Hazen

Sludge Settleability Improvements at the East End WWTF

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PORTLAND WATER District

Facility Description

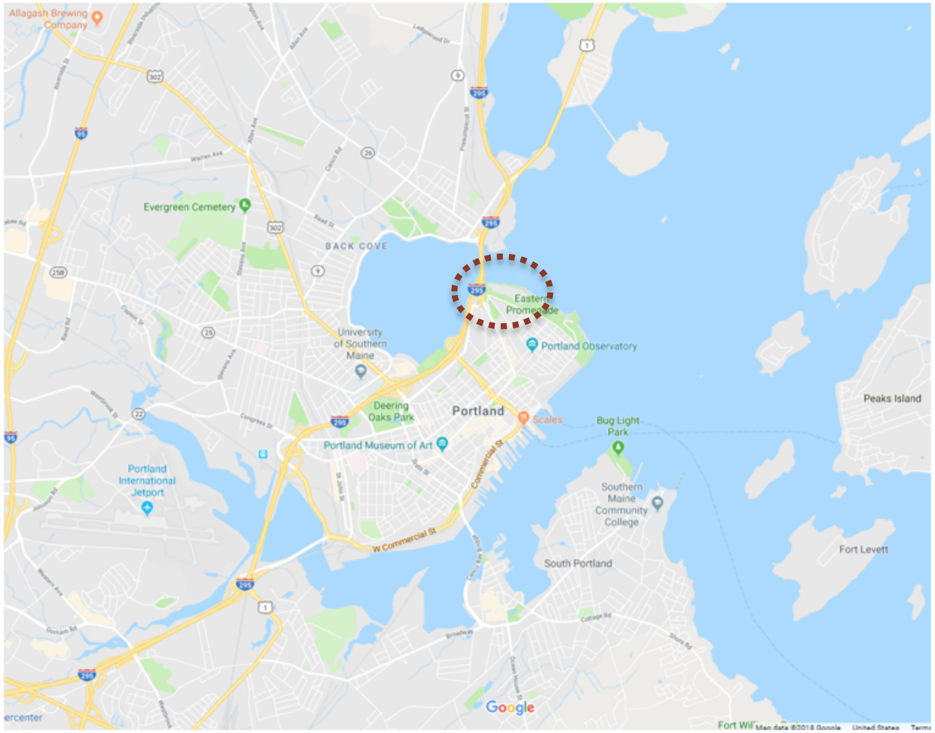
Owned and Operated by the Portland Water District (PWD)

Located in Portland, ME

Activated Sludge Treatment

Design Capacity: 19.8 MGD

Wet Weather Capacity: 80 MGD (secondary treatment: 36.8 MGD)



Project Drivers

Mechanical Surface Aerators could no longer efficiently deliver oxygen to the activated sludge process

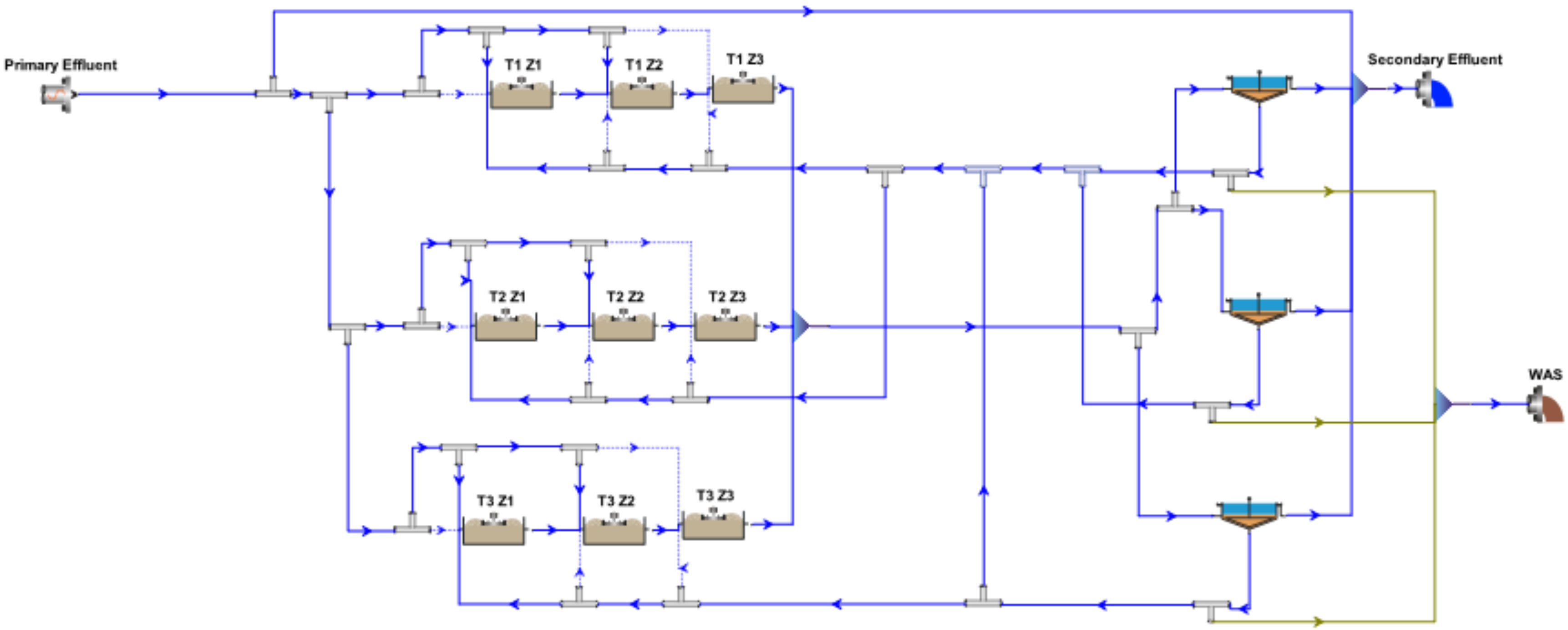
Improve sludge settleability

- Sludge Volume Index (SVI) average values of 250 mg/L
- Filamentous Microorganisms

Increased process and energy efficiency

Process Model Development & Calibration

BioWin 4.0 (Envirosim Ltd.)

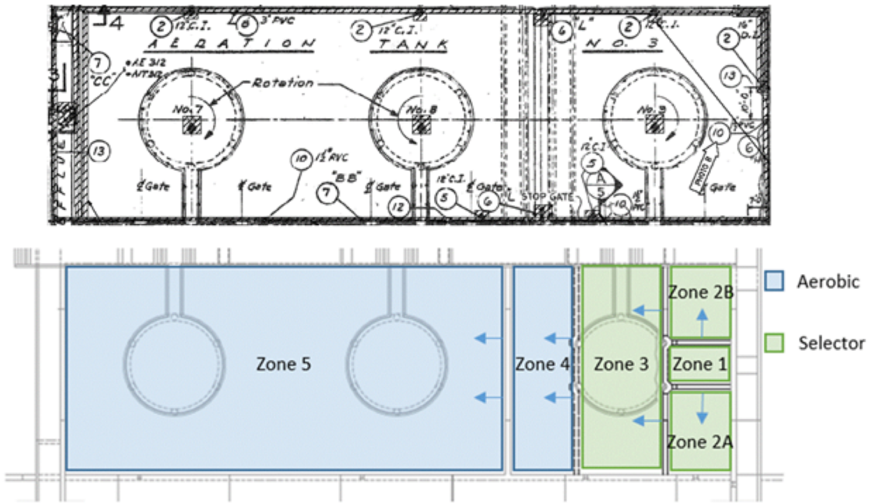


Process Model Development & Calibration

BioWin 4.0 (Envirosim Ltd.)

Four potential selector scenarios developed:

1. Anaerobic Selector
2. Anaerobic Selector with Additional Volume
3. Anoxic Selector
4. Anoxic Selector w/ NRCY



Aeration System Evaluation

Three options considered:

1. Fine Bubble Diffusers
2. INVENT Mixer/Aerators
3. Hybrid of 1 and 2

Invent Hyperclasic Mixing and Aeration System Brochure

Aeration Technology Evaluation

Aeration Technology	Advantages	Disadvantages
Fine Bubble Diffused Aeration	• Can be competitively bid • Not tied to single vendor • Well established technology • Research to limit fouling and degradation underway	• Diffuser maintenance & replacement requires taking basins out of service • Membranes need to be protected when basin is out of service • Efficiency decreases with time due to fouling • Pressure through diffuser can increase with time due to fouling
INVENT Mixer/Aerator	• Limited fouling of air sparger ring expected • Tank draining reduced • Can decouple mixing from aeration to avoid excessive aeration	• Additional energy & electrical requirements • Limited installation base • Effective process volume reduced if mixer fails • Limited 3rd party validation of air transfer efficiency

Aeration Technology Evaluation

Aeration processes are often the largest consumer of electricity at WWTF's

Alternative	Blower Power (kW-hr)	Mixing Power (kW-hr)	Aerator Power (kW-hr)	Total Power (kW-hr)
Diffused Air	2,614,000	78,000	0	**2,692,000**
INVENT®	1,890,000	65,000	1,800,000	**3,755,000**
Hybrid	2,472,000	43,000	405,000	**2,920,000**

Blower Technology Evaluation

Three options considered:

- Integrally Geared Single Stage
  - (3) 9,440 scfm (450 hp) blowers
- Multistage Centrifugal with and without VFDs
  - (2) 8,500 scfm (500 hp) and (2) 5,660 (300 hp) scfm blowers

Blower Technology Evaluation

Blower Technology	Advantages	Disadvantages
Multistage Centrifugal Blowers	• Simple Lubrication System • Low Capital Costs • Mechanically Simple • Multiple Vendors • Can be efficient when unthrottled • Easy to maintain	• Low efficiency at turndown • Can have low range of turndown
Integrally Geared Blowers	• Most energy efficient blower • Greatest turndown • Most efficient turndown	• Complex lubrication system • Complex maintenance • High capital cost • Typically sole sourced

Blower Technology Evaluation

Alternatives Capital and Net Present Worth Cost Comparison

	Integrally Geared Single Stage	Multistage w/ Inlet Valve Throttling	Multistage w/ VFD's
Capital Cost: Aeration System	$1,330,000	$1,330,000	$1,330,000
Capital Cost: Blowers	$1,030,000	$730,000	$1,010,000
20-Year Net Present Operating Costs	$5,290,000	$6,480,000	$6,030,000
Total Net Present Cost	**$7,650,000**	**$8,540,000**	**$8,370,000**

Grant funding was received from Efficiency Maine

Process Air Blower Location – Existing Tunnel

Process Air Blower Location

Process Air Blower – Suction/Discharge

Electrical Room

Existing Primary Tank Gallery

Selector Zones

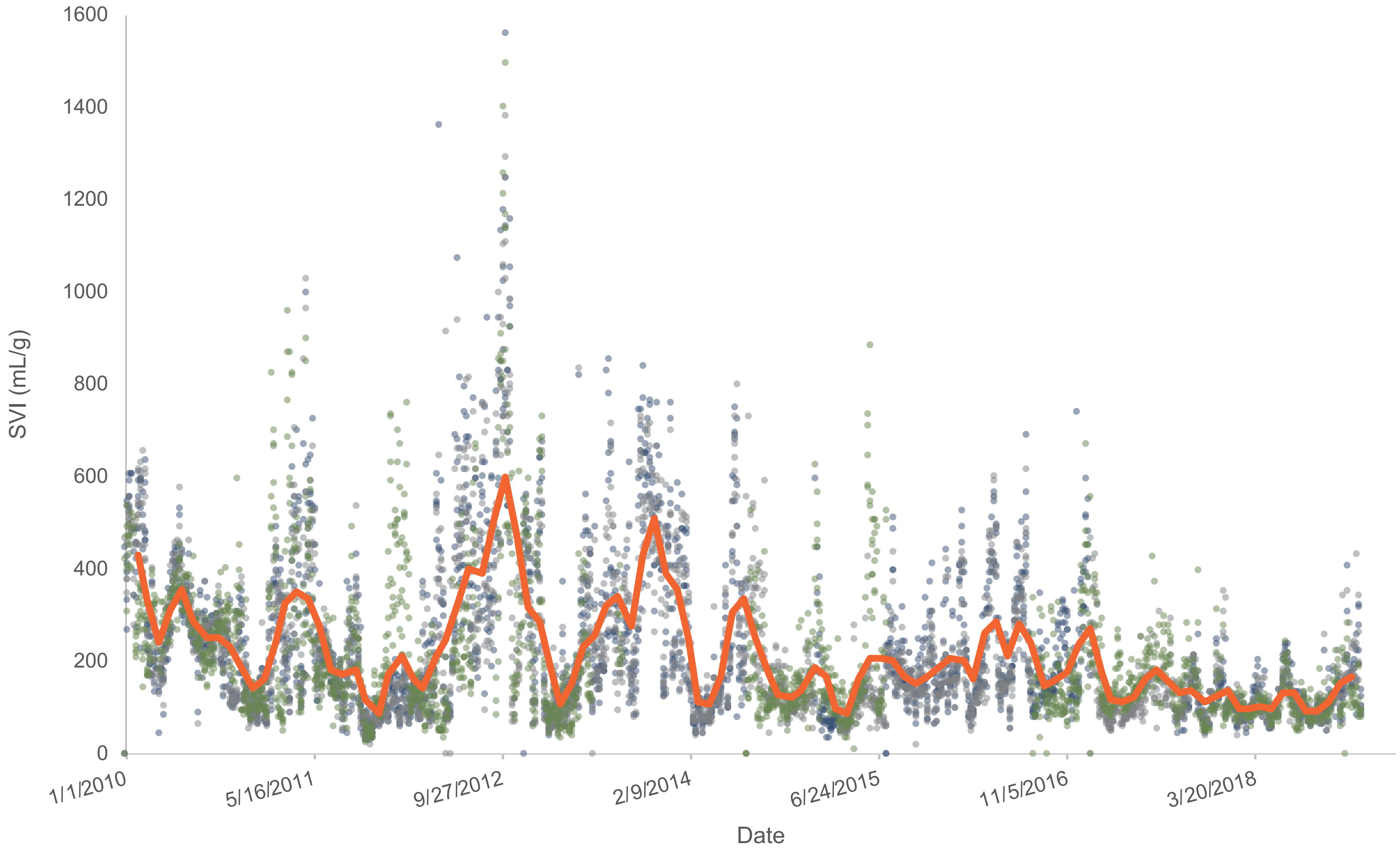
Construction Timeline

- Construction Start – *Sept. 2015*
- Aeration Train 3 online – *August 2016*
- Aeration Train 2 online – *March 2017*
- Aeration Train 1 online - *Sept. 2017*
- Substantial Completion – *Oct. 2017*

Initial Results

Initial Results

SVI Historical and Current Values



Operational Assistance

Site Visits and Conference Call

Minimum and Alternative Minimum Mixing

Optimize Setpoints

Power Consumption Evaluation

Flow Split

Diffuser Fouling Tracking with Purge Cycle

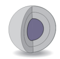
East End WWTF

Aeration Basin Operational Strategy Guidance

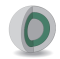
Portland Water District Hazen

OVERVIEW

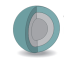
The East End WWTP includes a diffused aeration process utilizing fine bubble diffusers for aeration. Selector zones in the upfront portion of each aeration basin provide flexibility in operation while improving MLSS settleability. The selectors allow operation of the East End WWTP in three distinct modes:



Anaerobic/oxic (AO) process utilizing an anaerobic selector



Modified Ludack-Ettinger (MLE) process utilizing an anoxic selector



Conventional, fully-aerated plug-flow aeration basin

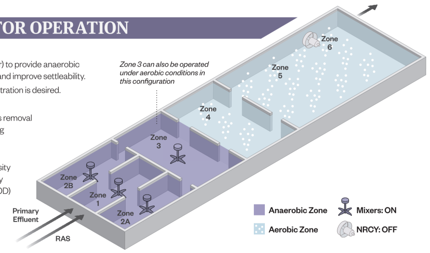
ANAEROBIC SELECTOR OPERATION

WHEN TO USE

- During **non-nitrifying** periods (i.e. cold weather) to provide anaerobic conditions to reduce potential filament growth and improve settleability.
- When reduction in effluent phosphorus concentration is desired.

OVERVIEW

- This operation promotes biological phosphorus removal (BPR) and selection for phosphate accumulating organisms (PAOs) and glycogen accumulating organisms (GAOs).
- This leads to better settling through higher density microorganisms and reduction of soluble readily biodegradable chemical oxygen demand (rbCOD) entering the aerobic zone.
- The SRT should be maintained at less than 5 days when operating in anaerobic mode.



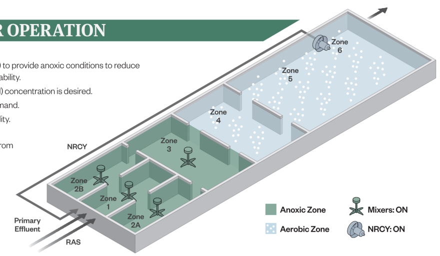
ANOXIC SELECTOR OPERATION

WHEN TO USE

- During **nitrifying** periods (i.e. warm weather) to provide anoxic conditions to reduce potential filament growth and improve settleability.
- When reduction in effluent total nitrogen (TN) concentration is desired.
- To improve alkalinity and reduce oxygen demand.
- During periods of increased odor susceptibility.

OVERVIEW

- Anoxic selectors utilize the return of nitrate from nitrifying systems to consume influent rbCOD under non-aerobic conditions.
- Anoxic selector operation can also increase alkalinity and decrease oxygen demands in the aerobic zone.
- This operation reduces potential filaments and improves settleability through the promotion of soluble carbon uptake under unaerated conditions.



OPERATIONAL PARAMETERS

Anoxic selector operation requires nitrification in the aerobic zones. The ability to nitrify is based on the wastewater temperature and the associated aerobic solids retention time (aSRT). Below are the target aSRTs to promote full nitrification and allow anoxic selector operation based on temperature.

Temperature	Required aSRT (days)
Less than 15°C	Not recommended*
15°C to 18°C	6-8
Greater than 18°C	4-6

Each NRCY pump can initially be established at 80% speed and then optimized based on NO_3-N measurements at the end of the anoxic zone.

Zone 3 Effluent NO_3-N (mg-L/L)	NRCY Rate Adjustment
More than 1.5 mg-N/L	Reduce by 20%
0.5 – 1.5 mg-N/L	Do not adjust
Less than 0.5 mg-N/L	Increase by 20%

The gates between the selector zones need to be opened to the setpoints below when the NRCY pumps are operating to ensure adequate hydraulic capacity. These gates should be closed when the NRCY pumps are not operating.

Baffle Walls	Gate Position (Feet Open)
1/2A and 1/2B	1.50
2A/3 and 2B/3	1.00
3/4	1.17

Nitrification when temperatures are less than 15°C may result in excessive solids loading to the secondary clarifiers.

FULLY-AERATED OPERATION (RARELY USED)

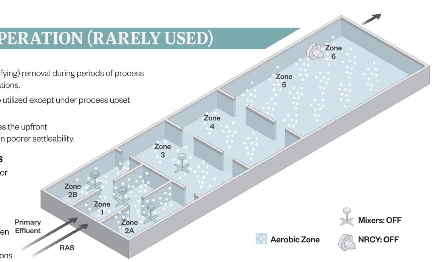
WHEN TO USE

- To maintain $cBOD_5$ and ammonia (when nitrifying) removal during periods of process upset and/or to reduce high MLSS concentrations.
- Fully-aerated operation is not expected to be utilized except under process upset conditions.
- Operating in the fully-aerated mode eliminates the upfront anaerobic/anoxic selector, which may result in poorer settleability.

FULLY-AERATED OPERATION TRIGGERS

Operation of Zones 1 through 3 as anaerobic or anoxic selectors is recommended to promote better settling MLSS. Fully-aerated operation of these selectors should only be considered under the following situations:

- Inability to maintain adequate dissolved oxygen (DO) in Zones 4 through 6
- Elevated effluent soluble $cBOD_5$ concentrations (greater than 10 mg/L)
- Elevated effluent ammonia concentrations (when nitrifying)
- When required MLSS concentrations to achieve treatment goals result in excessive solids loading to the secondary clarifiers

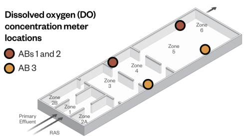


PROCESS MONITORING AND CONTROL

Solids retention time, settleability, dissolved oxygen concentration, and selector performance should be routinely monitored to ensure process objectives are met.

- The aerobic solids retention time (aSRT) is an important parameter and represents the amount of time the MLSS is aerated prior to being wasted from the system. Target aSRT values are dependent on temperature, DO concentration, pH and whether the plant is operated for nitrification.
- Settleability is commonly measured using the 30-minute sludge volume index (SVI), which represents the volume that one gram of MLSS occupies after 30 minutes of settling. Higher values indicate poorer settling MLSS. Well settling MLSS typically has an SVI below 125 mL/g.

Dissolved oxygen (DO) concentration meter locations



- Typical DO concentrations for similar processes are shown below. Note that airflow is also used for aerated zone mixing, and zone mixing requirements may result in operation at higher DO concentrations than those listed below.

Location	Typical DO Range (mg/L)
Zone 4	1.0-2.0
Zone 6	0.5-1.0

- Selector performance monitoring can provide additional operational information including Food-to-Mass (F:M) ratio and nutrient removal performance. The following table summarizes potential sampling and expected ranges to assist in selector monitoring and troubleshooting:

[#] Zone number (E) Effluent (I) Influent

Parameter	Sampling Location	Expected Range
Anaerobic Operation		
Soluble Ortho-Phosphate (PO_4-P)	3 E†	6-12 mg-P/L*
Nitrate (NO_3-N)	3 E†	< 0.1 mg-N/L*
Nitrate (NO_3-N)	6 E	< 1 mg-N/L*
Soluble COD	3 E†	< 40 mg/L
Selector Food-to-Mass	$F{:}M = \frac{1.5\text{-}3 \text{ lb BOD}}{\text{lb MLSS}}$	
Anoxic Operation		
Ammonia (NH_3-N)	6 E	< 2 mg-N/L*
Nitrate (NO_3-N)	3 E†	0.5-1.5 mg-N/L*
Nitrate (NO_3-N)	6 E	3-7 mg-N/L*
Soluble COD	3 E†	< 40 mg/L
Selector Food-to-Mass	$F{:}M = \frac{1.5\text{-}3 \text{ lb BOD}}{\text{lb MLSS}}$	

† Zone 2 effluent if Zone 3 is aerated ** Checked weekly*

OPERATIONAL TROUBLESHOOTING DURING ANAEROBIC OPERATION

Process Indicator:
- Microscopy shows Bio-P organisms
- Phosphorus release observed in selector zone
- sCOD uptake is measured in selector zone (target 70-80%)

Action items: Continue to monitor SVI and conduct profiles biweekly

Process Indicator: Microscopy shows increase in bulking filaments

Action items: Check DO and NO_3-N in selector

Notes:
- If DO is present, check that selector is unaerated and NRCY is not operational.
- If NO_3 is present, check that NCRY is not operational, and target SRT is in the 2-5 day range.

Process Indicator: Microscopy shows increase in bulking filaments, specifically related to sulfide bulking (Thiothrix and 021N with intracellular sulfide granules)

Action items: Convert Selector Zone 3 to aerobic operation

Notes: Decreased anaerobic volume will reduce sulfide production

Action items: Convert to Anoxic selector

Notes:
- Under anoxic operation, sulfide will be oxidized.
- SRT increase needed to nitrify, NRCY pumps in service

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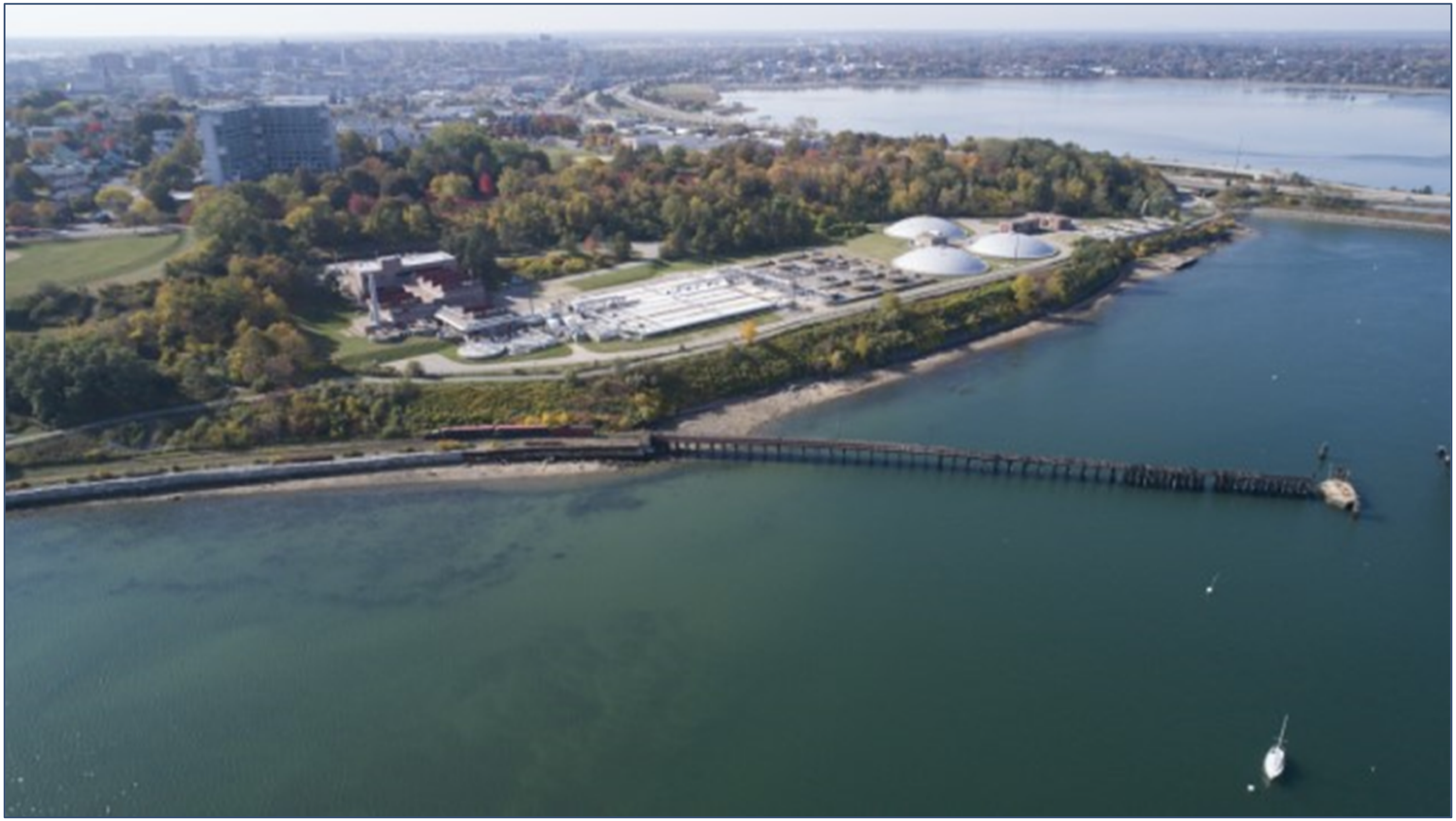
The East End WWTF



2017 EEWWTF Effluent Permit - Nitrogen

Effluent Monitoring

6. Establishing effluent monitoring and reporting requirements for total kjeldahl nitrogen (TKN), nitrate nitrogen plus nitrate nitrogen and total nitrogen.

Nutrient Optimization Report

7. Establishing Special Condition N entitled *Nitrogen*, requiring the permittee to submit an annual progress report to the Department that summarizes activities related to optimizing nitrogen removal efficiencies, documents the seasonal daily average nitrogen discharge load from the facility and tracks trends relative to the previous year. The progress report must also contain a scope of work or tasks/measures to be taken in the next 12-month period to further reduce the nitrogen loading from the treatment facility.

It is noted the facility is currently undergoing an upgrade of the aeration system that is scheduled to be completed in late spring or early summer of 2017. This permit requires the permittee to monitor the effluent from the East End waste water treatment facility for total kjeldahl nitrogen, nitrate –nitrogen and nitrite-nitrogen as well as report the total nitrogen for each month during the period May 1st – October 31st of each year beginning calendar year 2018. The summer of 2017 is considered a startup period for the new aeration system and gathering data during this time of flux in the system will not be representative of the performance of the new system. The intent of the nitrogen optimization effort is to achieve an anticipated 20% - 40% reduction of the current estimated seasonal loading of 2,437 lbs/day for total nitrogen. The annual progress report required by Special Condition N, *Nitrogen*, of this permit will document will document these efforts and will report on the seasonal loading of total nitrogen for the prior year.

Nutrient Optimization Efforts

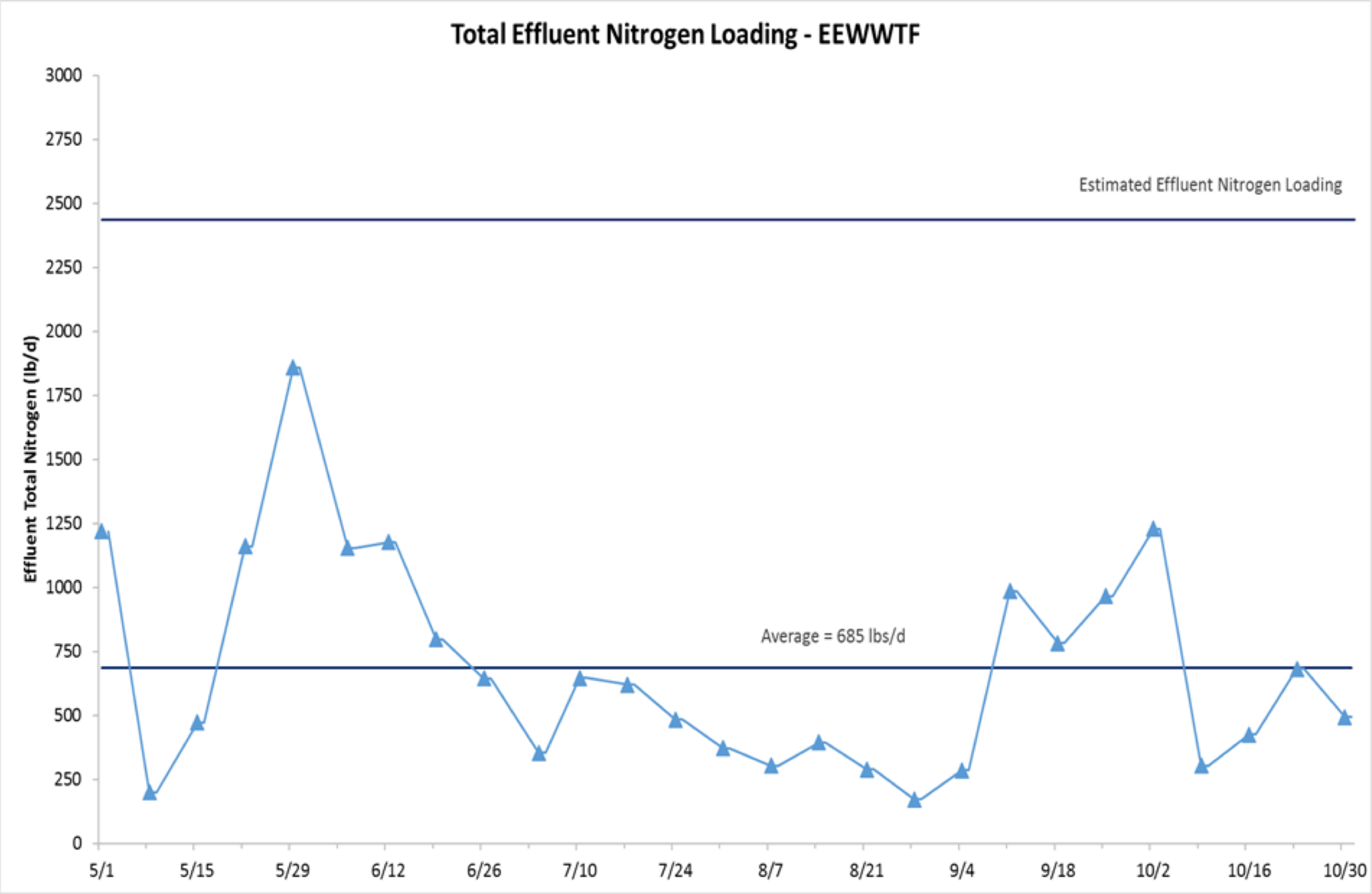
Goal of 20 – 40% reduction

(Based on design estimates)

Integrated Planning with Portland

In addition to requiring an evaluation of alternative methods of operating the existing wastewater treatment facility to optimize nitrogen removal efficiencies, the permittee has agreed to coordinate with the City of Portland in Integrated Planning efforts to identify efficiencies in implementing sometimes overlapping and competing regulatory requirements associated with waste water and storm water programs. Integrated Planning can assist the City of Portland and the PWD in prioritizing cost effective and water quality protective solutions by maximizing their infrastructure improvement dollars through the appropriate sequencing of work.

Effluent Nitrogen Loading



Casco Bay and Nitrogen – my thoughts

- Holistic view of water quality issue is needed
  - CBEP Nutrient Council
  - Non-point sources and point sources
- Water quality modelling
  - Significant issue during permitting process
  - “What if” scenarios – demonstrate benefit/impact
- Nutrient Criteria development
- Waste load allocations, target for overall reduction, etc.
- Education and involvement of stakeholders

Acknowledgments

Portland Water District

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Hazen and Sawyer

Deb Mahoney – Project Manager

Joe Rohrbacher, PE – Lead Process Engineer and Aeration Expert

Questions

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