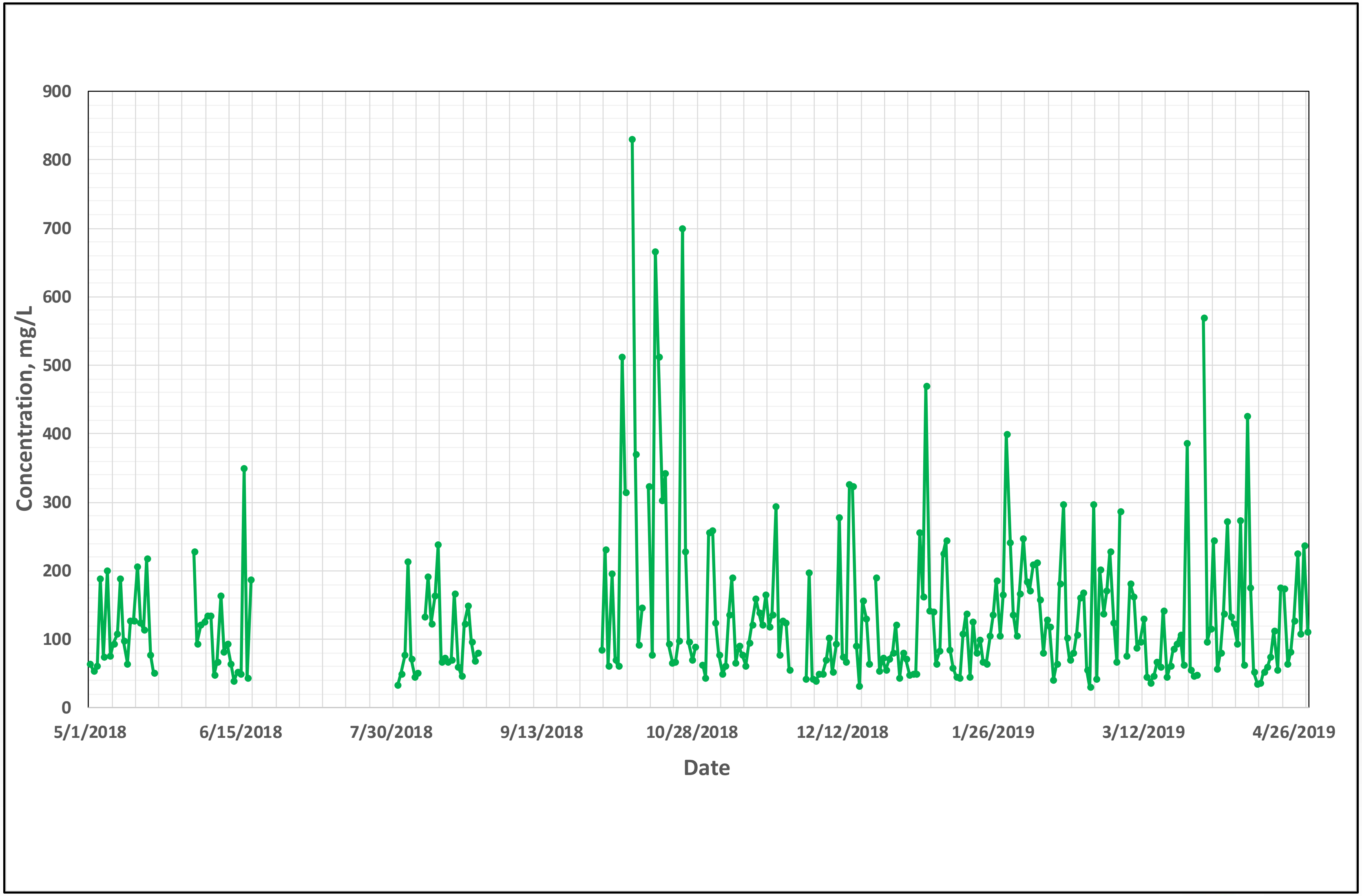
Nutrient Removal Performance Summary



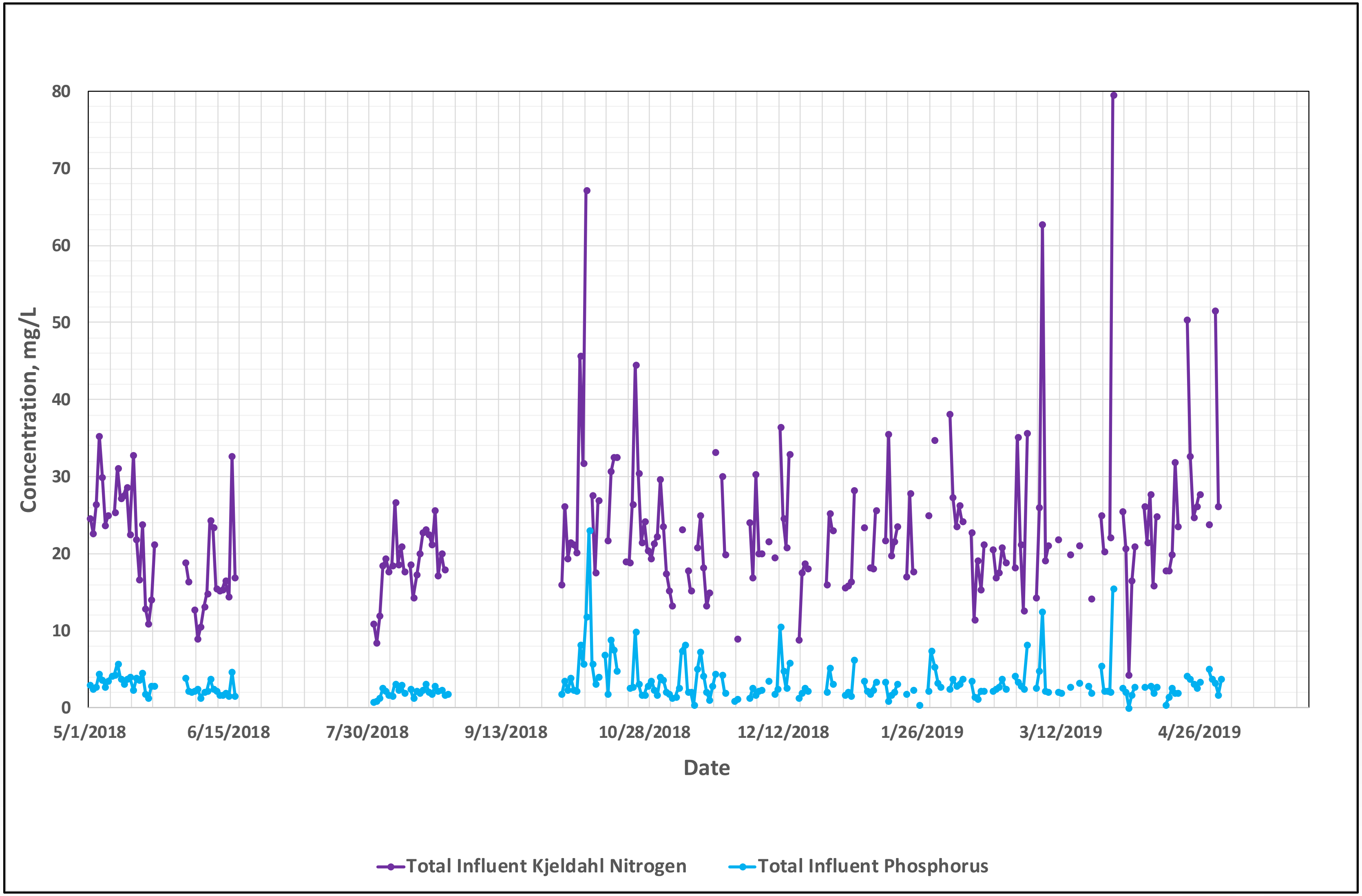
Total Plant Influent Flow



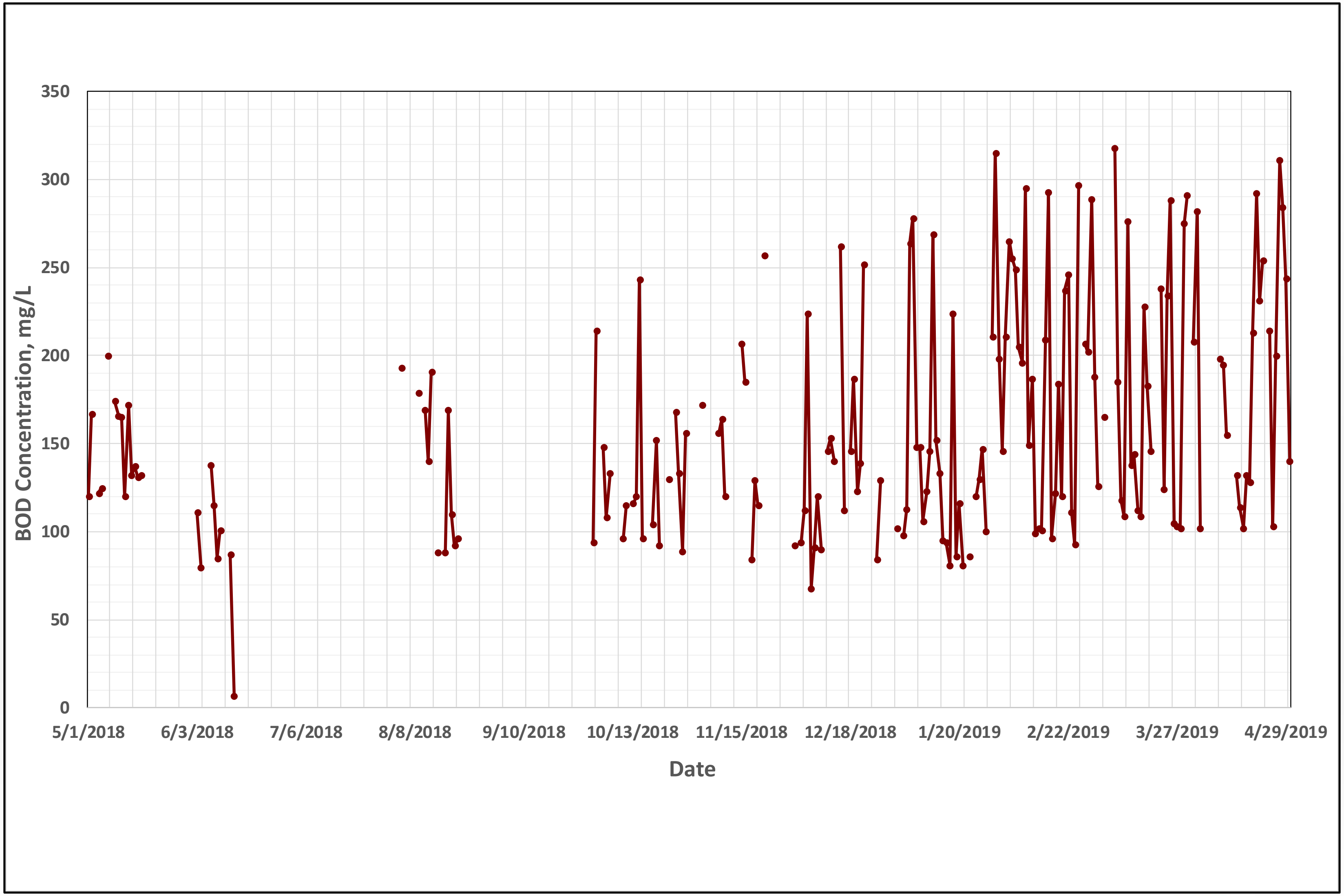
Plant Influent Suspended Solids



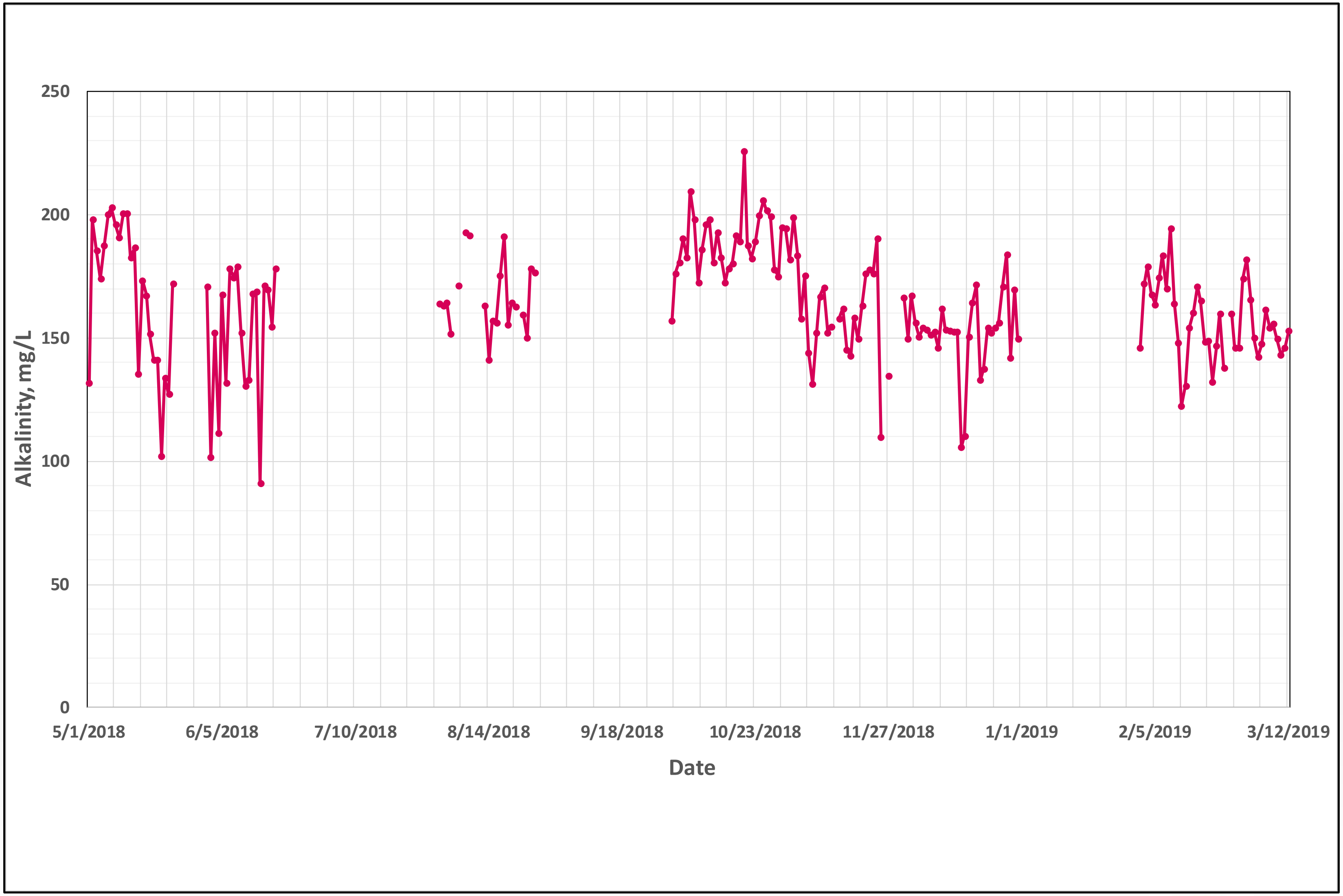
Plant Influent Nutrients



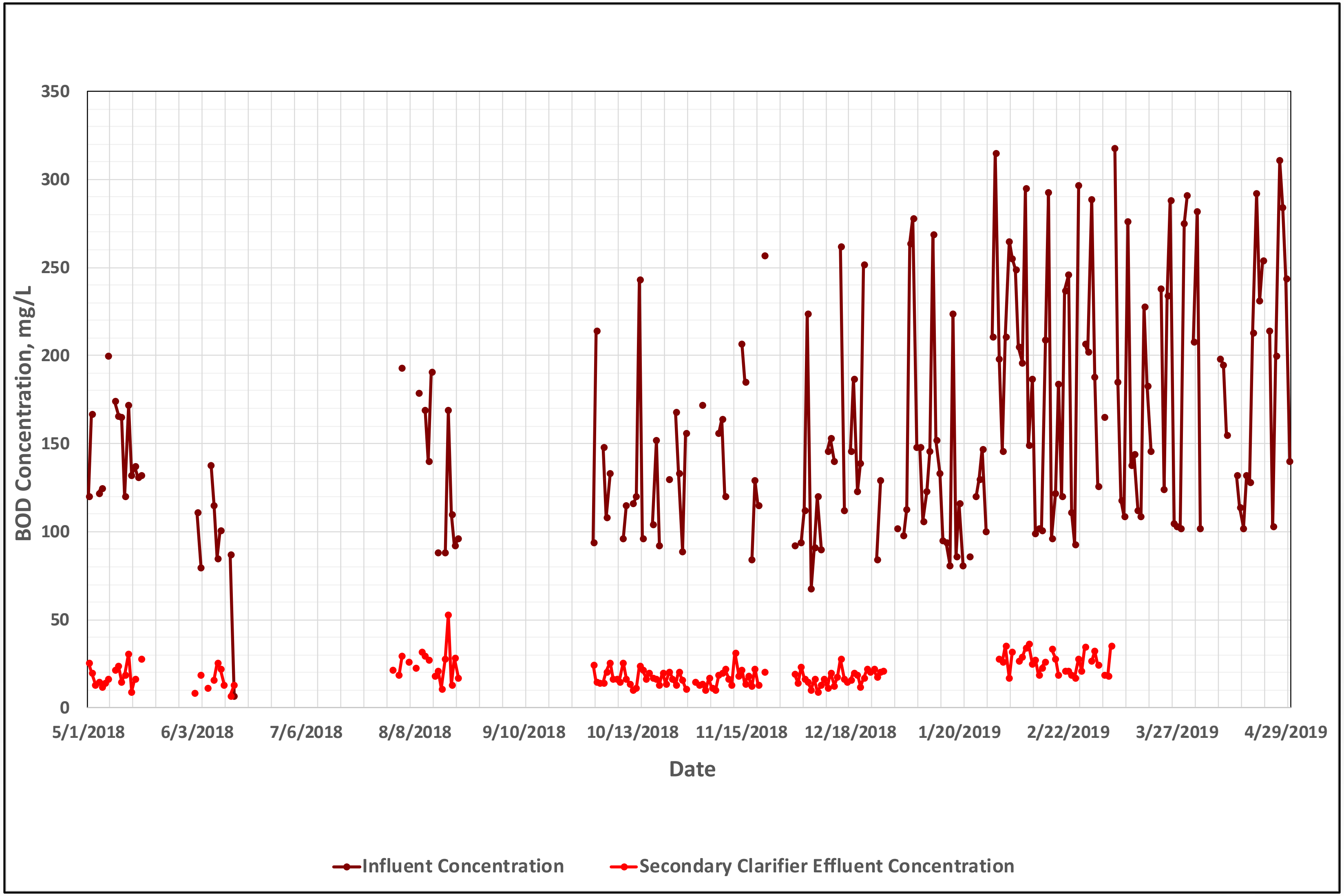
Plant Influent BOD



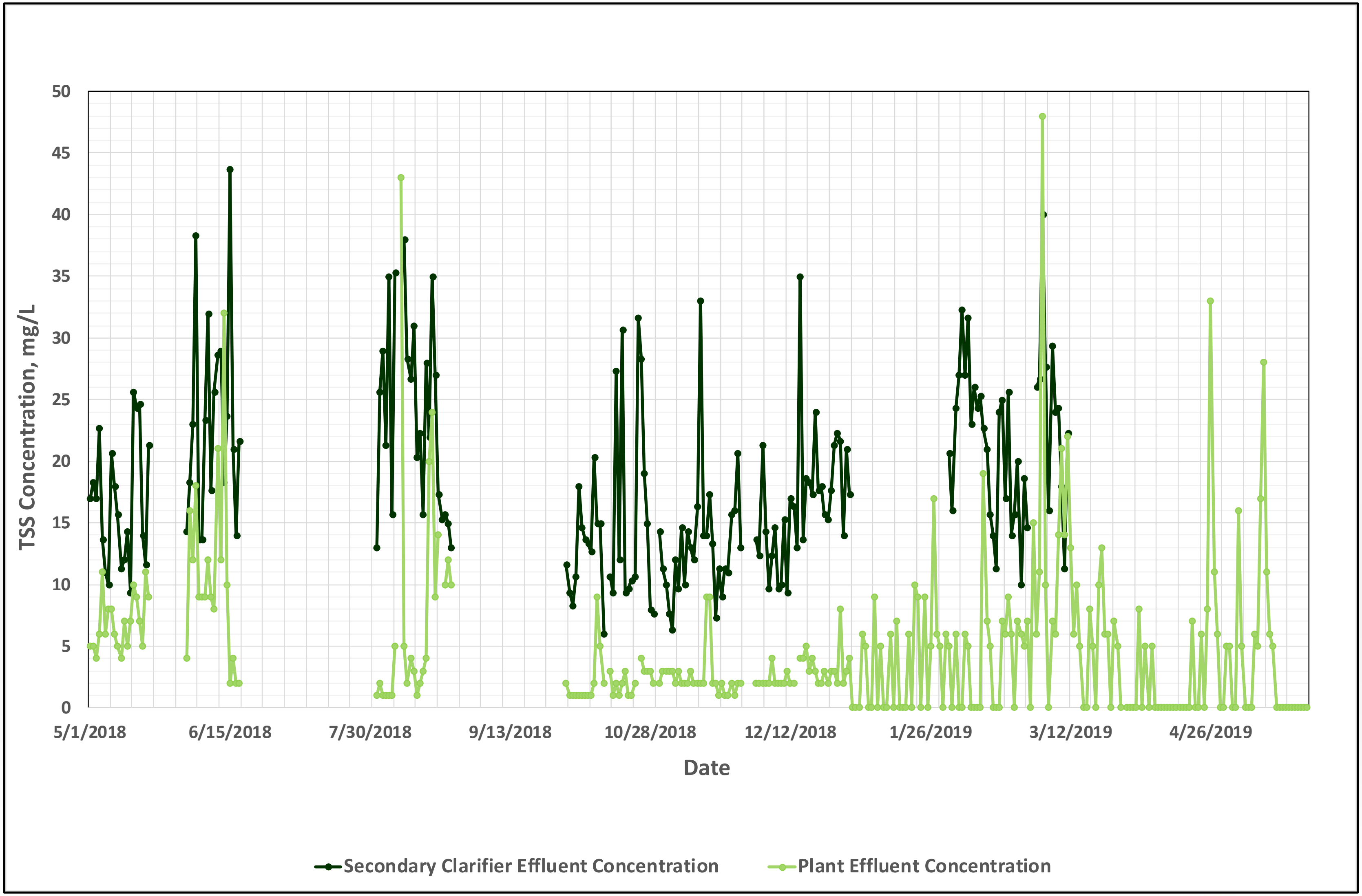
Secondary Clarifier Alkalinity



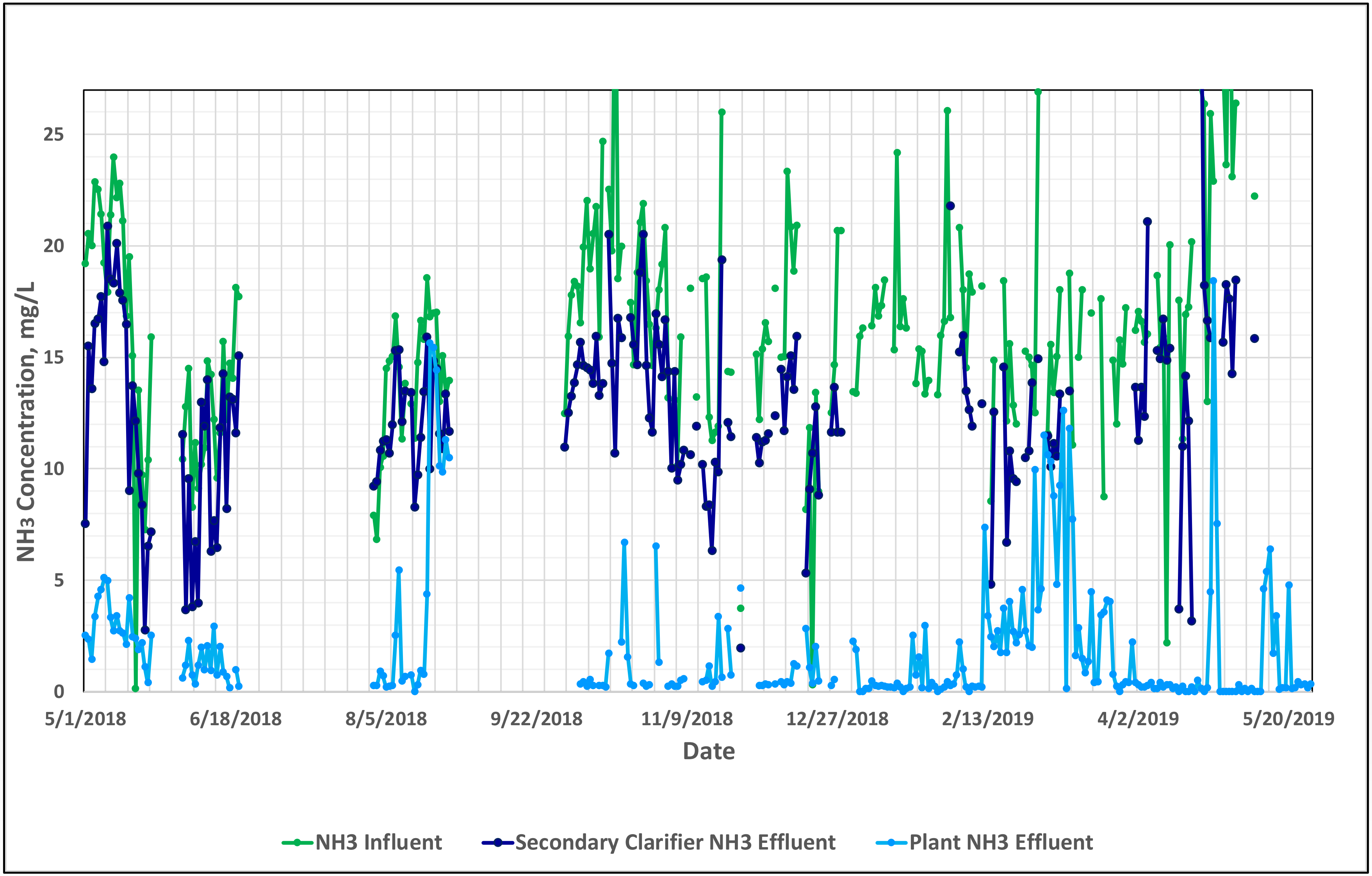
Biochemical Oxygen Demand Performance



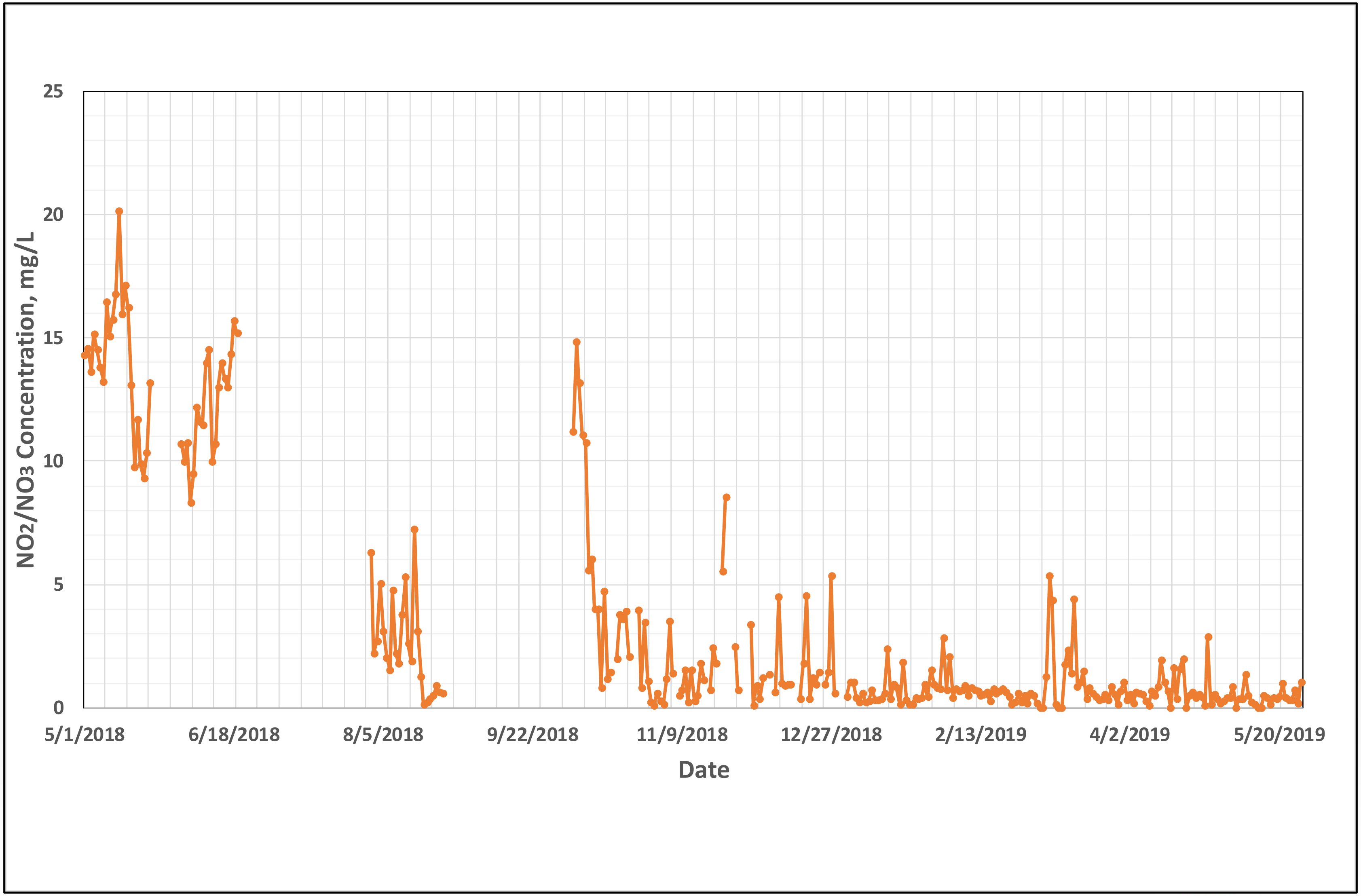
TSS Performance of ENR Facility



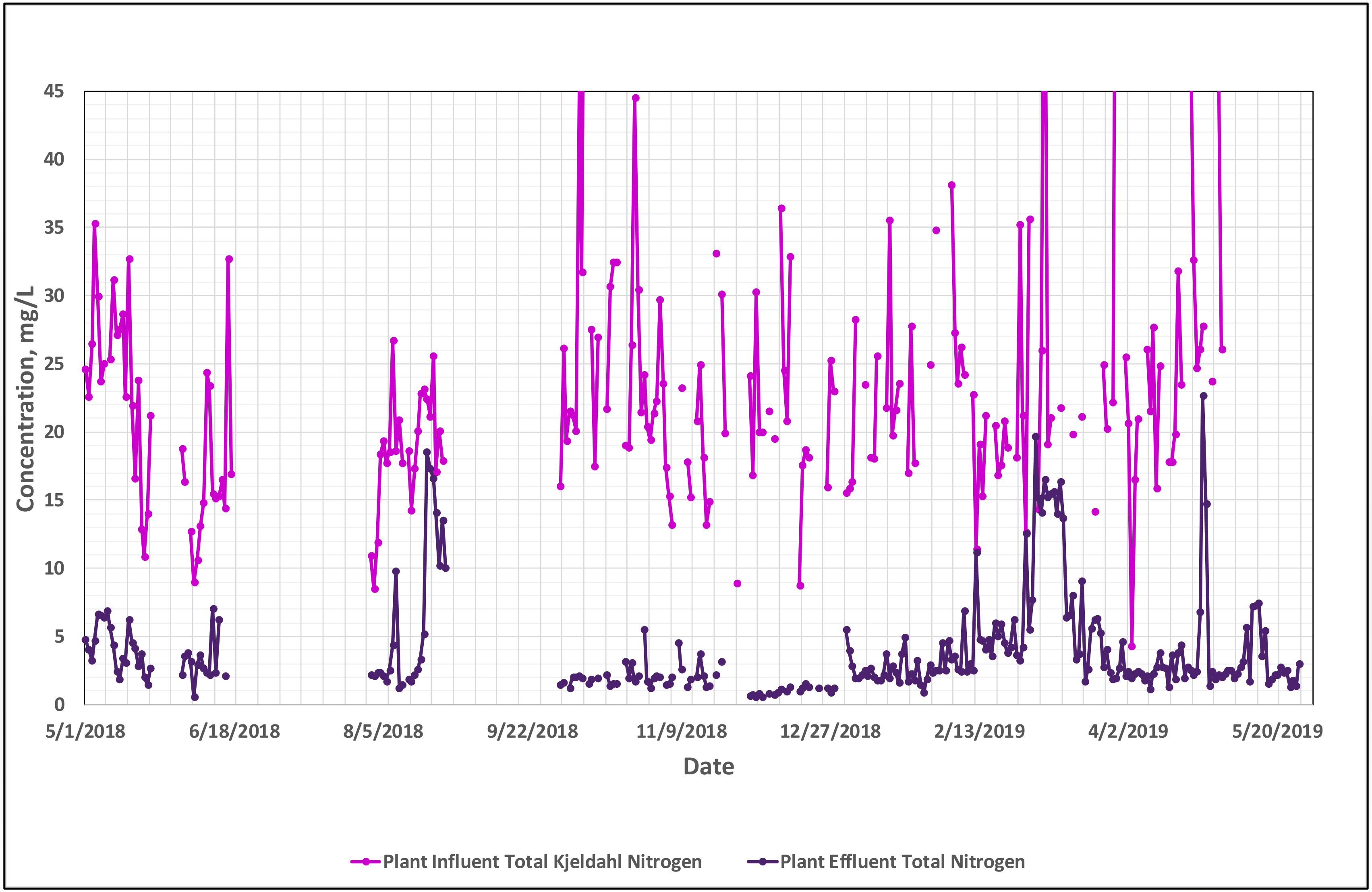
NH3 Performance



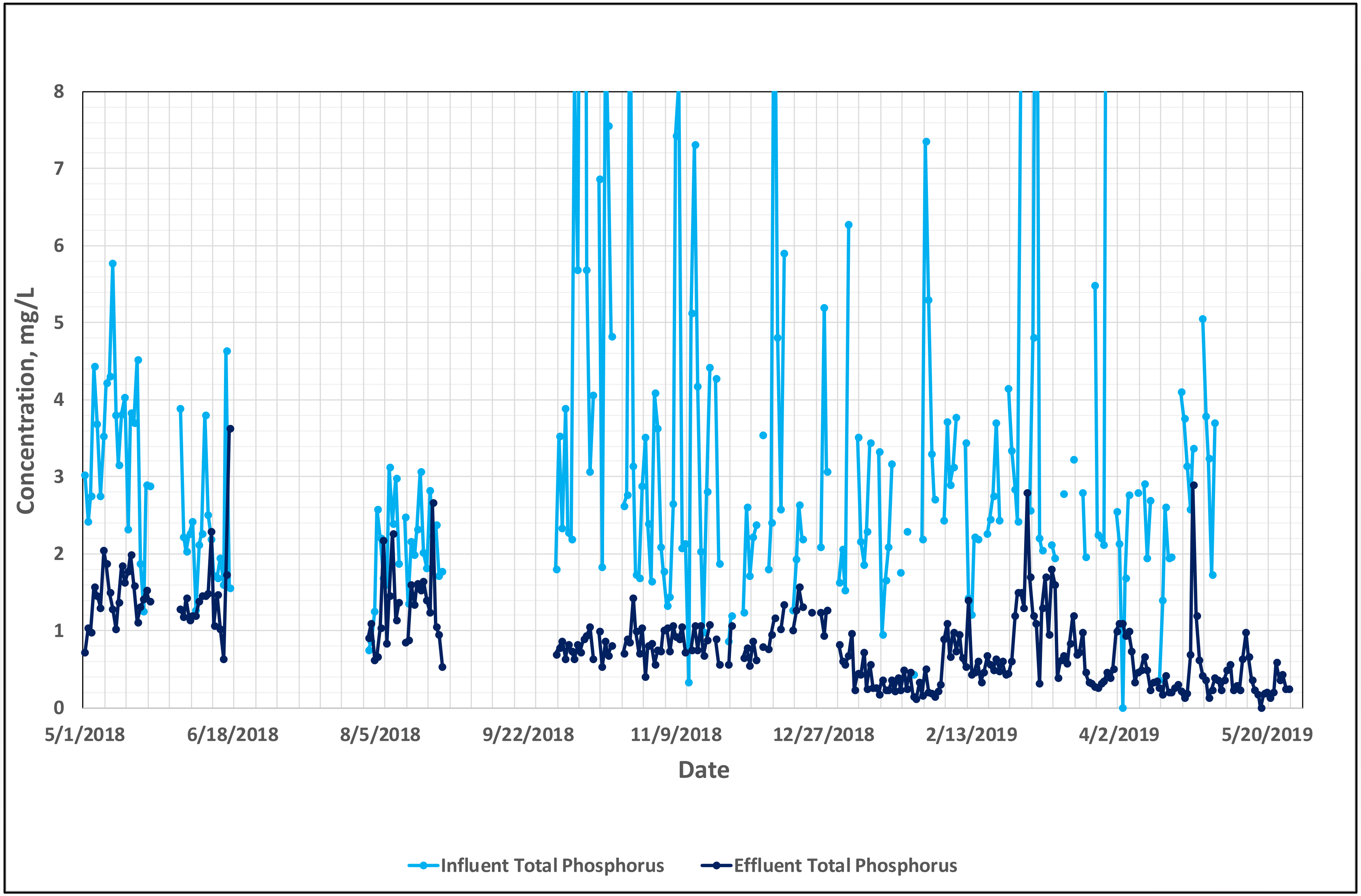
Effluent NO_3/NO_2



Total Nitrogen Performance

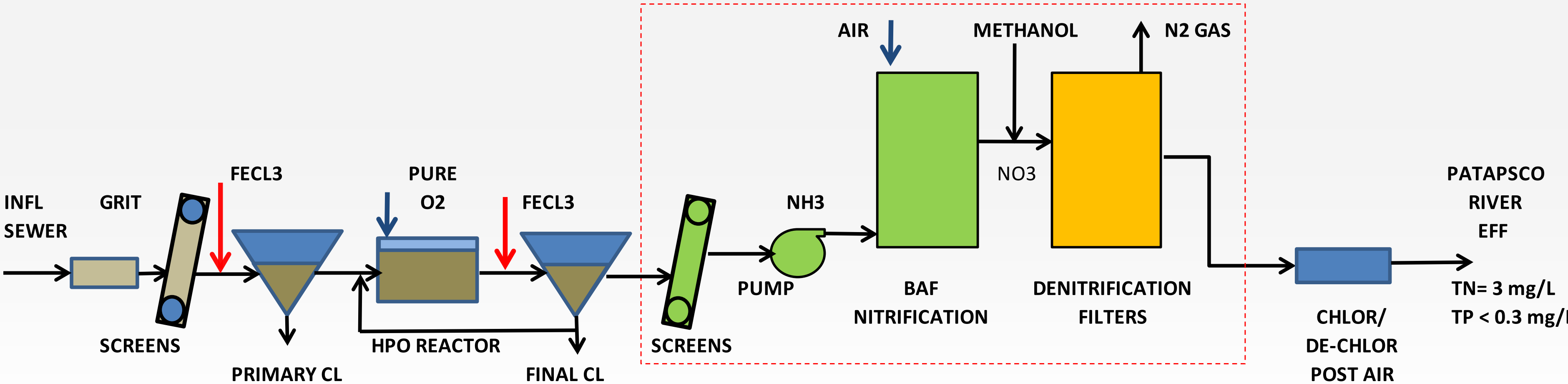


Total Phosphorus Performance



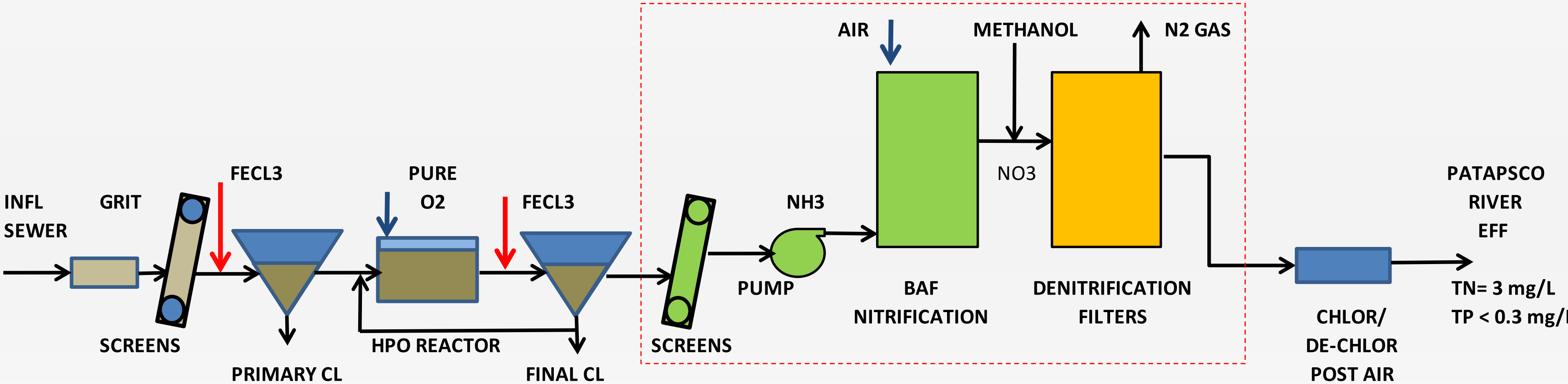
ENR Process Decisions – Preliminary Design

- ENR treatment of HPO effluent limited to 150 mgd
  - HPO effluent in excess of 150 mgd bypasses ENR & receives disinfection
  - Pump station lifts HPO effluent to ENR facilities
- BAF selected for nitrification based on pilot testing
  - BAF vendor selection deferred to final design
  - BAF structure configuration is vendor-specific
- Attached growth filters for denitrification following BAFs
  - Vendor selection deferred to final design



ENR Process Decisions – Preliminary Design

- Methanol for supplemental carbon source
- Multi-point chemical addition to precipitate phosphorus
- Upgrade existing unit processes to optimize ENR performance
- Plant-wide upgrade of process control system



Numerous other process configurations also used for ENR in Chesapeake Region

Final Design

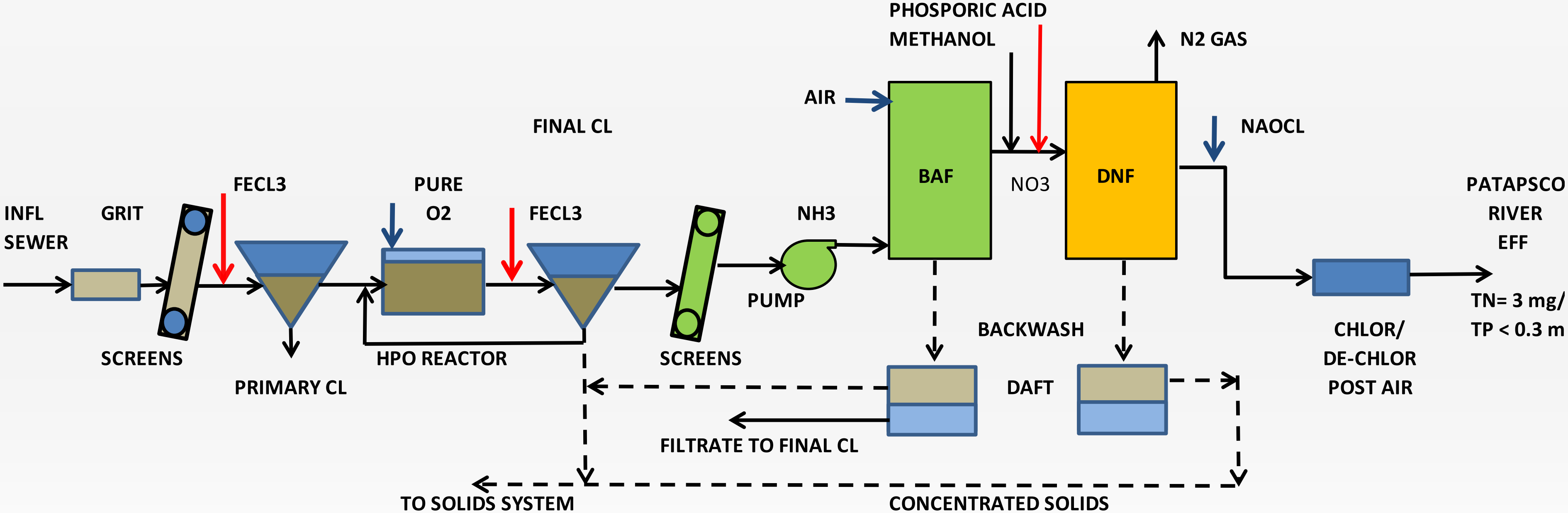
- Preliminary Design provided process concepts for moving forward
- Many decisions & process features remained to be decided

<u>PROCESS & DESIGN GOALS</u>

- To meet ENR goals, design a process that is operationally stable
- Incorporate features to reduce downtime
  - Minimizing downtime best meets ENR goals
  - Reduces City’s maintenance costs
- Construction imposes minimal risk to treatment operations

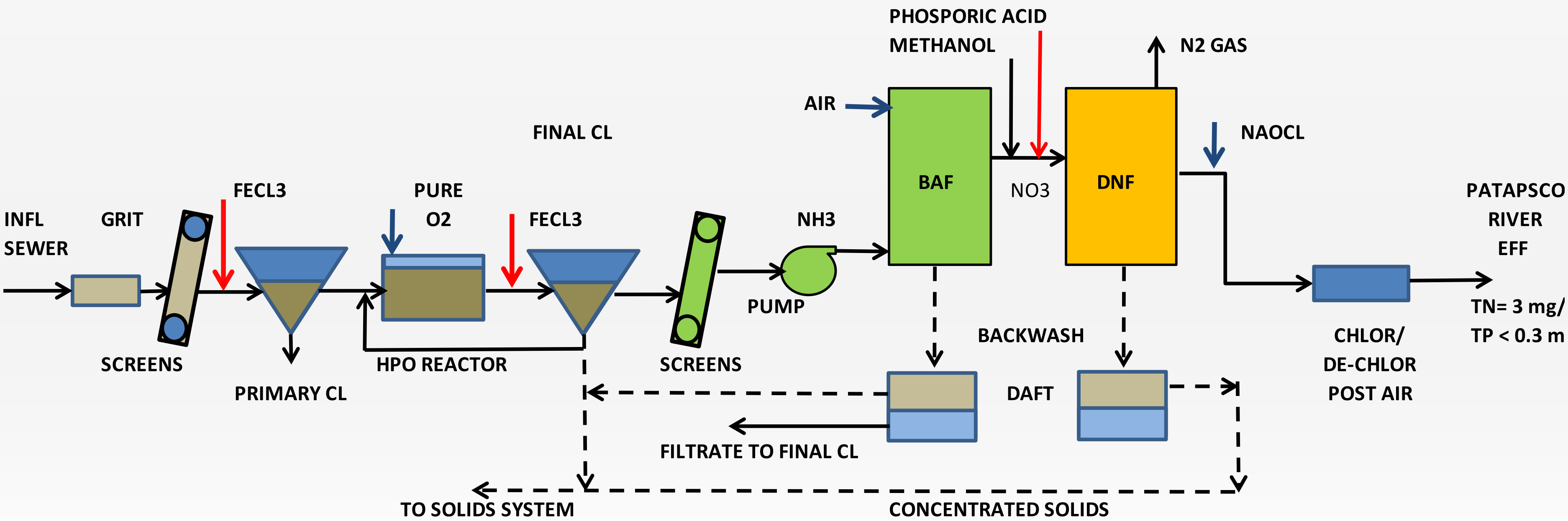
Key Goals - Stable ENR Process

- Maintain current upstream N removal via primary sludge & WAS
- Maintain BOD removal in HPO system - BAFs only nitrify
- Provide sufficient phosphorus in denitrification filters to sustain organisms, but effluent P levels must be low enough to meet ENR



Key Goals - Stable ENR Process

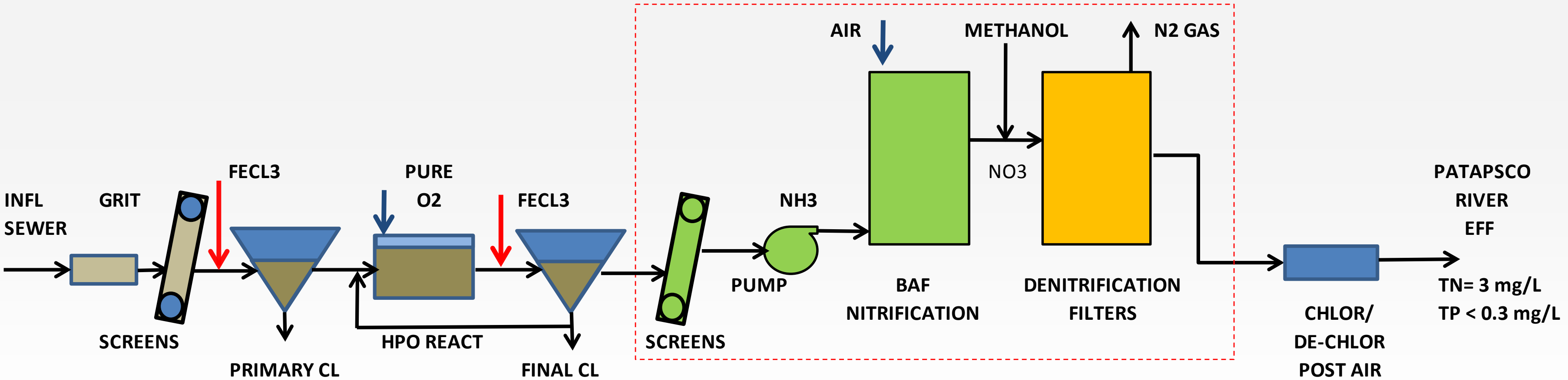
- Do not nitrify in HPO reactors
  - Avoid seeding nitrifiers via BAF backwash
- Do not hydraulically overload solids process with backwash water
- Select most appropriate BAF & denitrification filter vendors



Key Goals - Minimize Process Downtime

- Protect BAFs from clogging
  - Monitor final clarifier effluent TSS for upsets
  - Provide 6 mm mechanical screens upstream of BAF
  - Provide redundancy in mechanical screening system
  - Minimize algae formation in final clarifiers
- Automate system
  - Performance monitored in real-time
  - Large number of filters makes manual backwashing impractical
  - Provide modern plant-wide process control system

ENR Facilities



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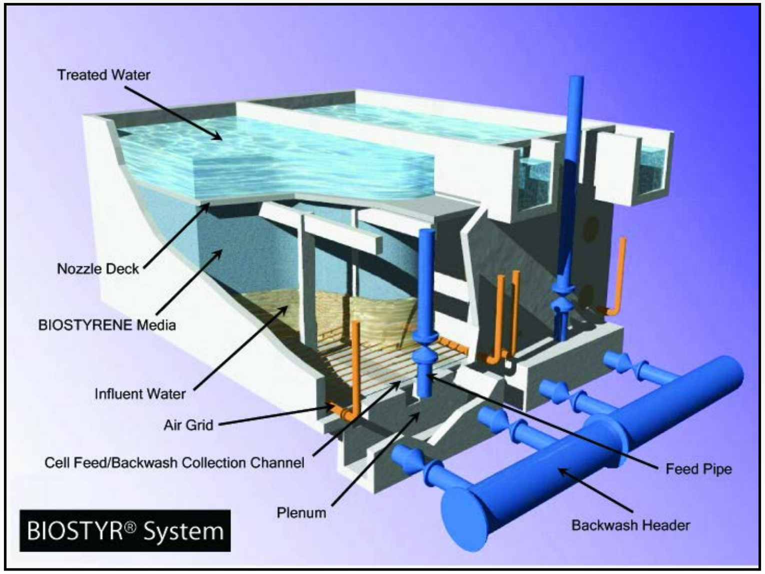
BAF Selection & Features

- **Kruger's BIOSTYR BAF – based on technical & economic evaluation**
- **At Patapsco BAF is used for nitrification-only, not BOD reduction**
  - **Small footprint for nitrification : 18.3 – 45.9 lb NH3/1000 cf/day (22 cells)**
  - **Polystyrene media – buoyant, retained by nozzle deck**
  - **Sludge is generated & removed by backwashing**
  - **Produces effluent low in solids & high in dissolved oxygen**
  - **No clarifiers are used**
  - **BAF system hydraulic head loss: 11 ft**
  - **Forward flow is upward thru media**
  - **Backwash flow is downward thru media**



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BAF Selection & Features

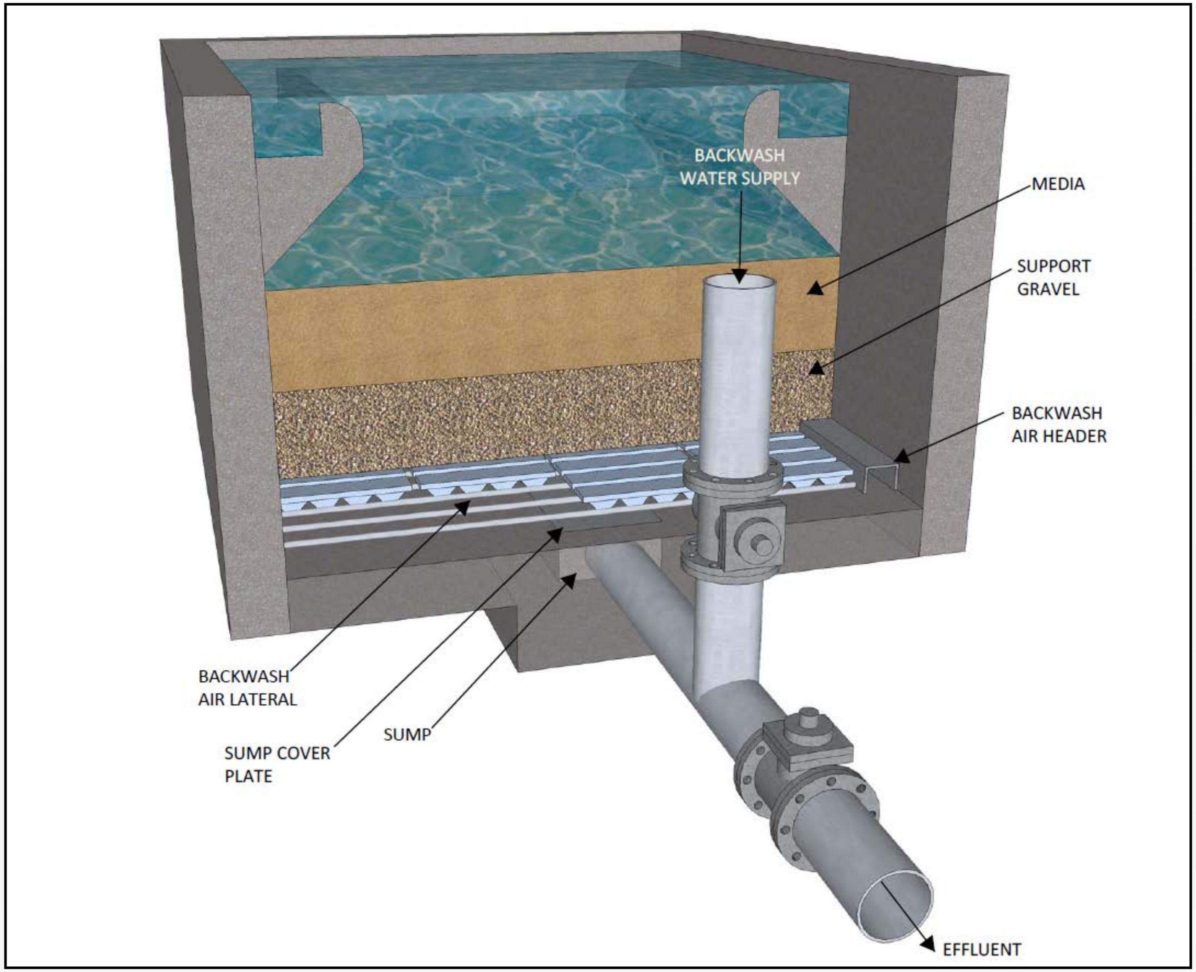
- Few BAFs were operating in U.S. in early 2000s, many in Europe
- Fully automated control of normal operation & backwashing

Kruger's BIOSTYR

Denitrification Filter Selection & Features

- Severn Trent's deep bed attached growth filter for denitrification
  - No pilot testing was performed in Preliminary Design
  - Sand media
  - Proven process in U.S. for nitrogen & TSS removal
  - Small footprint : 44.3 lb NO3 / 1000 cf / day (avg. load)
  - Average hydraulic loading: 1.52 gpm/sf
  - Significant hydraulic head loss: 8 ft
  - Forward flow is downward
  - Backwash is upward
- Methanol used as supplemental carbon source

Denitrification Filter Features



TETRA Deep Bed Filter

Site Constraints & Challenges

Active HPO effluent conduits

Soil stockpile containing chromium

Ex. Treatment Structures

Low Bearing Capacity Soils

High Groundwater

Contaminated soils

Existing Treatment Structures

Bulkhead tiebacks

Minimize Risk During Construction

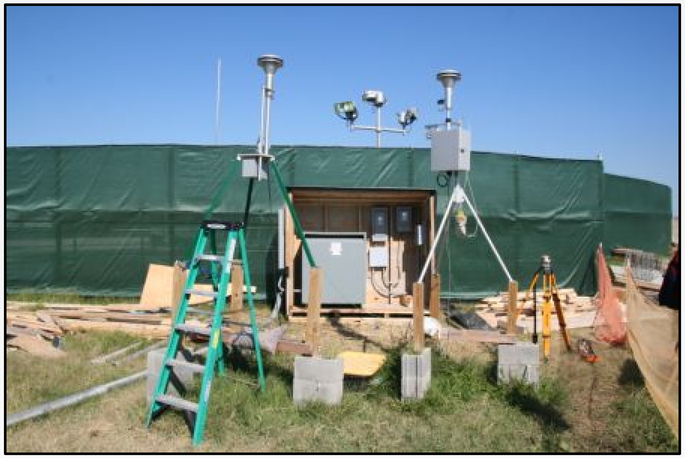
- Select least risky hydraulic connection points
- Connect to tanks & channels that can be reasonably isolated
- No connections to pressurized tanks and conduits
- Minimize structural interfacing to old structures

Only connections to existing structures

Challenge – Chromium Contamination

Site wide Hexavalent Chromium contamination

100% excavated soil removal



24 hr. air and dust monitoring

HDPE liner on all structures below groundwater

Piles – Low Bearing Capacity Soils

Denite filter pile driving – April 2011

More than 1,100 piles later, BAF pile driving

Nearly 2,200 pipe piles later, pile driving

Construction Progress - Concrete

24 in steel pipe pile to be embedded in the concrete foundation for all structures

40,000+ cy of concrete to be placed including the grade beams for the BAF structure

Construction Progress - Concrete

DNF gallery detailing the extensive formwork necessary to construct

Construction Progress - Concrete

Denitrification filters

Construction Progress

Construction Progress

Construction Progress

Construction Progress

Actual Facility vs. Design Rendering

Tertiary PS, BAF & Denite Filter

Tertiary Pump Station

Tertiary PS Screen

Tertiary PS

Biological Aerated Filter (BAF)

BAF Top Deck, Gallery & Blowers

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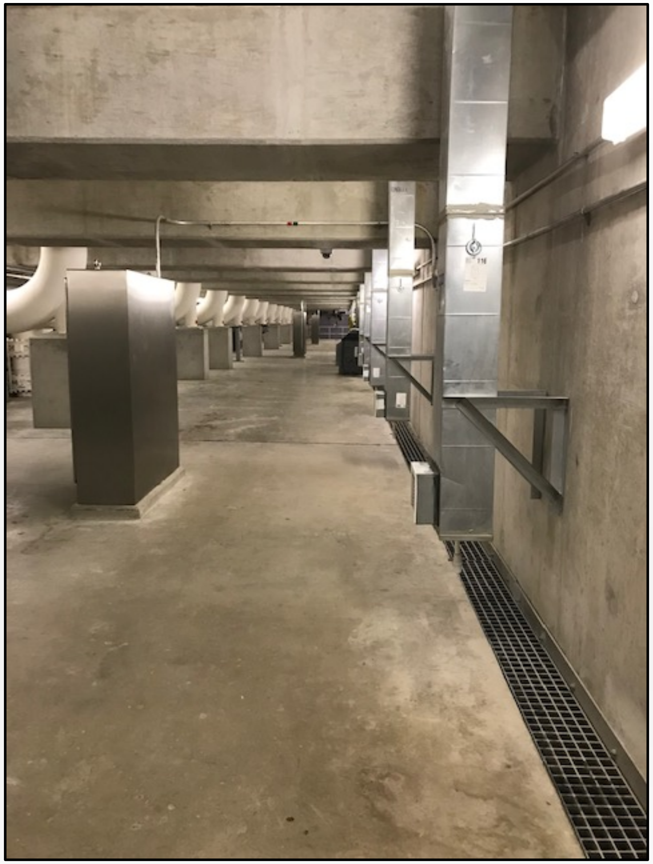
Pipe Bridge

Pipe Bridge

Denitrification Filter

Denitrification Filter Gallery



Denitrification Filter Gallery Catwalk

Denitrification Filter Top Deck

Methanol Feed Facility

DAFT & Polymer Feed System

Chlorine Contact Tank

ENR Effluent to Contact Tanks

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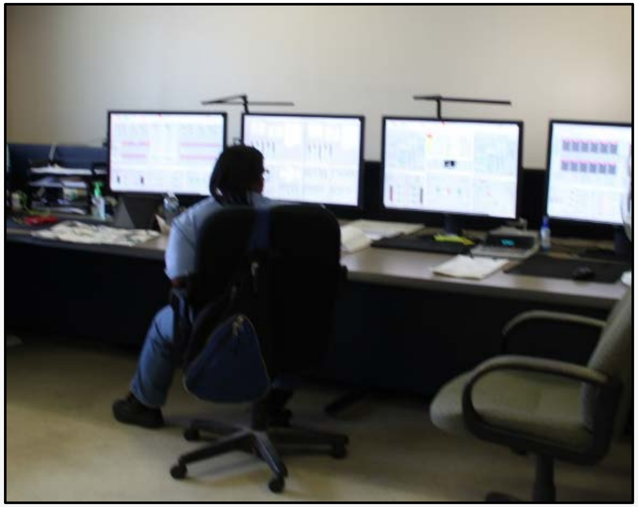
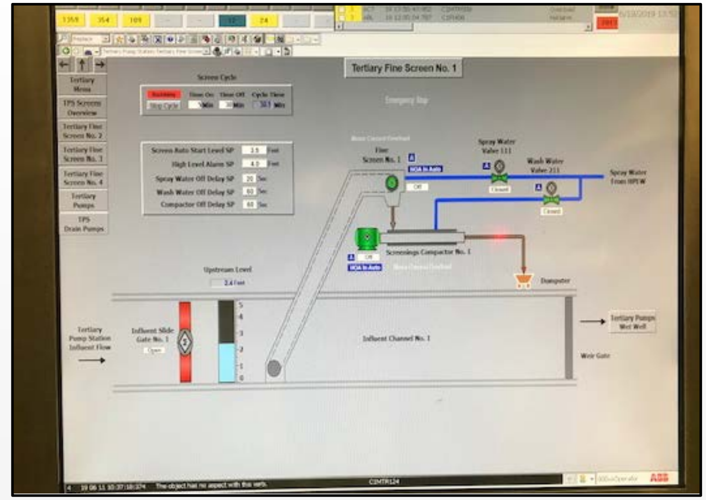
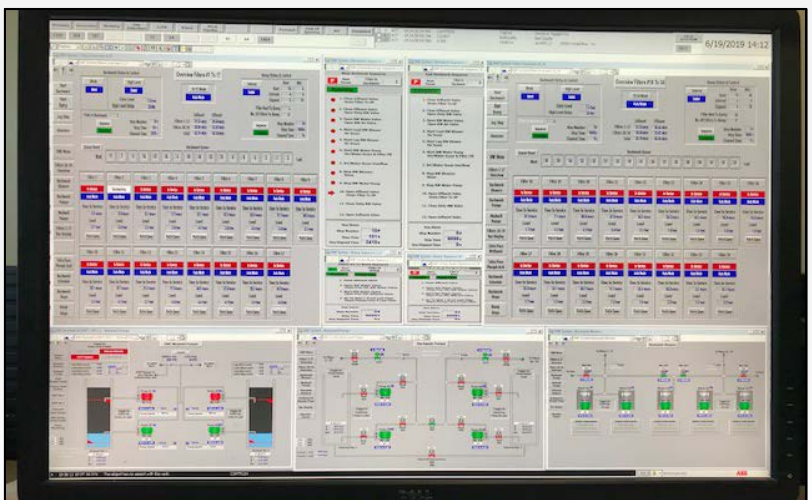
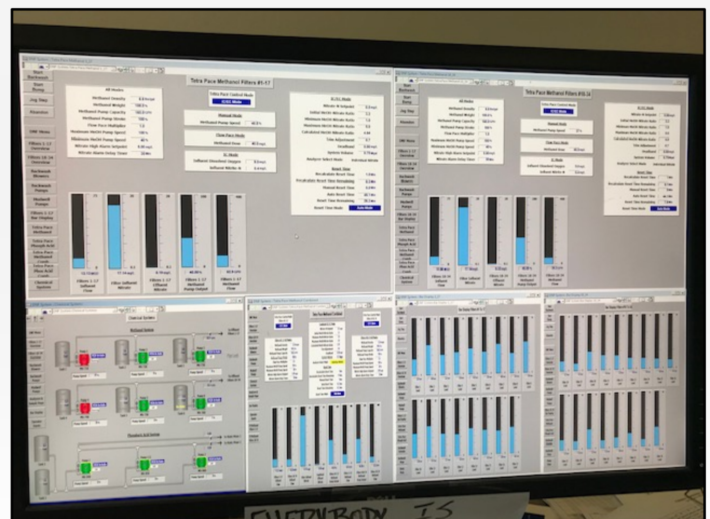
ENR Control Room

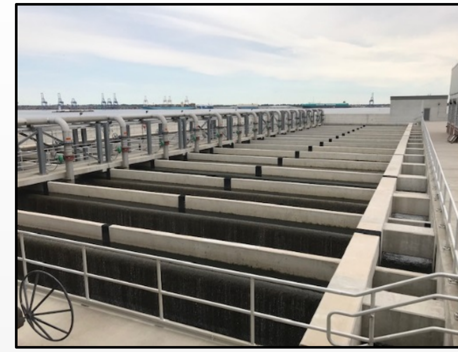




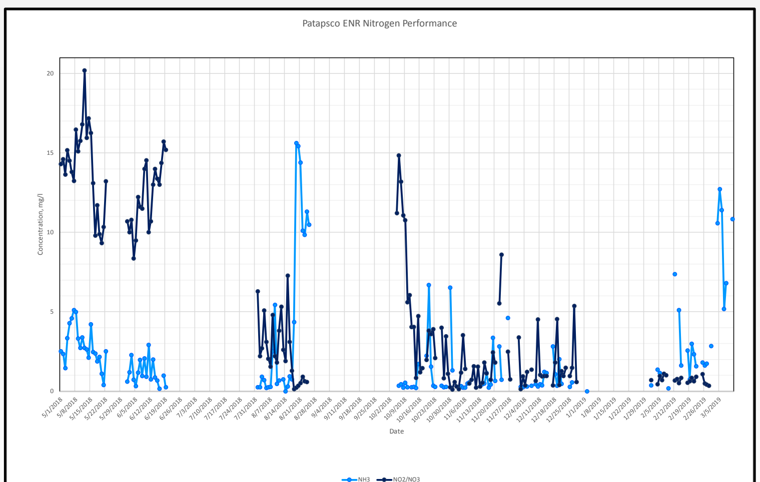




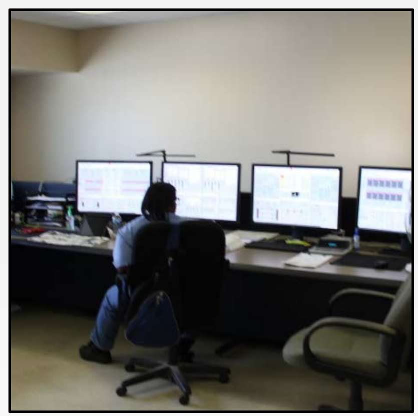
Project Results



Large ENR Facility constructed on a site with numerous constraints



ENR performance attainable



Fully automated & controlled

Minimize maintenance

Thank You for Your Time

Contact for Further Information

Bob Andryszak, PE

Director, Wastewater

RK&K

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Chesapeake Bay – Restore and Sustain