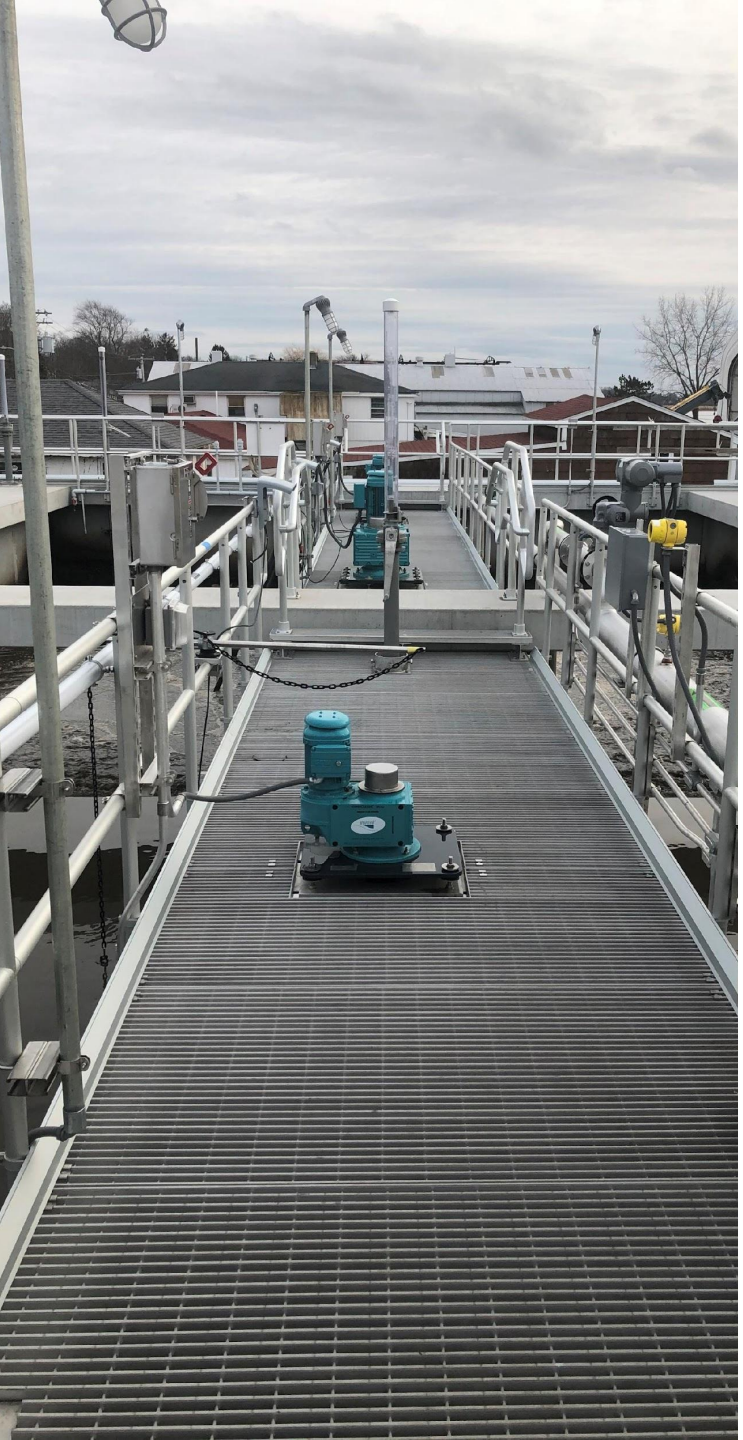

Optimizing Aeration Control to meet the needs of Process Intensification

Paul Dombrowski, PE, BCEE, WEF Fellow

Woodard & Curran, Inc.

Warren, RI WWTF Background

- WWTF upgraded to secondary treatment in 1981
- NPDES Permit (expired in 2010)
  - Monthly Average Permitted Capacity = 2.01 MGD
  - Typical secondary treatment limits (BOD_5, TSS=30 mg/L, FC=200 col/100 ml)
- Daily flows from 2010-2015 averaged 1.88 MGD with max month flows exceeding 3 MGD and estimated peak flows of 9 MGD during Spring conditions

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2010 NPDES Permit & 2013 Modification

- 2010 Permit included both monthly TN mass and conc. limits
- WWTF also needed flow limit increase
- 2013 Permit Modification
  - Monthly and Seasonal considerations for both flow and pollutant loading
  - Flow
  - Total Nitrogen
  - BOD_5 and TSS (17 and 23 mg/L seasonally)

Permit Season	Flow (MGD)	Monthly Mass Limit (lbs/d)	Seasonal Mass Limit (lbs/d)	Equivalent Concentration based on Seasonal Load Limit (mg/L)	Monthly Average Concentration Limit in Permit (mg/L)
Limits from 2010 NPDES Permit					
Winter	2.01	239.7	N/A	14.3	14.3
Summer	2.01	83.8	N/A	5.0	5
Limits with typical monthly flow limit approach					
Winter	3.43	239.7	N/A	8.4	8.4
Summer	3.43	83.8	N/A	2.9	2.9
Limits from 2013 NPDES Permit Modification					
Winter	3.43	N/A	239.7	8.4	9.5
Summer	2.53	N/A	83.8	4.0	5

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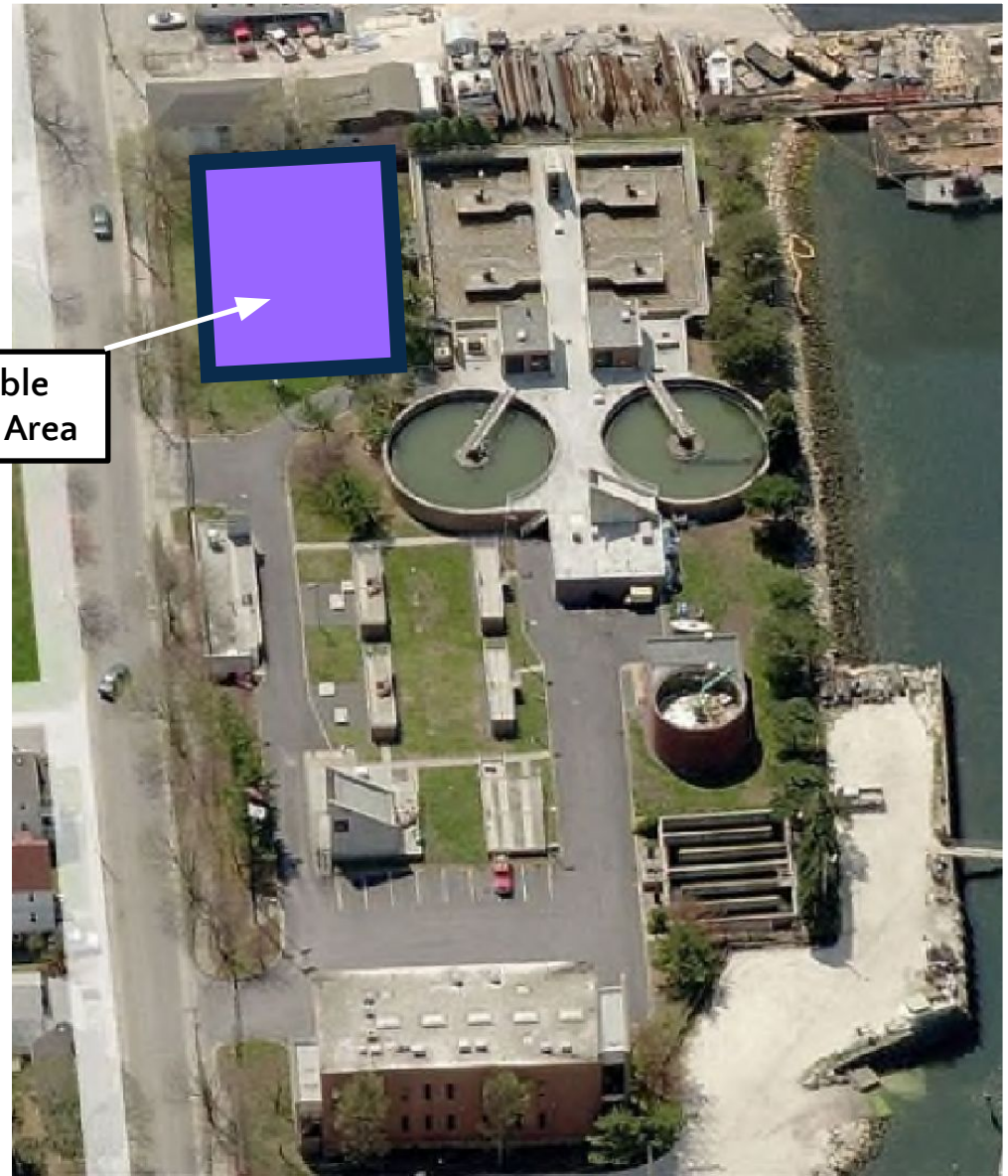
WWTF Upgrade Drivers

- Facility needs:
  - Increased wet weather capacity
  - Seasonal low level TN removal
  - Overall/Reliability Updates
- Facility Challenges:
  - Constrained site
  - Secondary clarifiers
- Limited available area, stringent TN limits and smaller secondary clarifiers required a high biomass solution – “process intensification”



Variable Operating Mode (VOM) Process Summary

- Summer Permit Season
  - 4-Stage Bardenpho mode
  - 5 mg/L monthly TN limit, 4 mg/L seasonal
- Winter Permit Season
  - Modified Ludzack-Ettinger (MLE) mode
  - 9.5 mg/L monthly TN limit, 8.3 mg/L seasonal
- Wet Weather Operation
  - Contact Stabilization mode
  - Reduces MLSS concentration to increase secondary clarifier capacity while achieving a moderate level of TN removal
  - Process modelling predicts TN performance of 8-12 mg/L during contact stab. operation
- Mode selection impacts on Aeration System
  - Independent mixing and aeration were required for many zones
  - During overnight operation of 4-Stage or MLE mode, airflows to Main Aeration Zone (Trains 1B, 2B) are 0-20 scfm
  - During Contact Stabilization mode, airflows to Main Aeration Zone are 800-1,000 scfm

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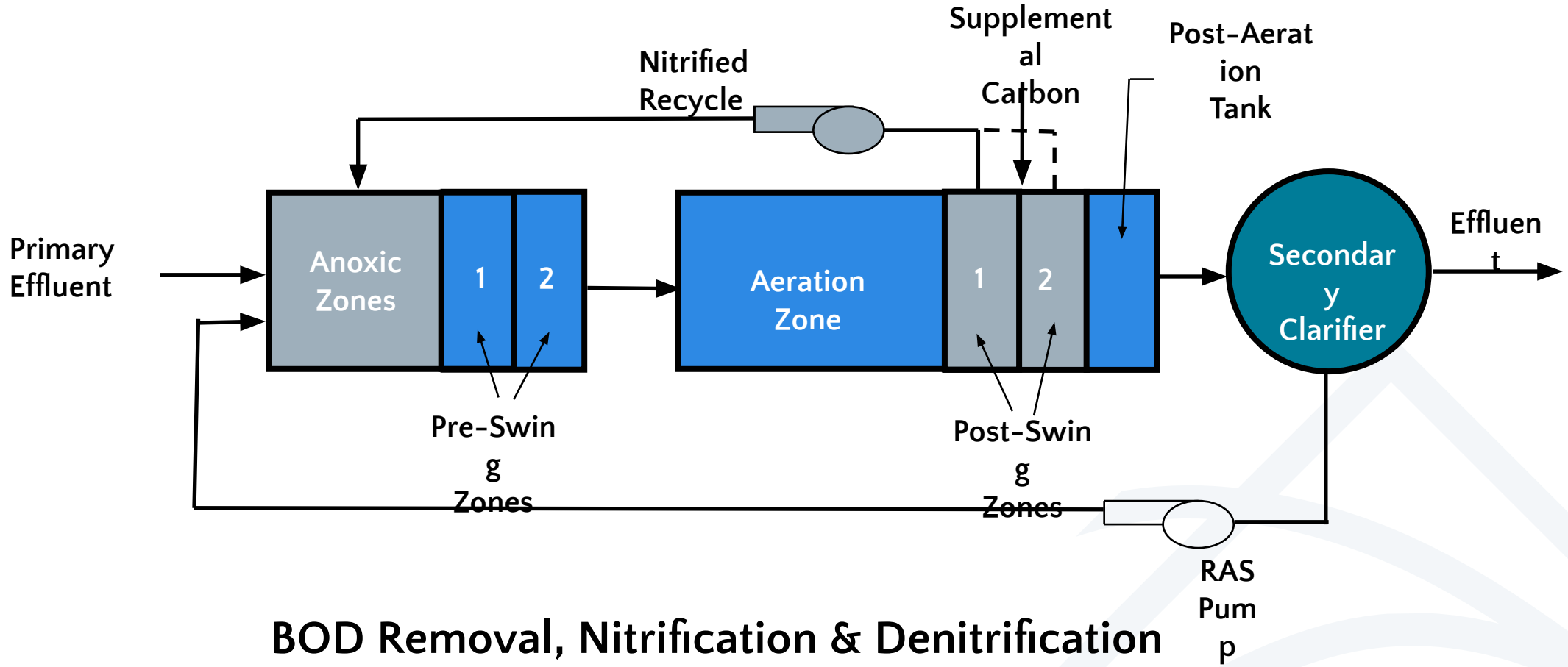
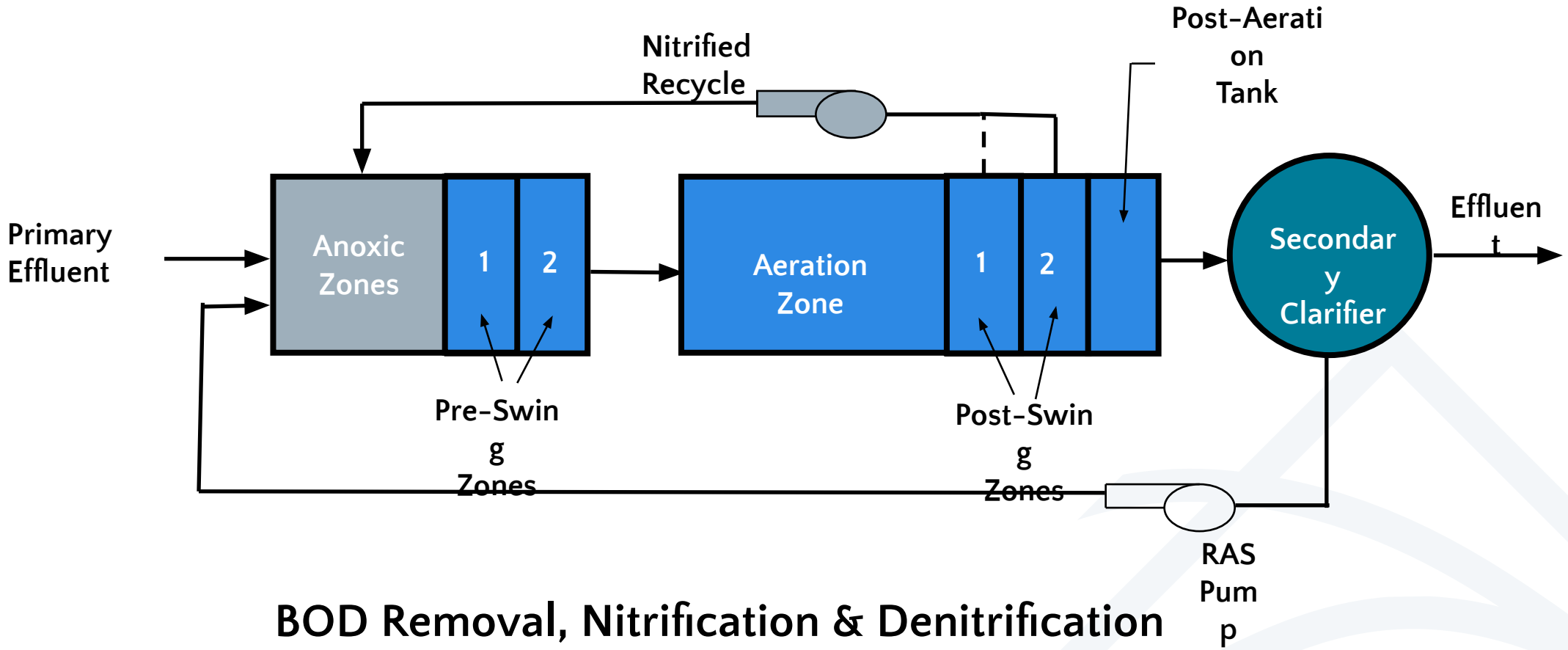
4-Stage Bardenpho Process



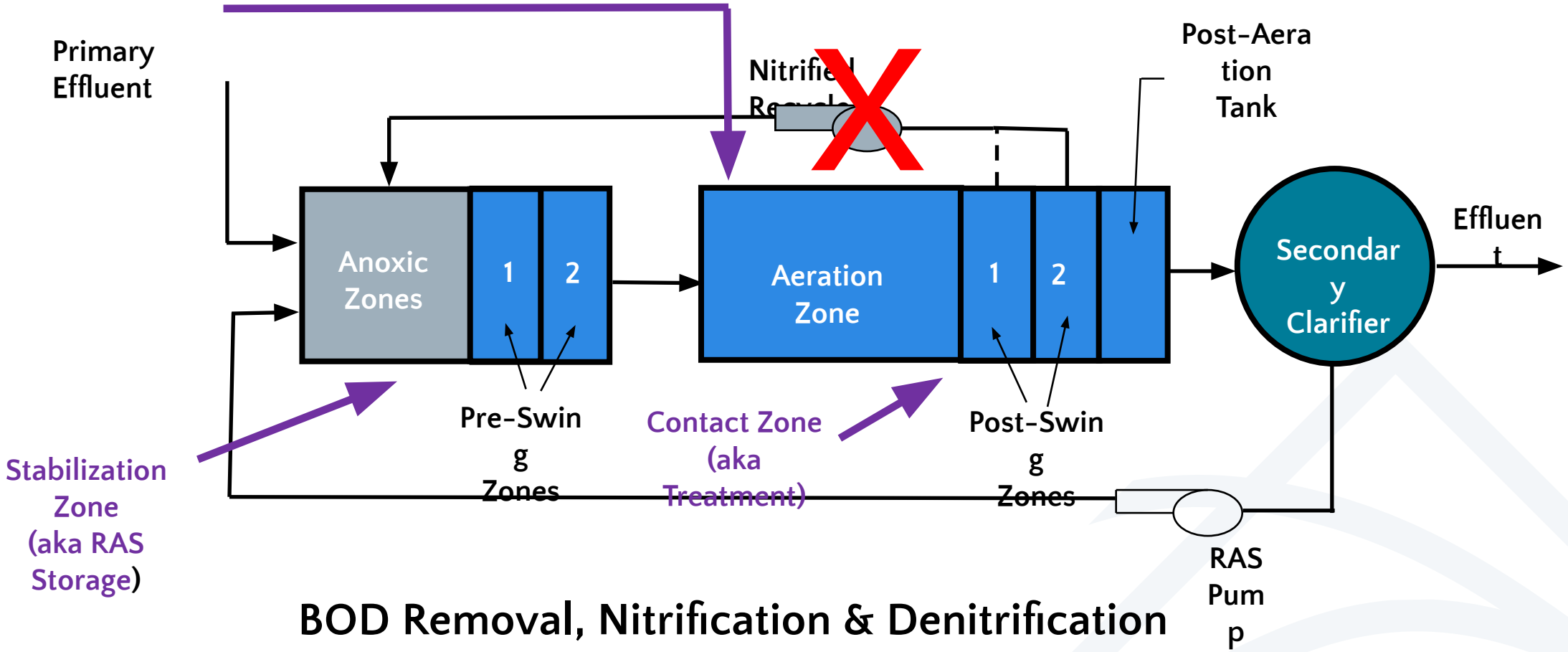
BOD Removal, Nitrification & Denitrification

Modified Ludzack-Ettinger Process

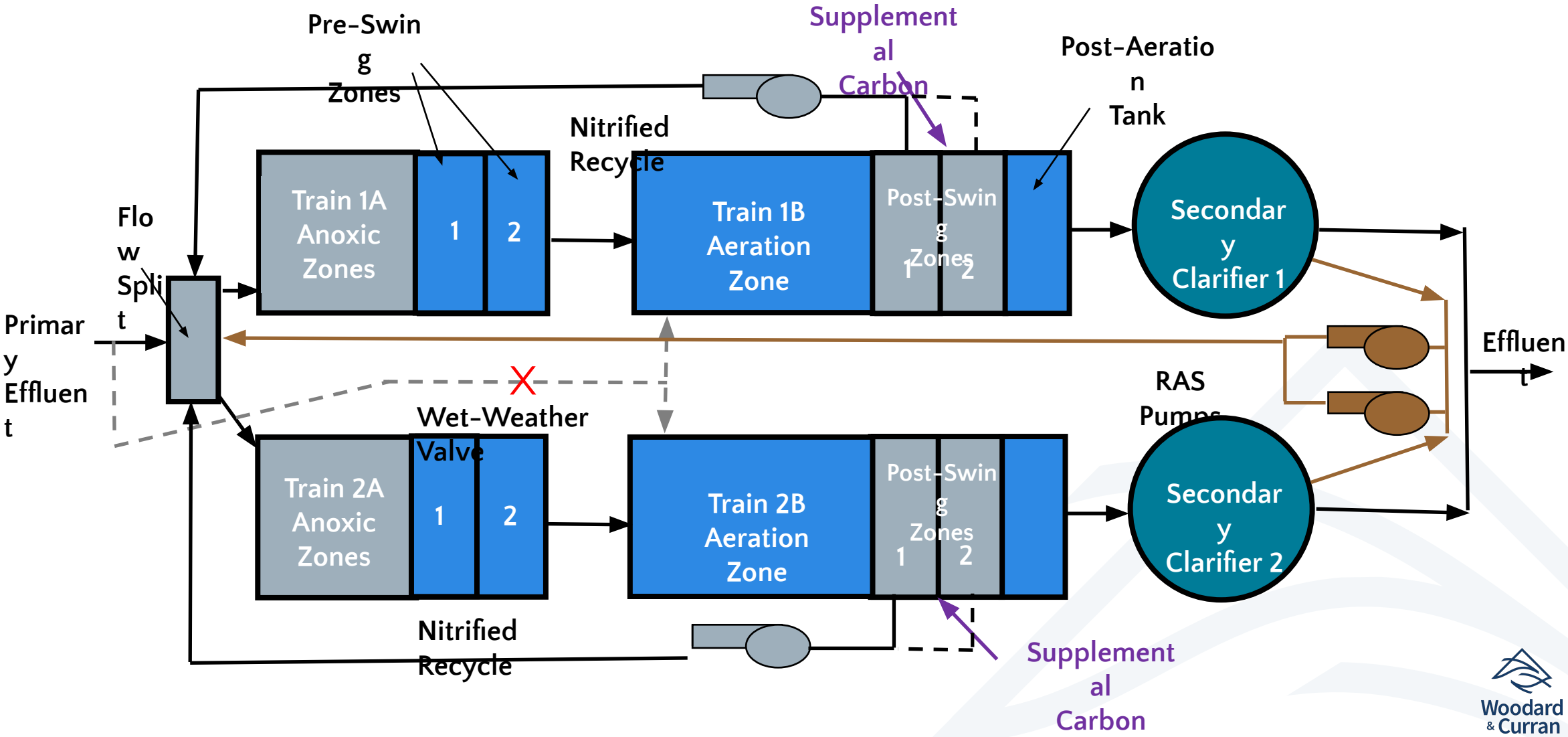


BOD Removal, Nitrification & Denitrification

Modified Contact-Stabilization Process



4-Stage Bardenpho Process – Warren, RI



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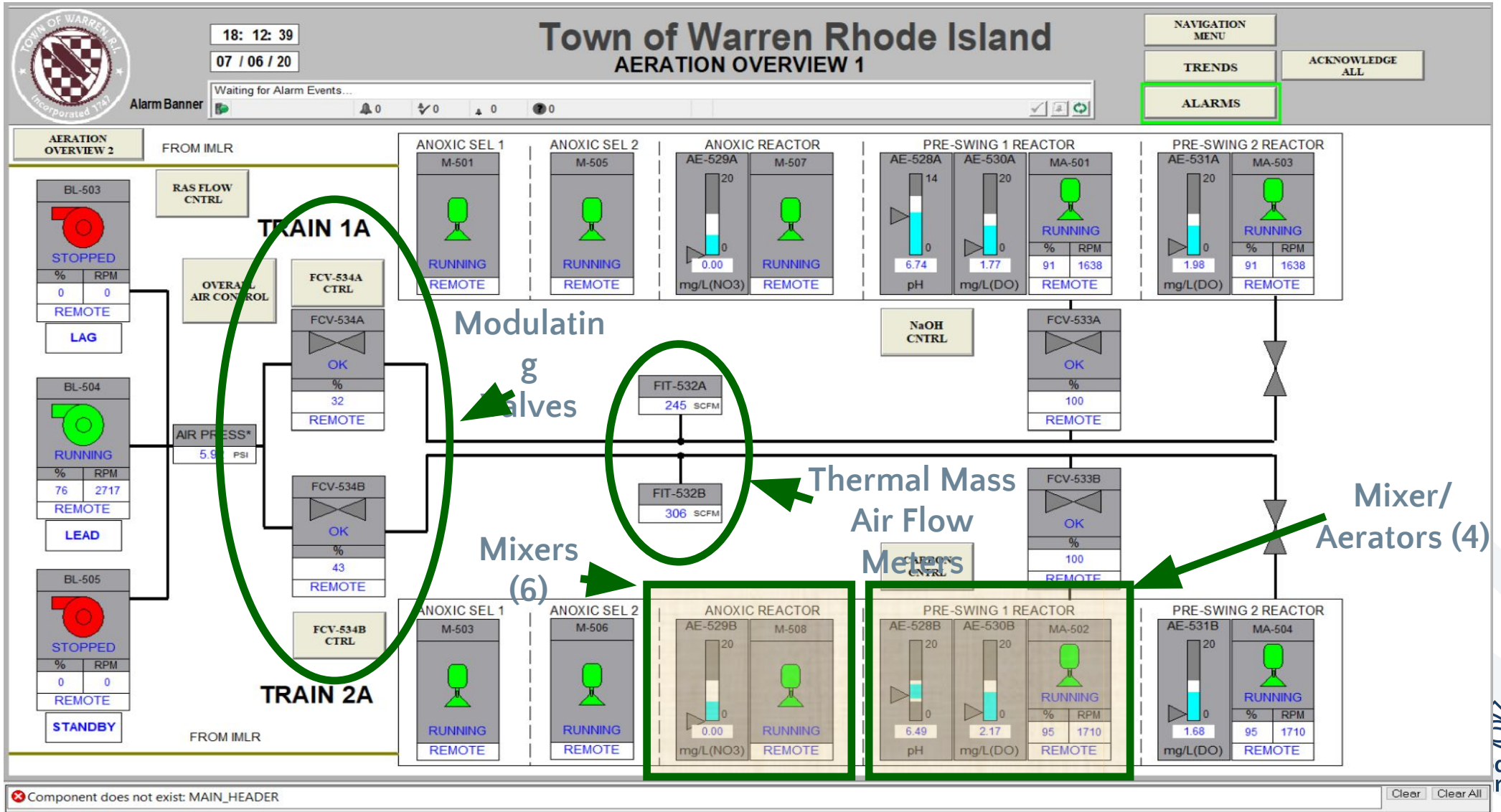
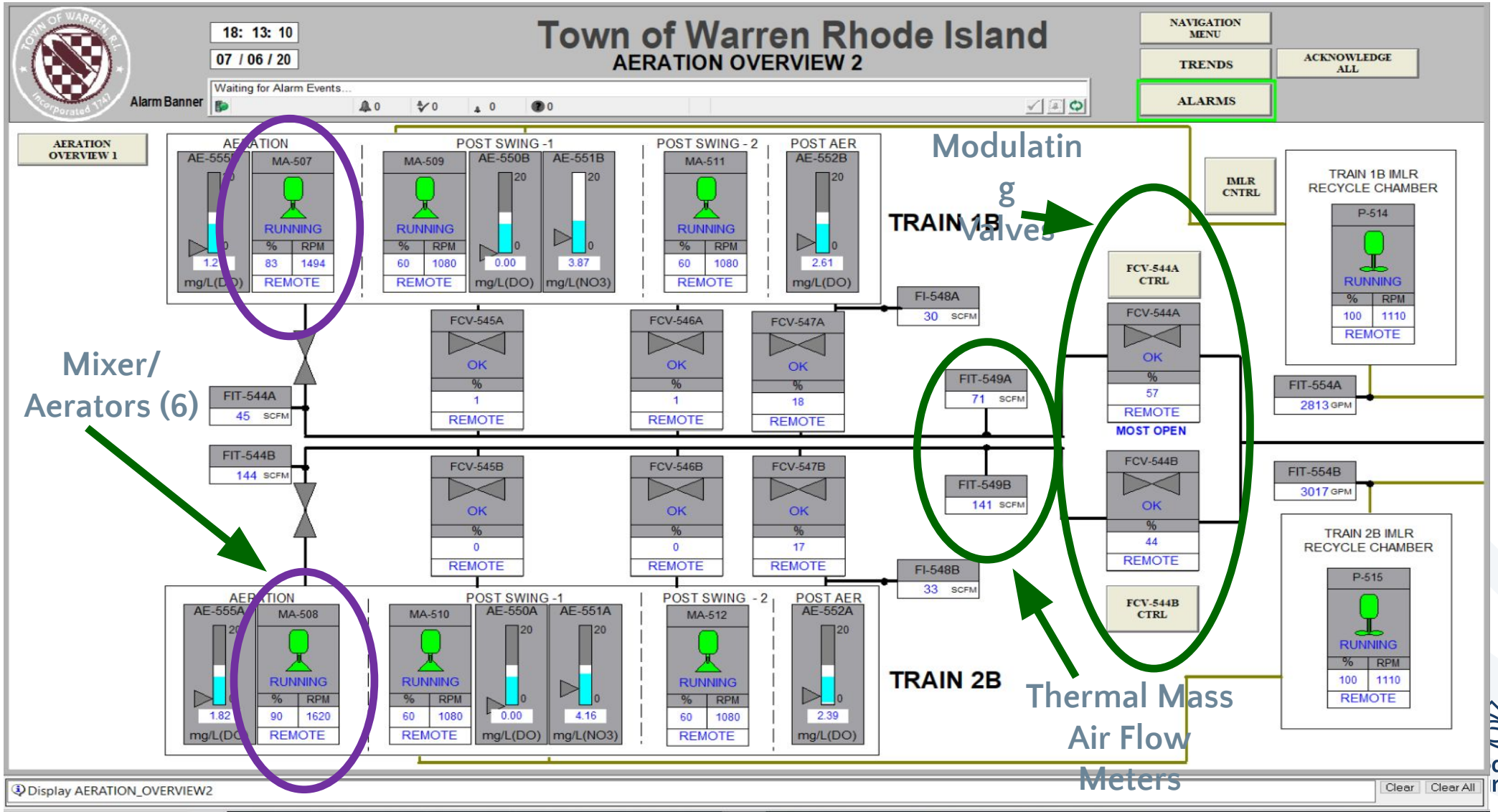
Trains 1A and 2A

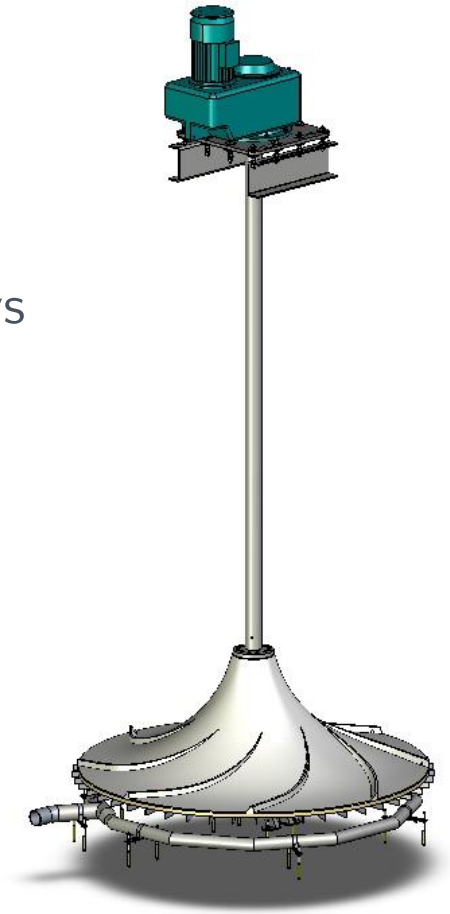


Trains 1B and 2B



Aeration and Mixing Key for Efficient BNR

- Required multiple modes of operation
- Flexibility with “swing zones”
  - Anoxic, Aerobic, or
  - Operating under Aerobic conditions but under very low airflows
- Invent Mixer/Aerators selected during design
  - Provides independent mixing
  - Allows turn down to protect against over aeration
  - Provides rapid increase in speed for efficient O2 delivery
  - Allows precise control of DO in every zone of reactors



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Typical Fine Bubble Aeration Control System

- System consists of:
  - Blowers deliver the air through the piping system
  - Valves control the distribution of air to the various diffuser grids in the aeration tanks
  - Diffusers generate the fine bubbles for efficient diffusion of oxygen into mixed liquor
  - Dissolved oxygen (DO) probes measure the oxygen levels in the mixed liquor
  - Airflow meters measure the airflow to each portion of the system receiving independent control
- Typical control approach includes:
  - DO probes measure actual vs. setpoint, and the control system determines a new target airflow with the blower speed adjusted based on overall system demand error
  - Valves are modulated to achieve new target airflows through each control valve with 1 valve remaining fully open as the “Most Open Valve” (MOV)

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Typical Fine Bubble Aeration Control System

- Keys to Precise and Stable Aeration Control
  - All control logic “runs” through airflow meter values both for blower speed and valve position control
  - Accurate control requires stable control of blower output and precise modulation of airflows, typically with specialized valves or actuators

Iris Diaphragm Valve

Rexa Hydraulic Actuator with Butterfly Valve

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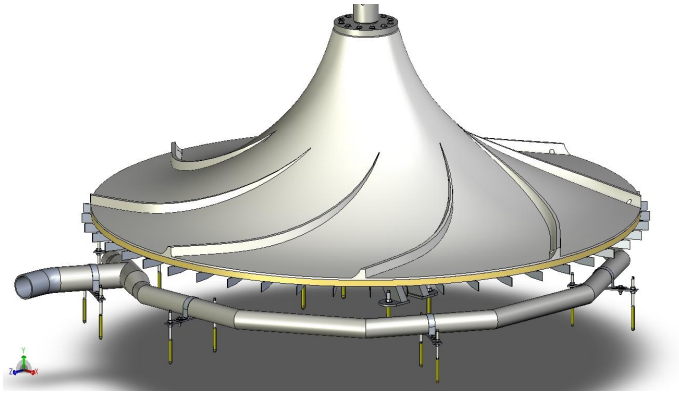
Aeration Control with Mixer/Aerators

- Mixer speed impacts 2 aspects of O_2 transfer:
  - Faster mixer speed = better oxygen transfer
  - Faster mixer speed = “pulls” more air to that mixer/aerator
  - Helps control air distribution and reduces valve changes
- Mixer speed changes provide exceptional aeration turndown
  - Typical 2 operating blower with diffused air provides 4:1 turndown
  - Mixer/Aerators provide 50:1 turndown
- Precise DO control allows optimization of each reactor zone
  - Provides precise DO operation in aerobic zones
  - Minimizes DO carry over to adjacent zones
- W&C Process and SCADA team developed this enhanced DO control method and worked closely with Mixer-Aerator supplier



Mixer/Aerator body and sparge ring

Train 2A

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Mixer-Aerator System Dissolved Oxygen Control

1. System evaluation timer – 10 minutes (floating proportional)
   a. Converts DO error from setpoint in all zones to a new speed target for blowers
   b. Use of mixer/aerators prohibits use of airflow as an intermediate parameter for valves
2. Mixer/Aerator changes speed directly in response to DO – 10 to 30 seconds (proportional with "downshift and range control mechanisms)
   a. 0.1% speed change when outside DO deadband
   b. Mixer/aerators change both O_2 transfer efficiency and airflow to each zone
3. Valve position evaluation timer – Typically every 5 minutes (step)
   a. Each header calculates a change in valve position when outside of deadband
   b. Single deadband – if outside deadband, changes valve position 2%
4. Valves use "Most Open Valve" (MOV) logic, but…
   a. Mixer/aerators function as "inner" deadband (0.1 mg/L DO)
   b. Valves function as "outer" deadband (0.2 mg/L DO)

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00: 09: 34

01 / 15 / 22

Town of Warren Rhode Island

Primary Effluent Trend

NAVIGATION MENU

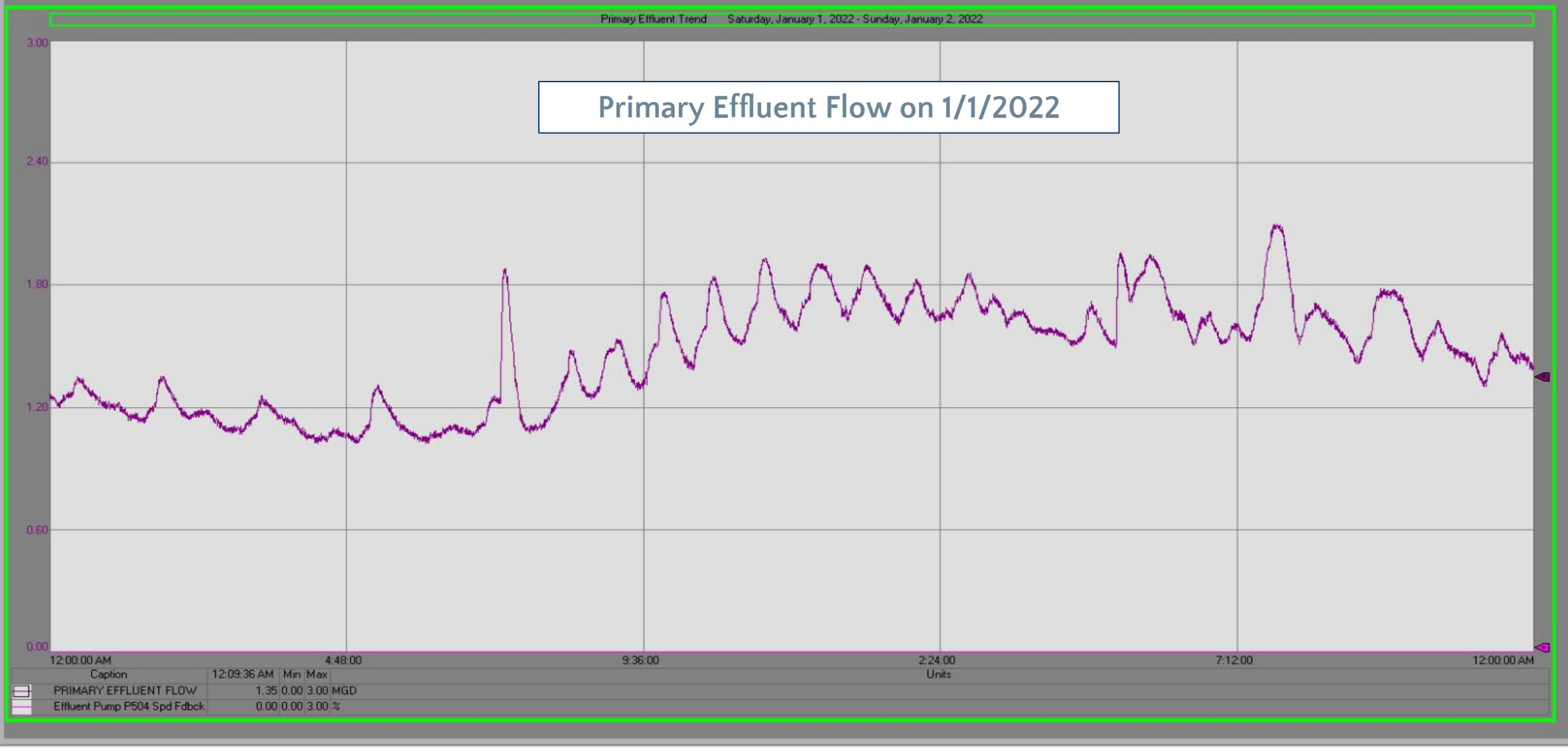
TRENDS

ALARMS

ACKNOWLEDGE ALL

Alarm Banner

0 2 0 0 0



Primary Effluent Flow on 1/1/2022

Display PRIMARY EFFLUENT TREND

Clear Clear All

00: 04: 58

01 / 15 / 22

Town of Warren Rhode Island

BLOWER SPEED

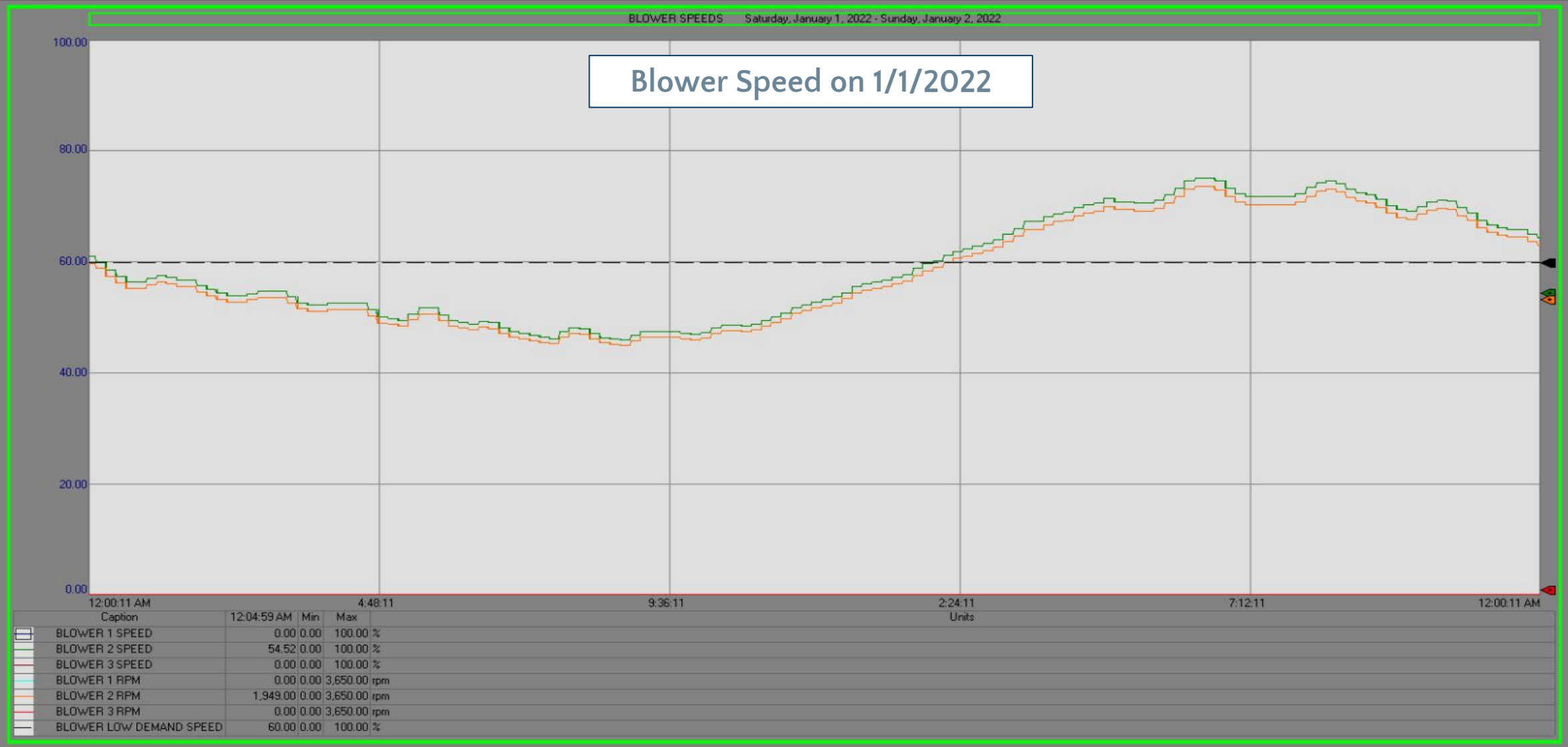
NAVIGATION MENU

TRENDS

ALARMS

ACKNOWLEDGE ALL

Alarm Banner 0 2 0 0 0



Caption	12:04:59 AM	Min	Max	Units
BLOWER 1 SPEED	0.00	0.00	100.00	%
BLOWER 2 SPEED	54.52	0.00	100.00	%
BLOWER 3 SPEED	0.00	0.00	100.00	%
BLOWER 1 RPM	0.00	0.00	3,650.00	rpm
BLOWER 2 RPM	1,949.00	0.00	3,650.00	rpm
BLOWER 3 RPM	0.00	0.00	3,650.00	rpm
BLOWER LOW DEMAND SPEED	60.00	0.00	100.00	%

Display BLOWER_SPEED_TREND

Clear Clear All

00: 00: 37

01 / 15 / 22

Town of Warren Rhode Island

DO Trend

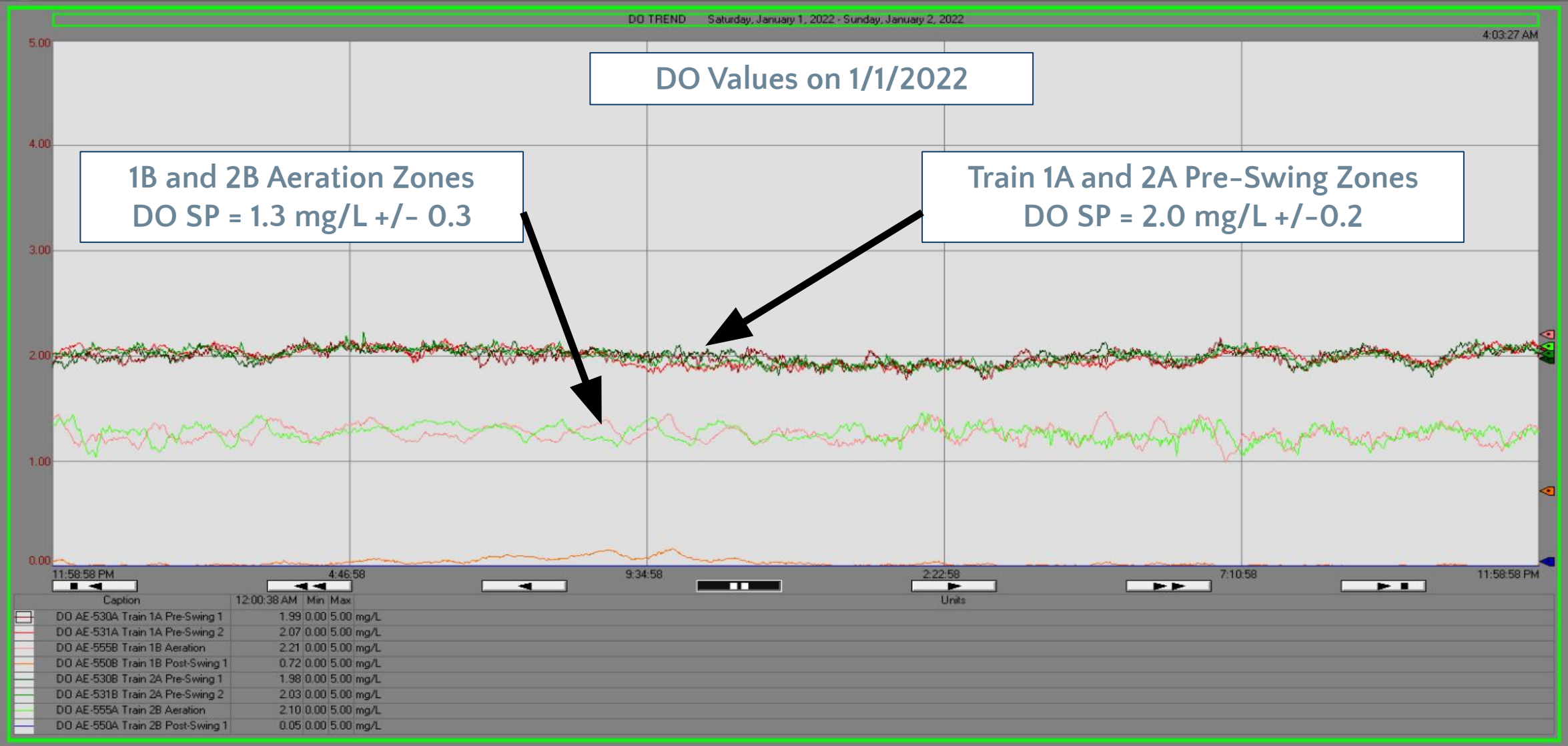
NAVIGATION MENU

TRENDS

ALARMS

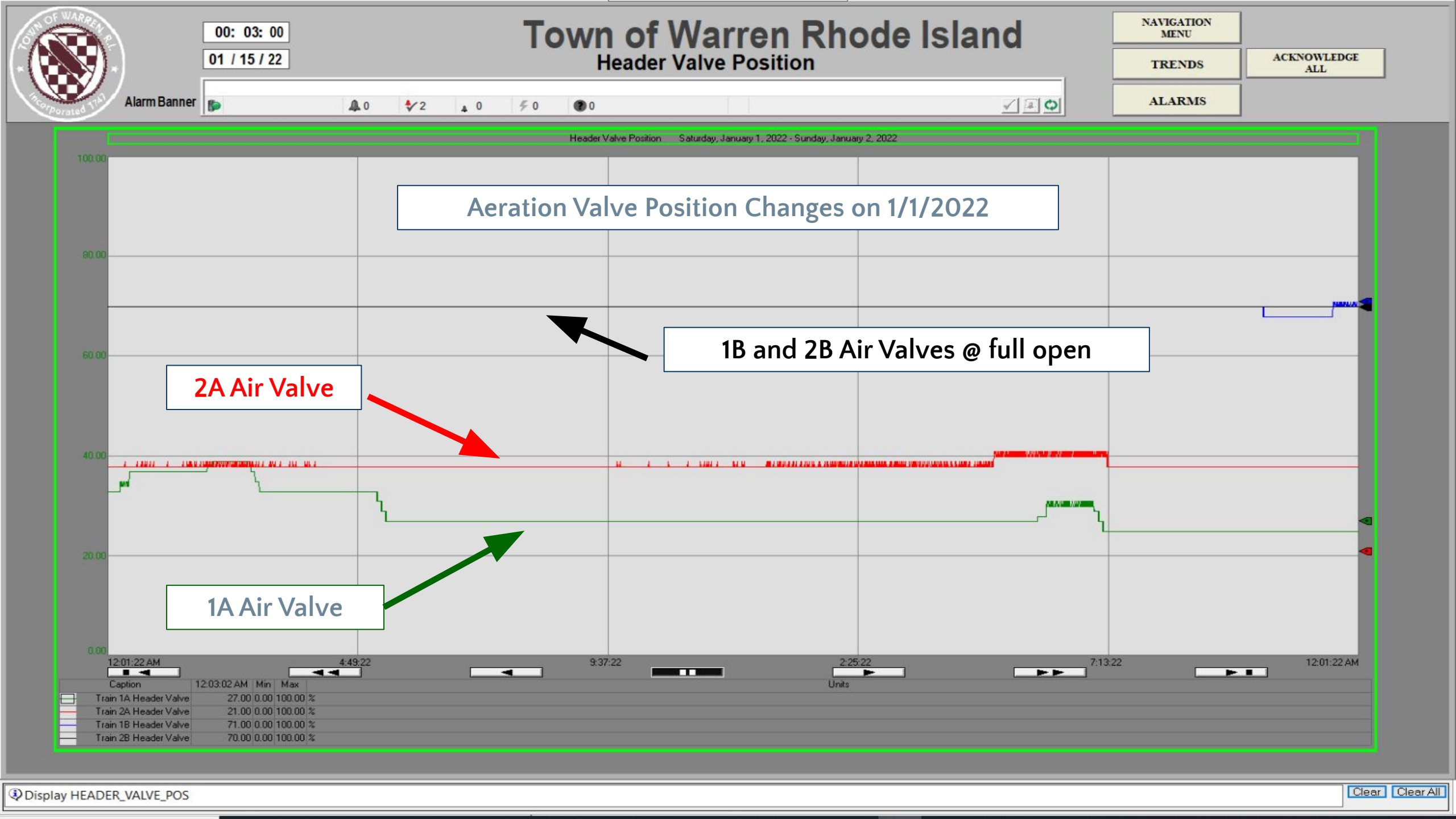
ACKNOWLEDGE ALL

Alarm Banner 0 2 0 0 0



The datalog data set '2022 01 15 0000' has been created in 'C:\RSVIEW_HIST\RSVIEW\'.

Clear Clear All


00: 03: 00
01 / 15 / 22
Town of Warren Rhode Island
Header Valve Position
NAVIGATION MENU
TRENDS
ALARMS
ACKNOWLEDGE ALL
Alarm Banner
Header Valve Position Saturday, January 1, 2022 - Sunday, January 2, 2022
Aeration Valve Position Changes on 1/1/2022
1B and 2B Air Valves @ full open
2A Air Valve
1A Air Valve
100.00
80.00
60.00
40.00
20.00
0.00
12:01:22 AM
4:49:22
9:37:22
2:25:22
7:13:22
12:01:22 AM
Caption 12:03:02 AM Min Max Units
Train 1A Header Valve 27.00 0.00 100.00 %
Train 2A Header Valve 21.00 0.00 100.00 %
Train 1B Header Valve 71.00 0.00 100.00 %
Train 2B Header Valve 70.00 0.00 100.00 %
Display HEADER_VALVE_POS
Clear
Clear All

Town of Warren Rhode Island

Primary Effluent Trend

01: 17: 53

01 / 15 / 22

Alarm Banner

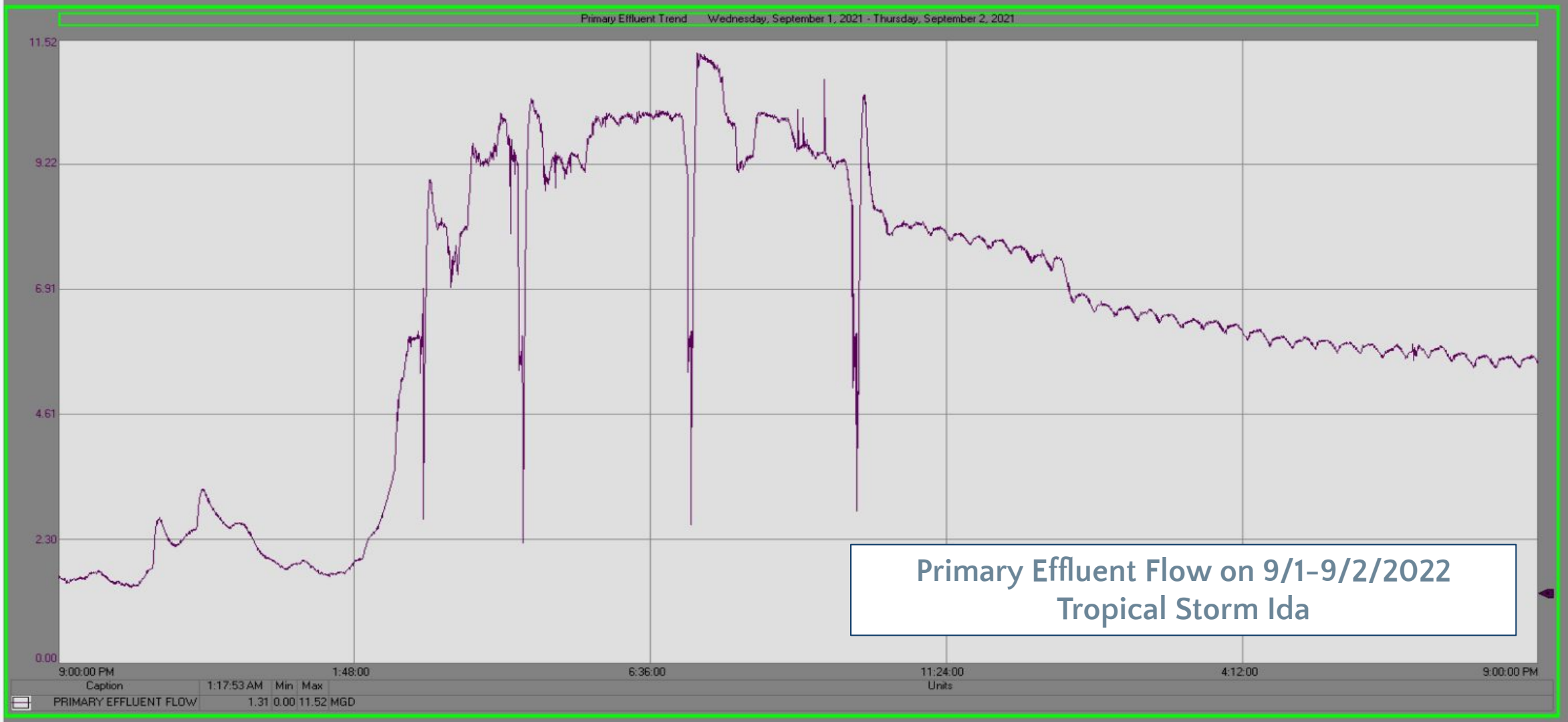
0 2 0 0 0

NAVIGATION MENU

TRENDS

ALARMS

ACKNOWLEDGE ALL



Primary Effluent Flow on 9/1-9/2/2022
Tropical Storm Ida

Display PRIMARY EFFLUENT TREND

Clear Clear All

01: 19: 41

01 / 15 / 22

Town of Warren Rhode Island

DO Trend

NAVIGATION MENU

TRENDS

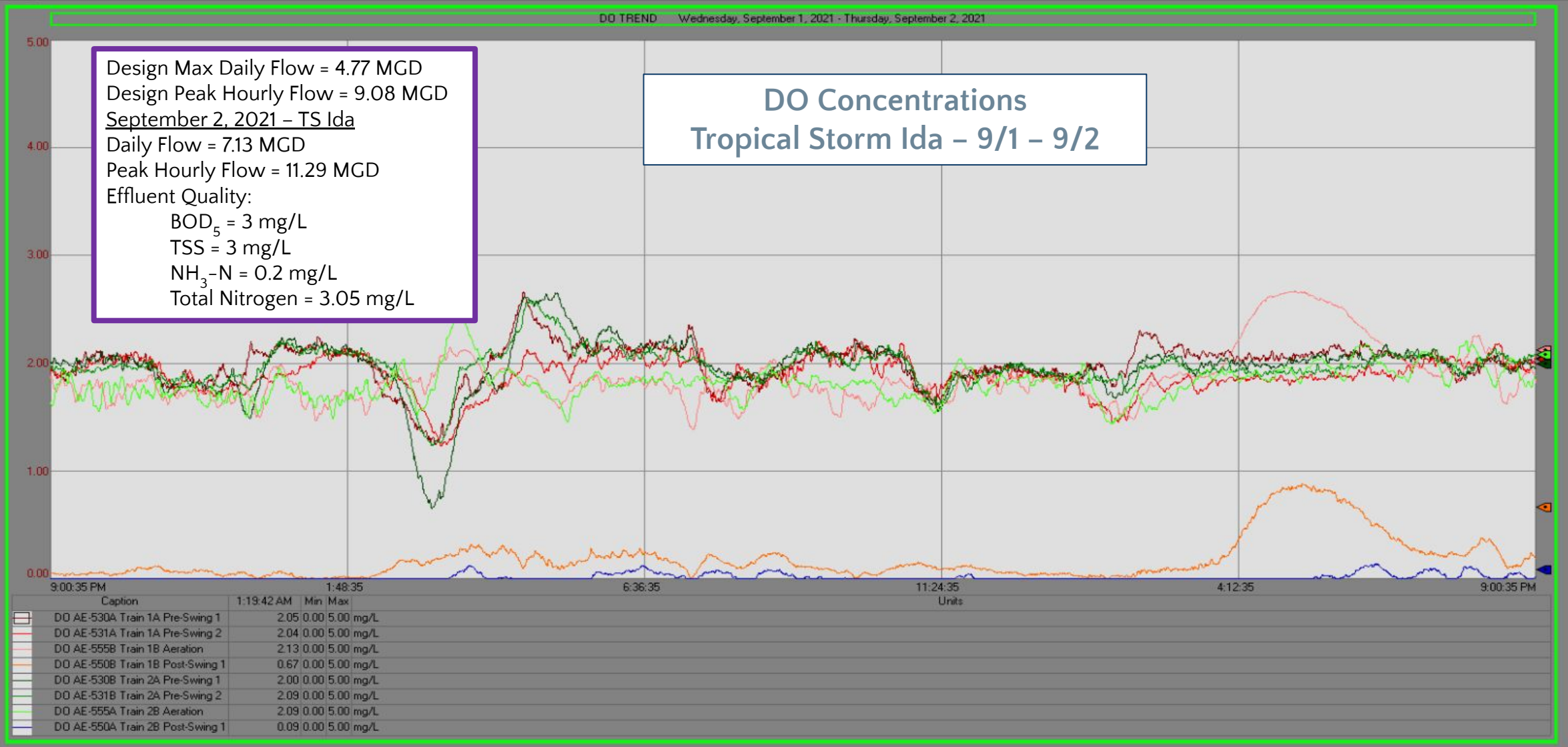
ALARMS

ACKNOWLEDGE ALL

Alarm Banner 0 2 0 0 0

Design Max Daily Flow = 4.77 MGD
Design Peak Hourly Flow = 9.08 MGD
<u>September 2, 2021 – TS Ida</u>
Daily Flow = 7.13 MGD
Peak Hourly Flow = 11.29 MGD
Effluent Quality:
BOD_5 = 3 mg/L
TSS = 3 mg/L
NH_3-N = 0.2 mg/L
Total Nitrogen = 3.05 mg/L

DO Concentrations
Tropical Storm Ida – 9/1 – 9/2



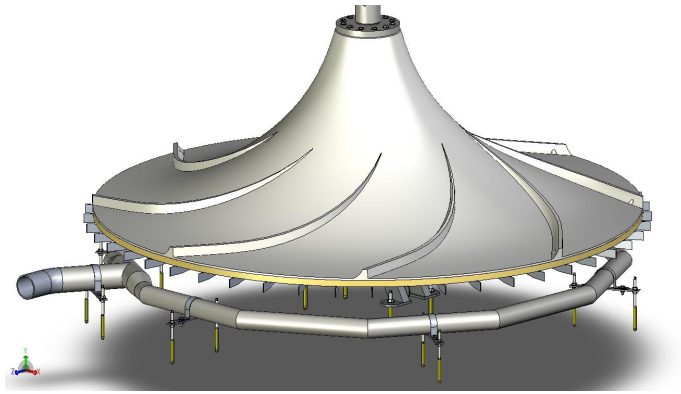
Caption	1:19:42 AM	Min	Max	Units
DO AE-530A Train 1A Pre-Swing 1	2.05	0.00	5.00	mg/L
DO AE-531A Train 1A Pre-Swing 2	2.04	0.00	5.00	mg/L
DO AE-555B Train 1B Aeration	2.13	0.00	5.00	mg/L
DO AE-550B Train 1B Post-Swing 1	0.67	0.00	5.00	mg/L
DO AE-530B Train 2A Pre-Swing 1	2.00	0.00	5.00	mg/L
DO AE-531B Train 2A Pre-Swing 2	2.09	0.00	5.00	mg/L
DO AE-555A Train 2B Aeration	2.09	0.00	5.00	mg/L
DO AE-550A Train 2B Post-Swing 1	0.09	0.00	5.00	mg/L

Display DO TREND

Clear Clear All

Summary

- Combination of mixer/aerators and most open valve approach provides responsive, stable, precise and efficient DO control
- Does not require specialized or expensive valves or actuators
- In 4-Stage Mode, system consistently achieves <5 mg/L for BOD and TSS as well as <3 mg/L for Total Nitrogen without supplemental carbon or alkalinity addition
- Turndown capability of the system has been demonstrated at 50:1 while maintaining accurate DO control



Woodard & Curran

Thanks

- Town of Warren:
  - Kate Michaud
  - Bob Rulli
- Suez / H2O Innovation
  - Dave Komiega
  - Norm Blank
  - Eric Komiega
- Woodard & Curran
  - Jon Himlan
  - Craig Gaudet

Woodard & Curran

Questions

pdombrowski@woodardcurran.com