Overview of Nitrogen Removal and the IFAS Process for the Narragansett Bay Commission
Background

- Discharge of nitrogen to Narragansett Bay contributes to:
  - Algae blooms and reduced dissolved oxygen
  - Impaired fish habitats

- Fields Point WWTF has 5 mg/L permit limit for Total Nitrogen (TN).
  - Took effect May 1, 2014.
  - TN Permit is seasonal for May 1 through Oct 31.

- The Integrated Fixed Film Activated Sludge (IFAS) process designed and built to meet TN permit limit.
Theory of Biological Nitrogen Removal
Biological Nitrogen Removal

- Two step process:
  - Step 1 – Nitrification – Ammonia present in wastewater is converted to nitrate (and a little nitrite).
  - Step 2 – Denitrification – Nitrate and Nitrite are converted to nitrogen gas and leaves wastewater to the atmosphere.
Nitrification

- First step in biological nitrogen removal process.
- $\text{NH}_4^+ + 2\text{O}_2 \rightarrow \text{NO}_3^{-1} \text{(nitrate)} + 2\text{H}^+ + \text{H}_2\text{O}$
- Aerobic process, requires air.
  - DO > 2 to 3 mg/L
Nitrification

- Requires longer sludge age to maintain nitrifiers.
- Generates hydrogen ions / consumes alkalinity
- Temperature dependent: works faster in warmer water.
Denitrification

- Second step in the biological nitrogen removal process.
- Carbon + $2\text{NO}_3^{-1}$ → $\text{N}_2$ (nitrogen gas) + $2\text{CO}_2 + 2\text{OH}^-$
- Anoxic process, takes place without air.
  - DO < 0.3 mg/L
  - Nitrate used as energy source (electron acceptor) instead of oxygen.
Denitrification

- Requires carbon source (BOD) for reaction.
- Generates hydroxide ions / recovers alkalinity.
- Process slows down when nitrate concentrations low.
Total Nitrogen Removal in the IFAS Process
(IFAS = Integrated Fixed Film Activated Sludge)
IFAS Process

- IFAS process selected in Preliminary Design.
  - Allowed for reuse of existing ATs.
- Process entails adding high surface area media to AT.
  - Solids grow on media to increase MLSS.
- Fixed growth:
  - Increases capacity in aeration zone.
  - Increases sludge age.
  - Promotes nitrification.
IFAS Process Schematic

NaOH
Primary Effluent

1<sup>st</sup> AX  Weir  IFAS-OX  IMLR  2<sup>nd</sup> AX  OX

Carbon Addition

Secondary Clarifiers

Effluent

WAS
IFAS Upgrade Summary

- Carbon Feed Facility for Supplemental Carbon in 2nd Anoxic Zone
- New Intermediate Screening Facility to Protect IFAS Retention Sieves
- New Caustic Feed to Adjust Alkalinity
- Extend Four Screw Lift Pumps
- Modify All Ten Aeration Basins for IFAS Process
- New Turbo Blowers for Increased Aeration Requirements
IFAS System

Pre-Anoxic  Weir  IFAS Zone  IMLR  Post Anoxic  Re-Aeration

PE & RAS  PE & RAS  PE & RAS  PE & RAS

SODIUM HYDROXIDE (ALKALINITY/pH)

IMLR Pump

Mixer (Typ 12)

CARBON FEED (FOOD)

AT EFFL
IFAS (AS) ZONE – Contains IFAS Media (Aerobic)

Location for Nitrification (conversion of ammonia to nitrate)

Screens to keep media in IFAS zone but allow MLSS to next zone

Aerobic (DO > 3.0 mg/l)

NH₃ + O₂ + nitrosomonas/nitrobacter \( \rightarrow \) NO₃

works best when alkalinity ~ 150 mg/l and pH > 7.0

SODIUM HYDROXIDE (ALKALINITY/pH)

CARBON FEED (FOOD)

Mixer (Typ 12)

IMLR Pump

AT EFFL
FIRST (Pre) ANOXIC ZONE - DO < 0.5 mg/l

Location for Initial Denitrification (conversion of nitrate to nitrogen gas)

NO₃ + PE (food) + RAS (bugs) = N(gas) + BOD removal (Total Nitrogen to 8-9 mg/l)
Mixers but slow enough not to generate O₂
Internal recycle of NO₃ enriched ML from IFAS zone

PE & RAS
PE & RAS
PE & RAS
PE & RAS

ANOXIC (DO < 0.5 mg/l)

4 X Q

IMLR Pump

SODIUM HYDROXIDE (ALKALINITY/pH)

CARBON FEED (FOOD)

Mixer (Typ 12)

AT EFFL
SECOND (Post) ANOXIC ZONE - DO < 0.5 mg/l

Location for Final Denitrification (conversion of nitrate to nitrogen gas)

In second anoxic zone there will still be some NO₃ enriched MLSS, but no food:
NO₃ + food (carbon source) + bugs = N₂ (gas)↑

PE & RAS
PE & RAS
PE & RAS
PE & RAS

4 X Q

ANOXIC (DO < 0.5 mg/l)
Mixer (Typ 12)

SODIUM HYDROXIDE (ALKALINITY/pH)

CARBON FEED (FOOD)

IMLR Pump
Process Equipment
Anoxic Mixers

- Each Aeration Basin has 12 Submersible Mixers.
- Mixers keep solids suspended in Anoxic Zones.
- Mixers operate 24 hrs/day
- HOA switch at each mixer and on Kruger PLC.
  - In Auto, mixers will automatically operate via Kruger PLC.
  - Hand mode provided for testing only.
I MLR Pump

- Each Aeration Basin has 1 IMLR Pump.
  - IMLR = Internal Mixed Liquor Recycle
- Recycle nitrates from Pump zone to Pre-Anoxic Zone.
  - Flow = 3 to 4 X Q, VFD Controlled
- Pumps operate 24 hrs/day.
- HOA switch at pump and on Kruger PLC.
  - In Auto, pumps will automatically operate via Kruger PLC:
    - Flow Pace, Flow pace w/ nitrate trim, Constant flow rate
    - Flow meter to verify flow and for control feedback.
  - Hand mode provided for testing only.
IFAS Media

- Each IFAS Zone filled with Media.
  - 52% Media Fill
- Media retained by Sieves.
- Screens are installed at tank drains and scum outlets in concrete divider walls.
Aeration

- Coarse Bubble Diffusers at bottom of IFAS Zones.
- Aeration to IFAS Zones controlled to maintain target DO.
  - Each IFAS Zone has DO Probe, air flow meter, and control valve.
- Other aerated zones manually adjusted
  - Weir zone, Pump Zone, + Re-aeration Zone
Return Activated Sludge

- New RAS Pipe provided to AT Influent Channel.
  - Better RAS distribution from clarifiers.
  - Reduce DO in Pre-Anoxic Zone.
- New RAS Pipe has a flow meter and control valve.
- Existing RAS control valves and flow meters not modified.
Process Instrumentation

- **pH**
- **Flow**
- **Air**
- **Tanks 1 & 10 Only**
- **Mixer (Typ 12)**
- **AT EFFL**
- **NO$_3$**
- **NH$_4$**
- **NO$_3$**
- **SODIUM HYDROXIDE (ALKALINITY/pH)**
- **PE & RAS**
- **DO**
- **Tanks 1 & 10 Only**
- **CARBON FEED (FOOD)**
- **Tanks 1 & 10 Only**
- **P**
- **Flow**
- **P**
- **Tanks 1 & 10 Only**
- **P**
- **Tanks 1 & 10 Only**
- **P**
- **Tanks 1 & 10 Only**
- **P**
- **Tanks 1 & 10 Only**
Operations and Control
IFAS Process Control – NaOH Feed

- Caustic feed controlled pH > 7.0 in IMLR Pump Zone.
- pH Meter in IMLR Pump Zone (Tanks 1 and 10 only) used to verify mixed liquor pH after nitrification.
- Caustic feed pumps are flow paced.
  - Controls trim with AT Influent Channel pH meter.
  - Adjust metering pump stroke and control set point to get target IMLR Pump Zone pH.
IFAS Process Control – Aeration

- Air Flow to IFAS Zone controlled to get target DO.
  - IFAS Zone DO will vary from 3 to 6 mg/L as needed to fully nitrify.
  - Ammonia meter in Re-aeration Zone and in IMLR Pump Zone (Tanks 1 and 10 only) monitors nitrification.
  - Target ammonia for full nitrification = Less than 1 mg/L as NH$_4$-N.
- Adjust DO setpoint seasonally as needed to fully nitrify.
IFAS Process Control – Aeration (cont.)

- Air to IFAS Zone controlled to maintain DO setpoint.
  - DO Meter, flow meter, and control valve provided at IFAS Zone for aeration control.

- Minimum aeration required for mixing and to keep media from accumulating at sieves.
  - Controls do not go below the minimum aeration set point.
IFAS Process Control – IMLR Pump & VFD

- IMLR Flow Rate controlled to get target nitrate in IMLR Pump Zone.
  - IMLR Pump Zone nitrate range = 1 to 2 mg/L as NO₃-N.
- IMLR Flow Rate varied with Kruger PLC.
  - Three control loops to select from: Flow Pace, Flow pace w/ nitrate trim, Constant Flow Rate.
  - Nitrate in Pre-Anoxic Zone (Tanks 1 and 10 only) used w/ nitrate trim.
- IMLR Flow meter used for control feedback.
IFAS Process Control – Carbon Feed

- Carbon feed adjusted to minimize effluent nitrate.
- Carbon feed rate varied with Kruger PLC.
  - Three control loops to select from: Nitrate Load, Nitrate Reference Table, Constant Feed.
  - Nitrate meters in IMLR Pump Zone and Re-aeration Zone used w/ nitrate load mode.
- Adjust metering pump stroke and control loops to minimize Re-aeration zone nitrate.
RAS / WAS / Clarifier Process

- Set RAS and WAS Rates as needed to maintain MLSS.
  - Design MLSS of 2,750 mg/L.
  - This MLSS does not include the fixed growth.
- Kruger’s suggested clarifier loading rates:
  - Hydraulic = 400 to 630 gpm/ft²
  - Solids = 14 to 22 lbs/ft²/day
- Monitor clarifier blanket depths and settling / SVI.
  - IFAS not expected to significantly change SVI.
# Process Monitoring

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT Influent pH</td>
<td>1 / per shift</td>
<td>On Line Instr.</td>
</tr>
<tr>
<td>IFAS Zone DO</td>
<td>1 / per shift</td>
<td>On Line Instr.</td>
</tr>
<tr>
<td>IMLR Zone Nitrate</td>
<td>1 / per shift</td>
<td>On Line Instr.</td>
</tr>
<tr>
<td>AT Eff. NH$_3$ and NO$_3$</td>
<td>1 / per shift</td>
<td>On Line Instr.</td>
</tr>
<tr>
<td>Air Flow Rate</td>
<td>1 / per shift</td>
<td>Flow Meter</td>
</tr>
<tr>
<td>IMLR Flow Rate</td>
<td>1 / per shift</td>
<td>Flow Meter</td>
</tr>
<tr>
<td>RAS Flow Rate</td>
<td>1 / per shift</td>
<td>Flow Meter / DCS</td>
</tr>
<tr>
<td>WAS Flow Rate</td>
<td>1 / per shift</td>
<td>Flow Meter / DCS</td>
</tr>
<tr>
<td>Clarifier Blanket Depth</td>
<td>1 / per shift</td>
<td>Blanket Meter / DCS</td>
</tr>
<tr>
<td>Caustic Feed Rate</td>
<td>1 / per shift</td>
<td>Chemical Use</td>
</tr>
<tr>
<td>Carbon Feed Rate</td>
<td>1 / per shift</td>
<td>Chemical Use</td>
</tr>
</tbody>
</table>
## Sampling and Analysis for Process Control

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Frequency</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>AT Inf. TSS</td>
<td>1 / per day</td>
<td>Lab Test</td>
</tr>
<tr>
<td>MLSS TSS and VSS</td>
<td>1 / per day</td>
<td>Lab Test</td>
</tr>
<tr>
<td>Attached Growth on Media</td>
<td>1 / per week</td>
<td>Lab Test</td>
</tr>
<tr>
<td>AT Inf. and Eff. BOD</td>
<td>1 / per day</td>
<td>Lab Test</td>
</tr>
<tr>
<td>AT Inf. and Eff. COD</td>
<td>1 / per week</td>
<td>Lab Test</td>
</tr>
<tr>
<td>AT Inf. and Eff. TKN / NH$_3$ / NO$_3$</td>
<td>1 / per day</td>
<td>Lab Test</td>
</tr>
<tr>
<td>AT Inf., Eff., &amp; Pump Zone Alk. &amp; pH</td>
<td>1 / per day</td>
<td>Lab Test</td>
</tr>
<tr>
<td>IFAS Zone Dissolved Oxygen</td>
<td>1 / per day</td>
<td>Portable Probe</td>
</tr>
<tr>
<td>IFAS Zone Temperature</td>
<td>1 / per day</td>
<td>Thermometer</td>
</tr>
</tbody>
</table>
Process Differences from Former Process

- No significant change in effluent BOD or TSS.
- No significant change in MLSS expected.
  - Design MLSS = 2,750 mg/L.
- No significant change in SVI expected.
  - Slight improvement in settling seen at other IFAS plants.
- Decreased chlorine use in Chlorine Contact
  - Less chlorine is required for disinfection.
  - Reduced nitrate and ammonia in effluent to oxidize.
Kruger IFAS Design Capacities

- **Internal Recycle** = 230 MGD
- **RAS** = 65 MGD
- **WAS (max conditions)** = 42,000 lbs/day
- **MLSS** = 2750 mg/L
- **Solids Retention Time**
  1. Anoxic SRT = 2.44 days
  2. Aerobic SRT = 2.64 days
- **Clarifier Rates**
  1. **Overflow Rate** = 400 – 630 gallons/ft²/day
  2. **Solids Loading Rate** = 14 – 22 lbs/ft²/day
## Kruger IFAS Operating Parameters

**Permit season – May 1 – October 31**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Setpoint/Target</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYBAS DO (IFAS)</td>
<td>3 – 6 mg/L</td>
<td>as required to establish full nitrification (&lt;1 mg/L NH4-N) out of pump zone</td>
</tr>
<tr>
<td>IMLR</td>
<td>5.0 – 23.0 MGD</td>
<td>as required to maintain NOX-N in the pre-HYBAS zone between 1 – 2 mg/L</td>
</tr>
<tr>
<td>MLSS/WAS</td>
<td>2750 mg/L</td>
<td></td>
</tr>
<tr>
<td>RAS</td>
<td>1.0 – 6.5 MGD</td>
<td></td>
</tr>
<tr>
<td>C/N ratio</td>
<td>4.6 or as required</td>
<td>May vary depending on actual field conditions</td>
</tr>
</tbody>
</table>
Questions?