

# FUTURE SUPPLY ACTIONS PROGRAM WEBINAR SERIES

## ARTIFICIAL INTELLIGENCE STUDY

March 23, 2023



THE METROPOLITAN WATER DISTRICT  
of SOUTHERN CALIFORNIA



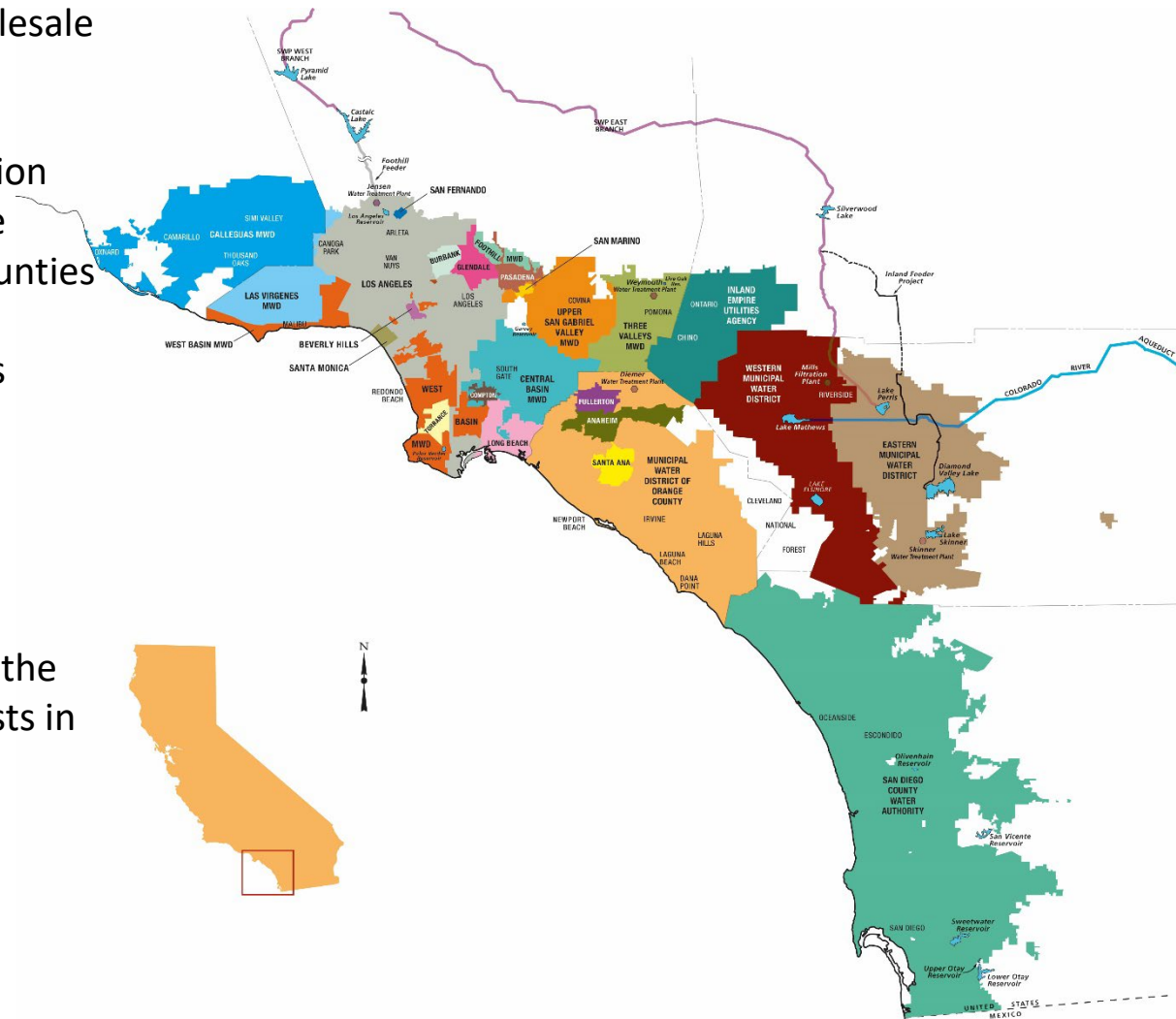
# Agenda





# The Metropolitan Water District of Southern California

- Nation's largest wholesale water provider
- Service area: 19 million people/5,200 square miles/parts of six counties
- 26 member agencies
- Supports \$1 trillion regional economy
- Imports water from Northern Sierra and the Colorado River, invests in local projects





# Metropolitan's Role for Southern CA

The collage consists of six images arranged in a 2x3 grid, each with a green text overlay:

- REGIONAL PROVIDER:** Aerial view of a large water canal in a desert landscape with mountains in the background.
- INNOVATION:** A modern water treatment facility with a sign that reads "A NEW SOURCE OF WATER FOR SOUTHERN CALIFORNIA" and "FOR QUALITY OF LIFE".
- VISION:** A black and white historical photograph of workers inside a large tunnel.
- VISION:** A modern black and white photograph of workers inside a large tunnel.
- Flexible System:** A laboratory setting with glass flasks and a person working in the background.
- SAFE & RELIABLE:** A photograph of a meeting room with people seated around a table, looking at a screen displaying a woman speaking.



# Future Supply Actions Funding Program

Future Supply Actions established in 2010 IRP

Drive innovation

Pilot new approaches  
and technologies

Remove barriers to  
supply development

Benefit the region

Local Resources

Groundwater

Stormwater

Reuse

Desalination



## Current Program

### Member Agency

- 14 studies
- \$3.1 million

### Water Research Foundation

- 6 potable reuse studies
- 1 agricultural reuse study
- \$975k



# Speaker Spotlight



**John Zhao**

Las Virgenes Municipal  
Water District



**Andrew Salveson**

Carollo



**Darrell Johnson**

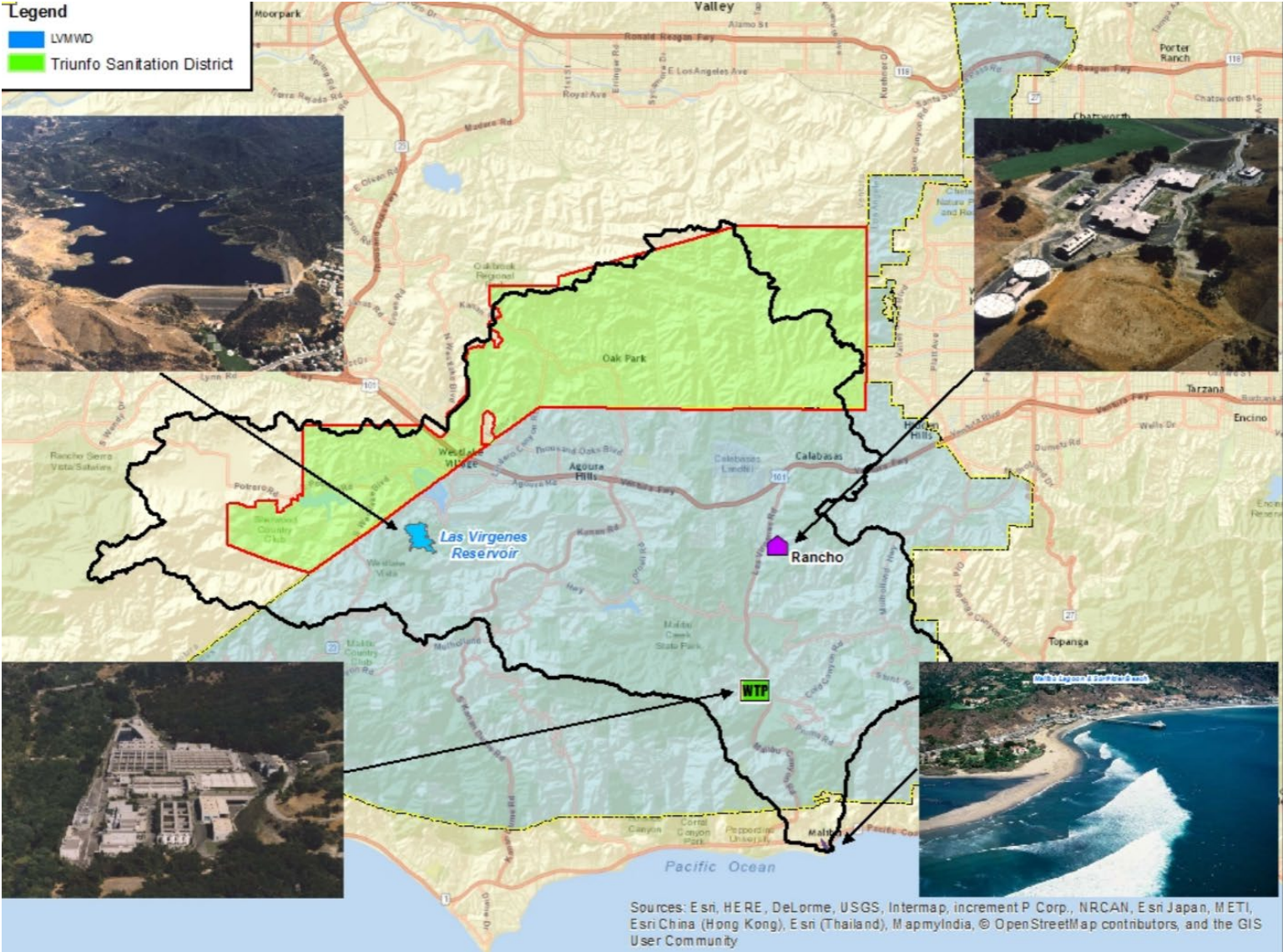
Las Virgenes Municipal  
Water District



**Amos Branch**

Carollo

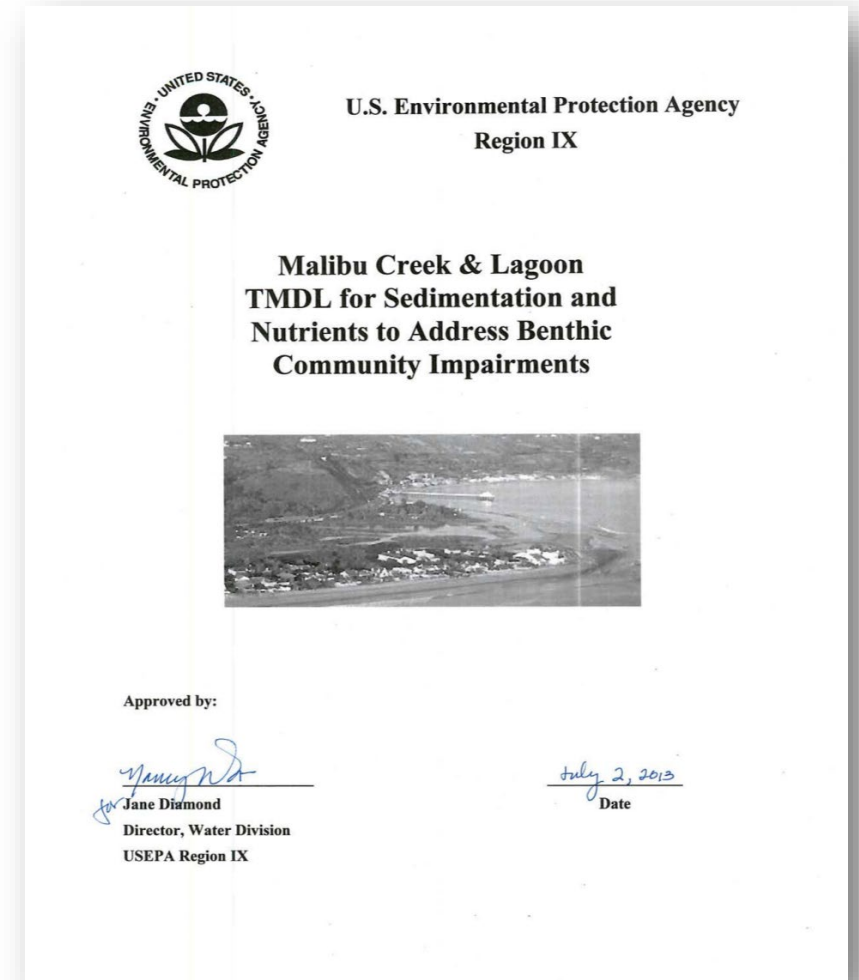
# Las Virgenes Water District and Triunfo Sanitation District JPA collaboratively protect the Malibu Creek Watershed



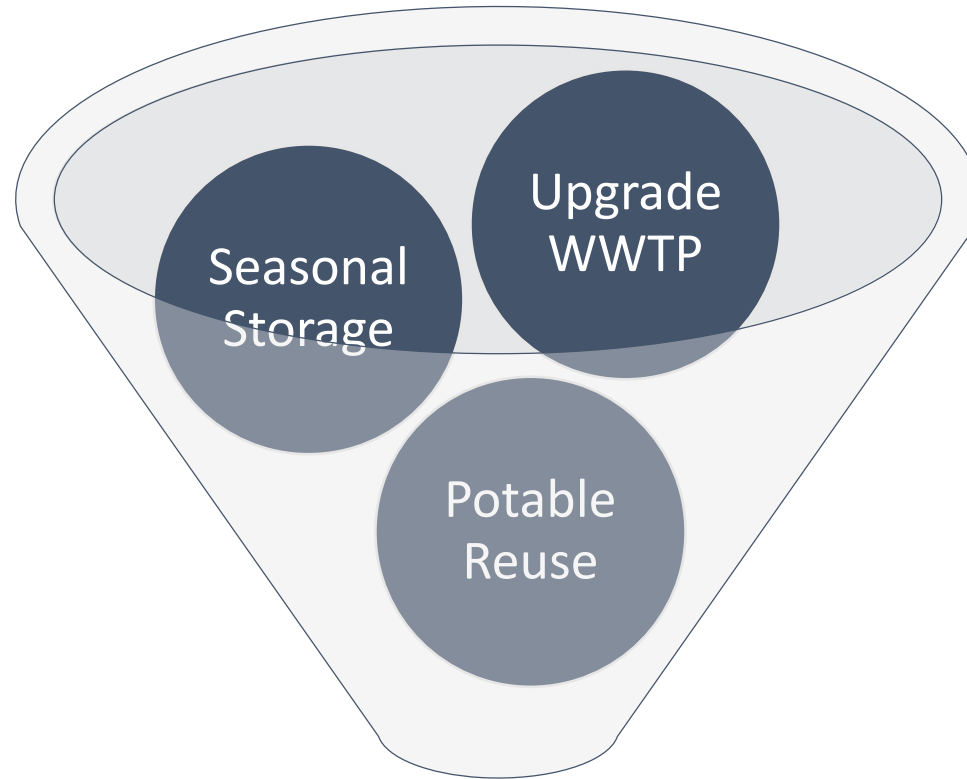


# In 2013, the EPA established a new TMDL for Malibu Creek with stringent nitrogen and phosphorus limits

- Implemented by LARWQCB May 2017
- Summer Limits (April 15 – November 15)
  - 1 mg/L (total nitrogen) & 0.1 mg/L (total phosphorous)
  - By May 16, 2022
- Winter Limits (November 16 – April 14)
  - 4 mg/L (total nitrogen) & 0.2 mg/L (total phosphorous)
  - By November 16, 2030



Which of these will best meet the Malibu Creek TMDL and benefit the community at a reasonable cost?



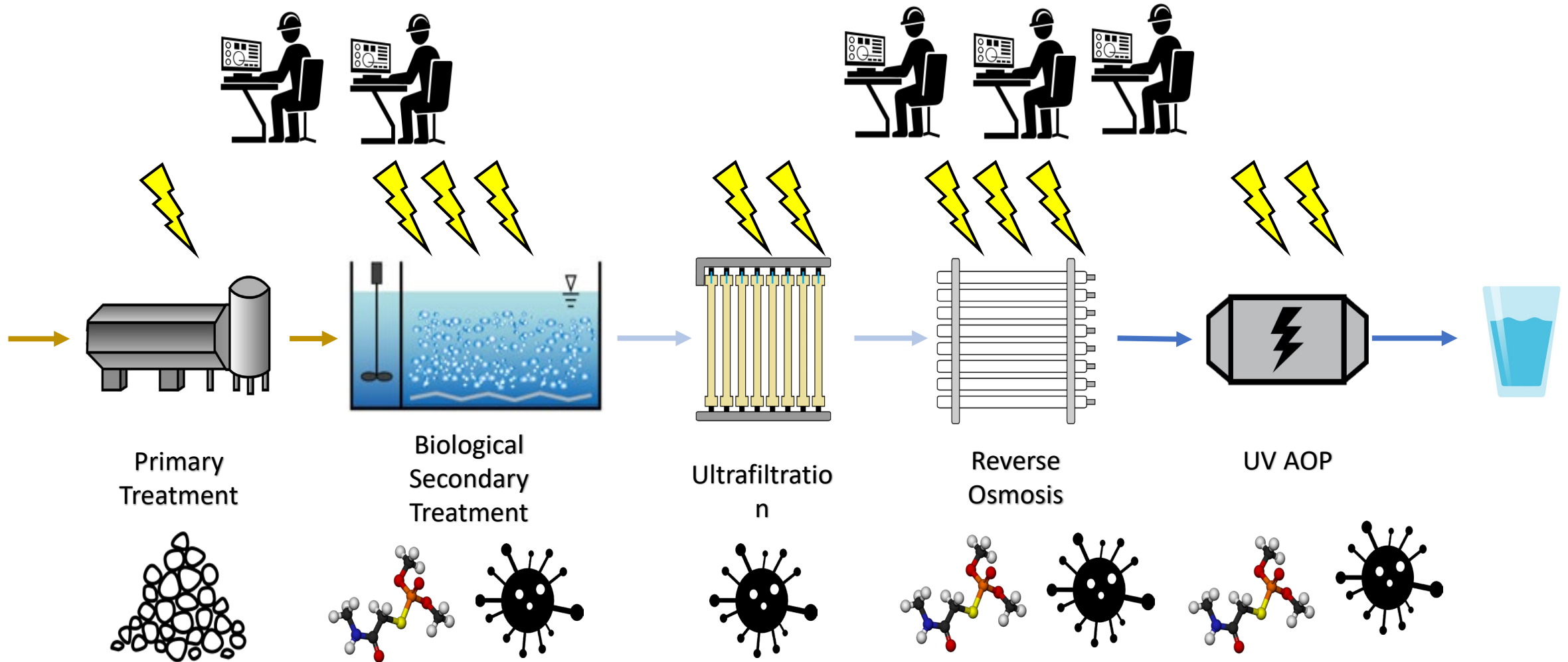
**Potable Reuse via Reservoir  
Water Augmentation**



**PURE WATER PROJECT  
LAS VIRGENES-TRIUNFO**

Bringing Our Water Full Circle

# JPA Taking a Holistic Approach to Energy Use and Water Quality



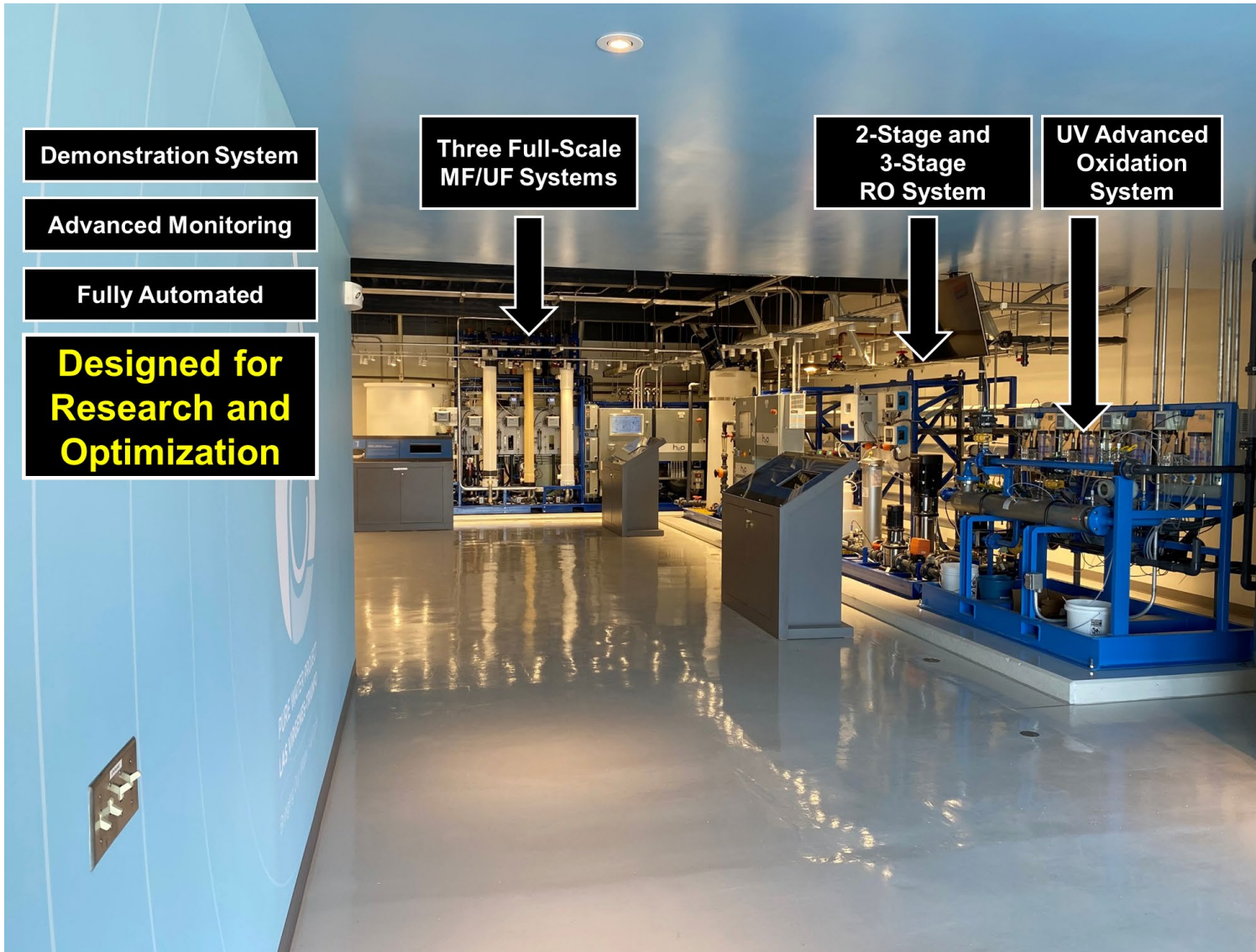
## Tapia Water Reclamation Facility



## Las Virgenes Triunfo JPA Pure Water Demonstration



# Las Virgenes Triunfo JPA Pure Water Demonstration



- Three Full Scale MF/UF
- Run in Parallel (same feed source)
- Independently Monitored and Controlled
- Now almost 3 years of 24/7 operating data

# Future Supply Actions Las Virgenes AI Research Scope

- Task 1 – Model Predictive Control to Reduce Energy Consumption at WRFs
  - Quantify the Potential for Energy Savings
  - Investigate the Utility of Ammonia Control to Reduce Addition for Chloramination
- Task 2 – Pathogen Based AWWPF Control
  - Investigate Alternative Virus Surrogates
  - Investigate the Feasibility for Semi Autonomous Operation to Enhance Energy Savings

## Project Partners



## Later Contributors



# Reducing Energy Use While Maintaining Water Quality in the Biological Secondary Treatment Process

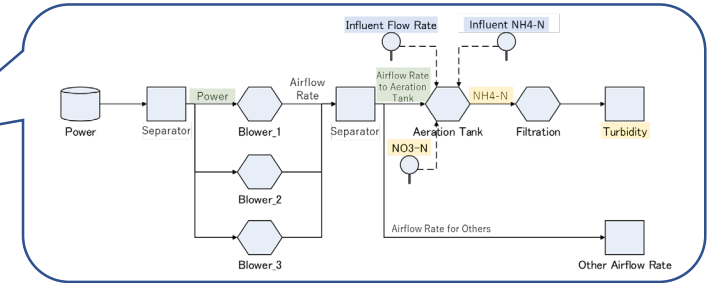
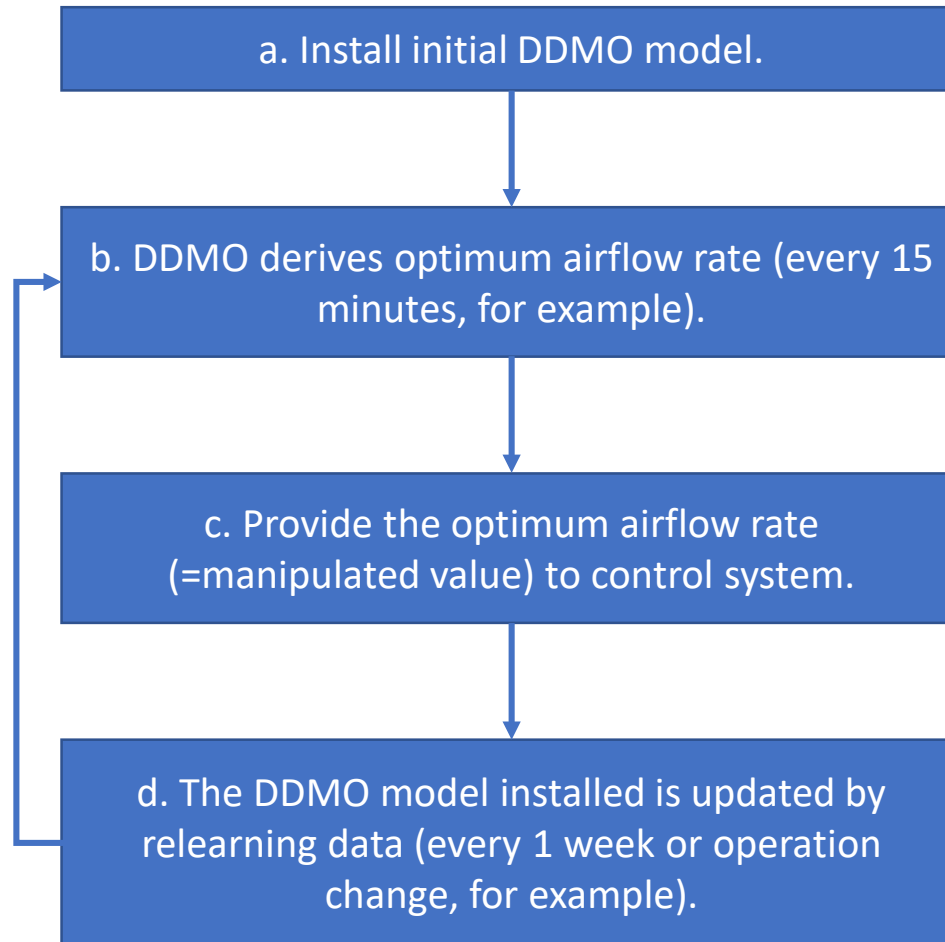


- Nutrients and Performance
- Airflow
- Power

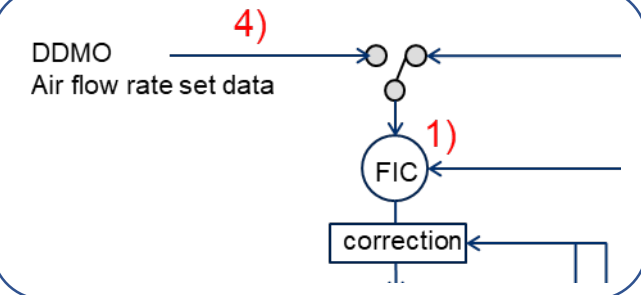


# ML/AI for WRF Optimization – Data Driven Model Optimization (DDMO)

- Take training data from Tapia WRF
- Set goals based on nitrogen species targets and determine optimized blower operation mode.
- Predict aeration savings
- Compare DDMO output with Biowin simulation of the same plant.



Optimum airflow rate is derived in terms of influent water qualities so that effluent water qualities are tolerant of the discharge limitation.



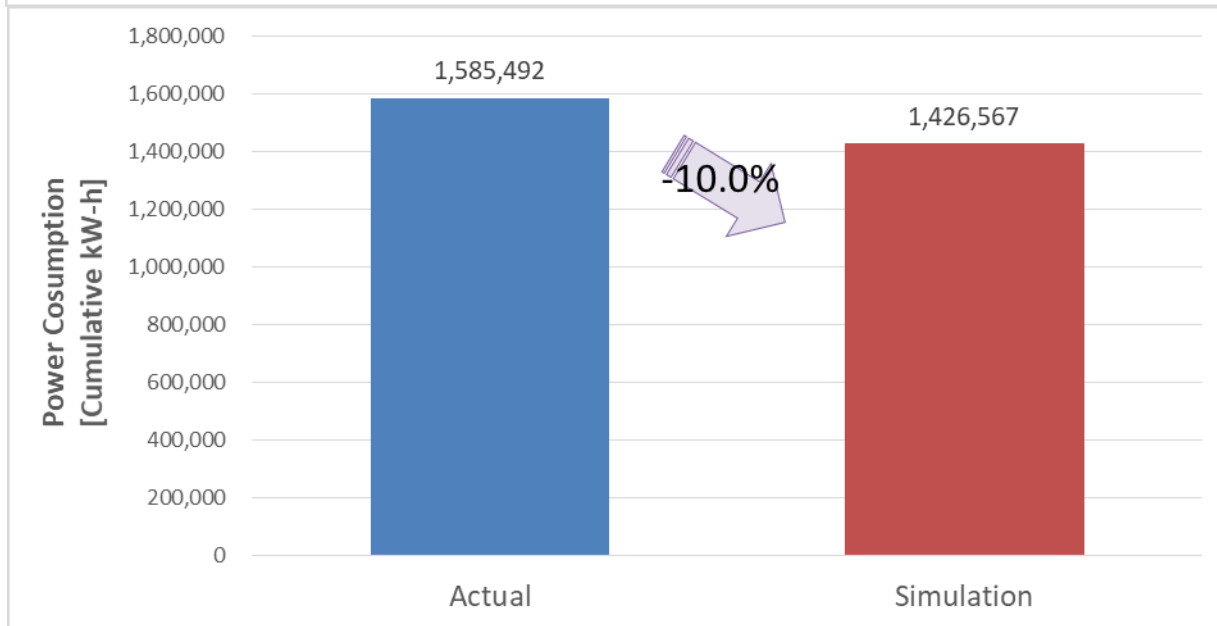
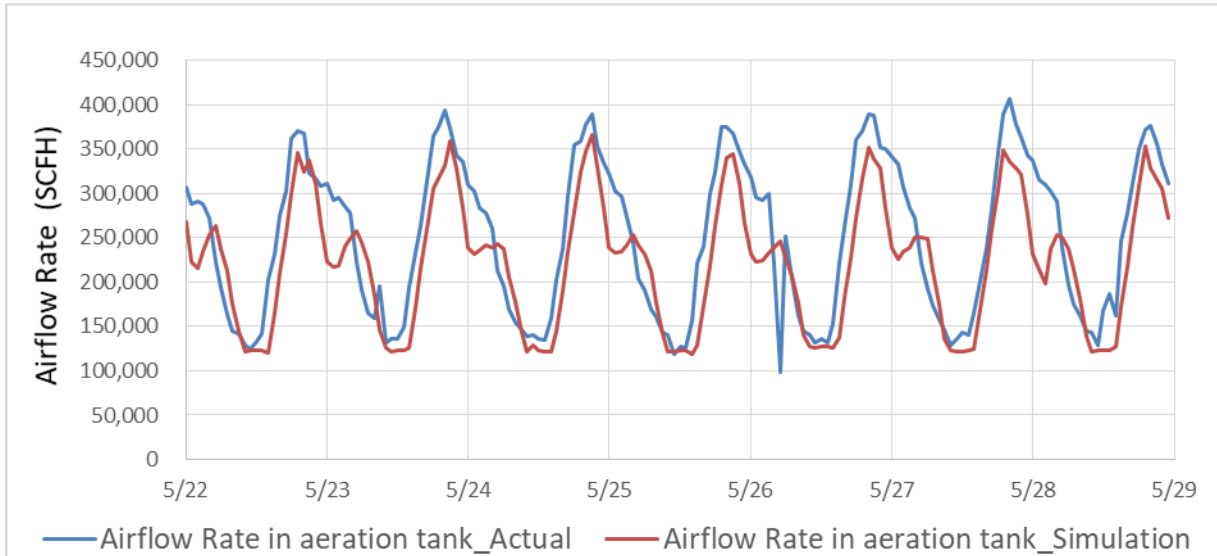
<Equations in DDMO model>  

$$\text{Effluent NH}_4\text{-N}[t] = \text{coef}_1 * \text{influent water} + \text{coef}_2 * \text{influent NH}_4\text{-N} + \dots$$

$$\text{coef}_1, \text{coef}_2, \dots \text{ are updated automatically.}$$



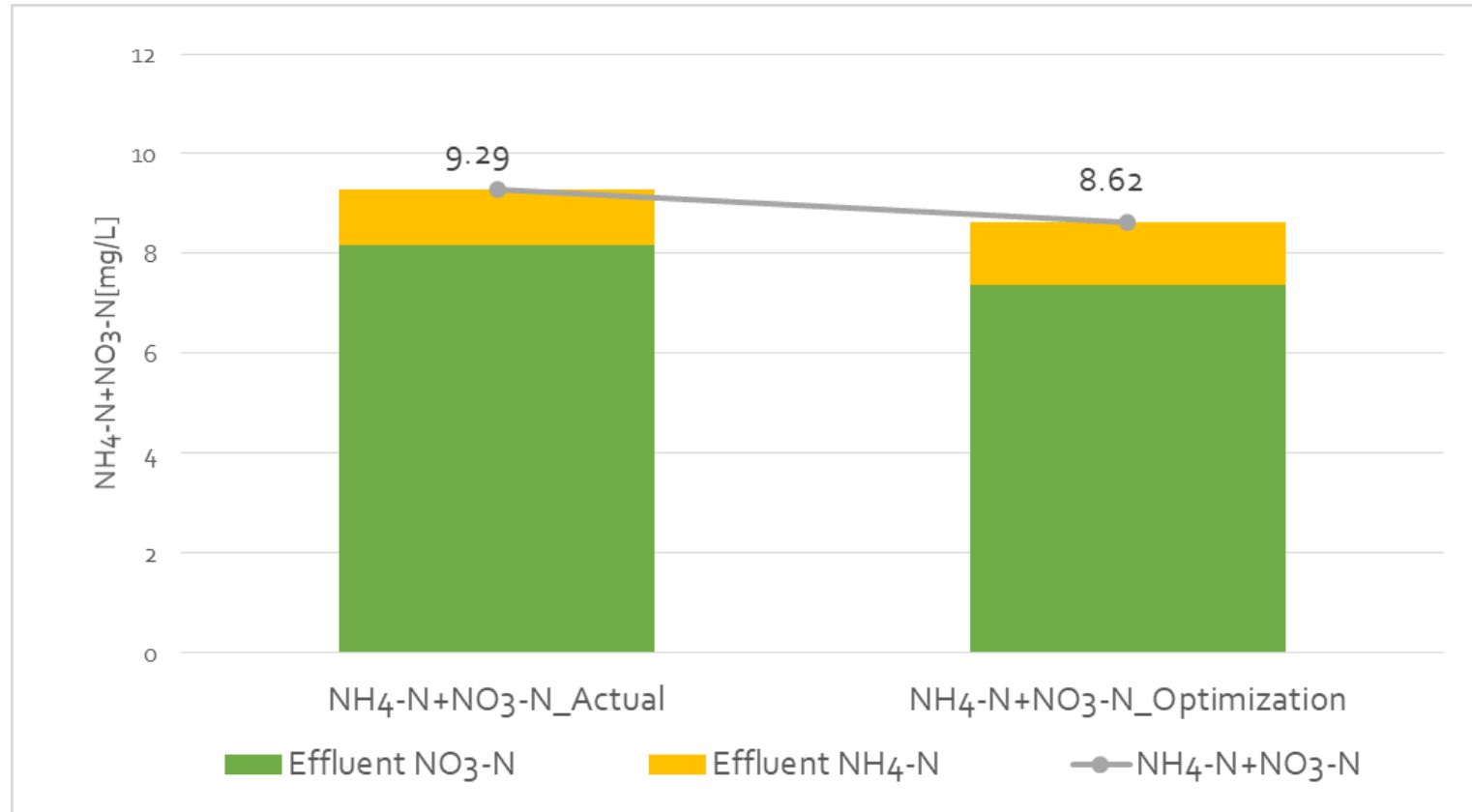
# DDMO Initial Results – Offline Evaluation on Historic Data



- Use historic data to train and then simulate a period.
- Simulated optimum air control vs actual to achieve ammonia effluent goals
  - 10% potential energy savings.
  - Marginal increase in effluent ammonia.
- Also simulated with optimization goal of reduced ammonia (30%), resulted in 2.7% energy increase (as expected).

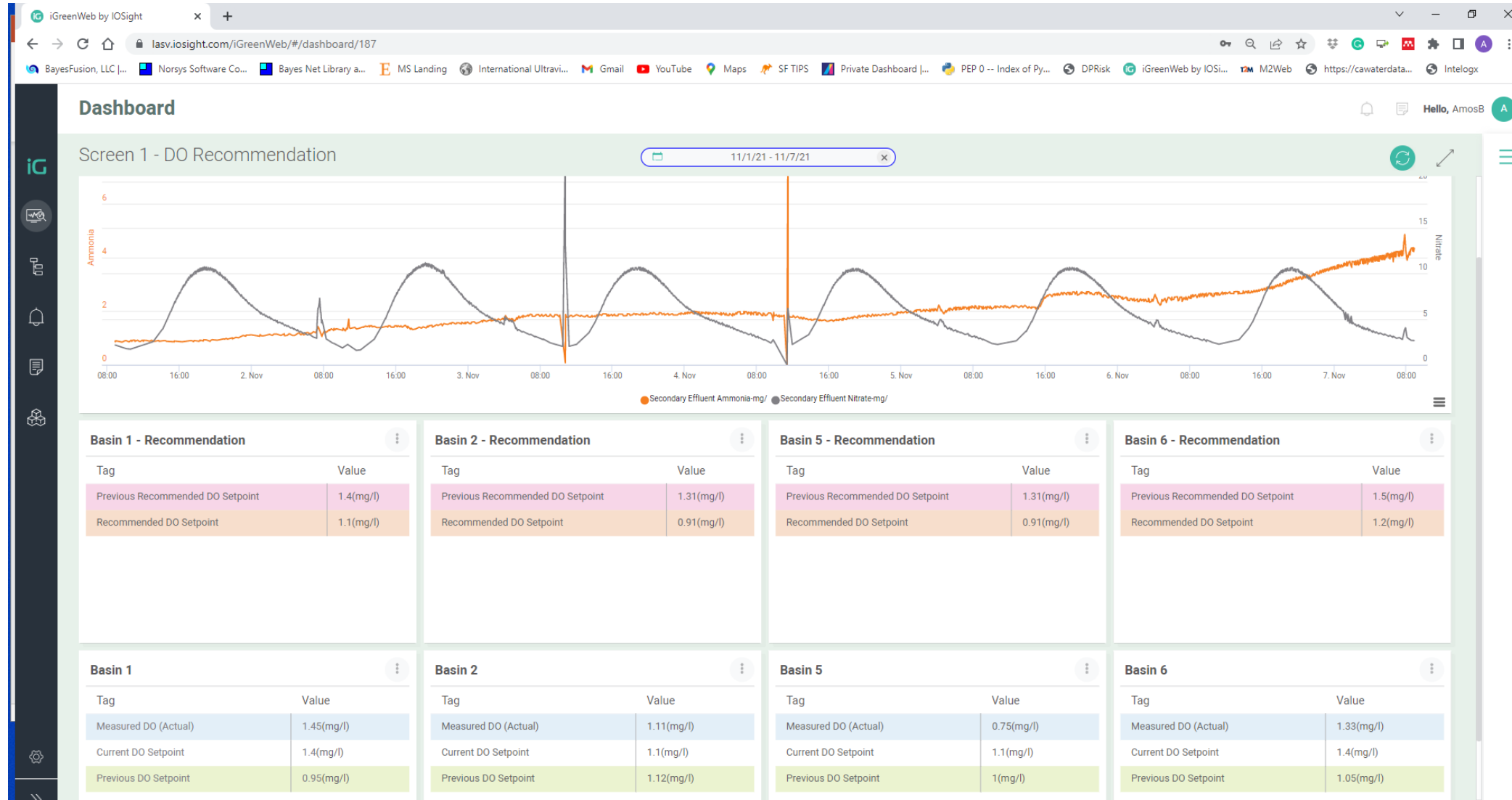
# DDMO Initial Results – Offline Evaluation on Historic Data Revisited

- Revisited with new blowers (September 2020)
  - Still potential for 10% energy savings
  - Marginal increase in effluent ammonia
  - Slight reduction in TN
- Verify and validate by using DDMO recommendations to adjust blower setpoints according to the optimized simulation results.

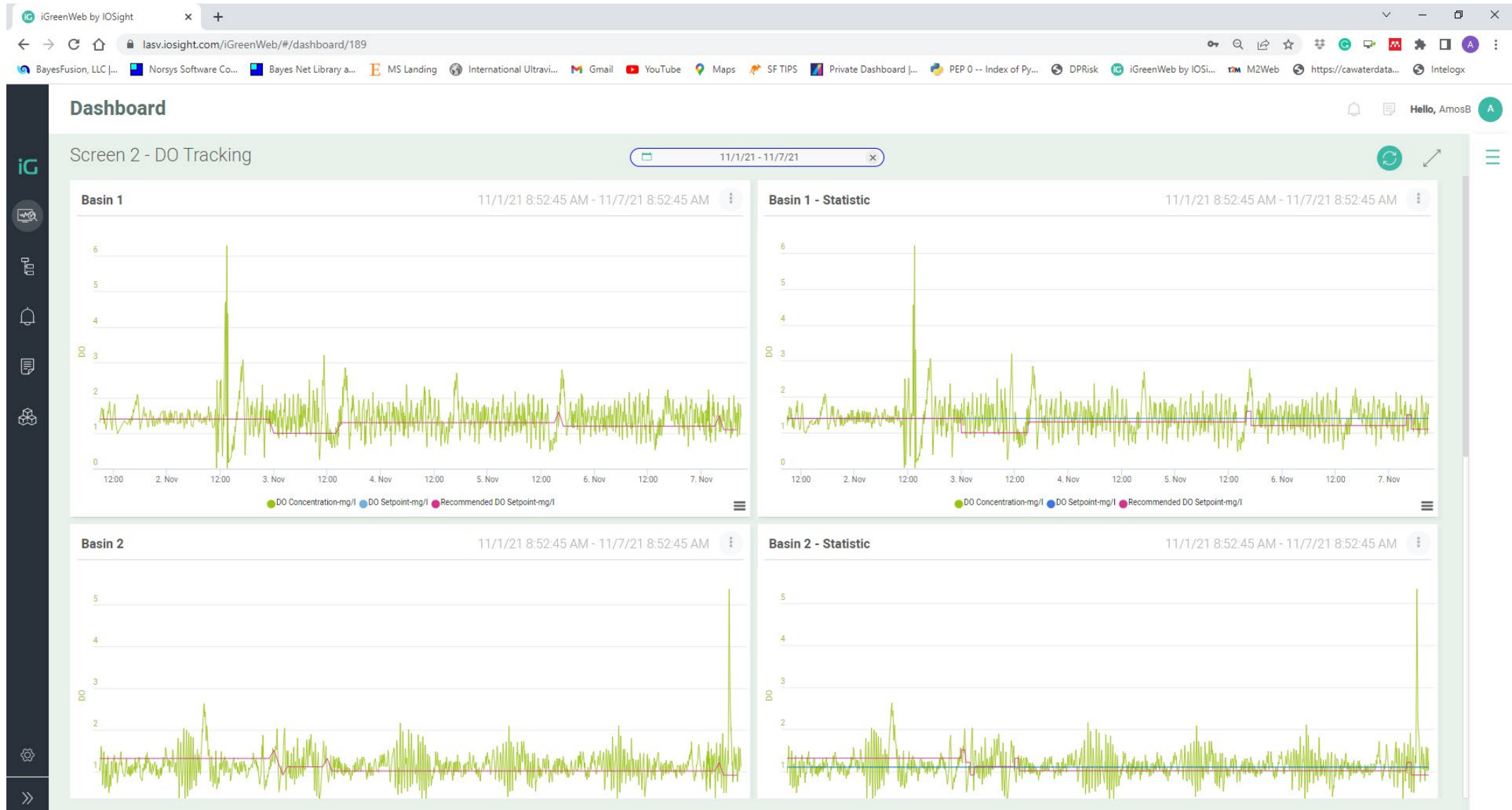


# Future Work Kickstarted by This Initial Project – Real Time Interface

- Predictions by Yokogawa for optimized DO setpoint
- Data transfer via IOsight iGreen and
- Setpoint changes by ops staff.

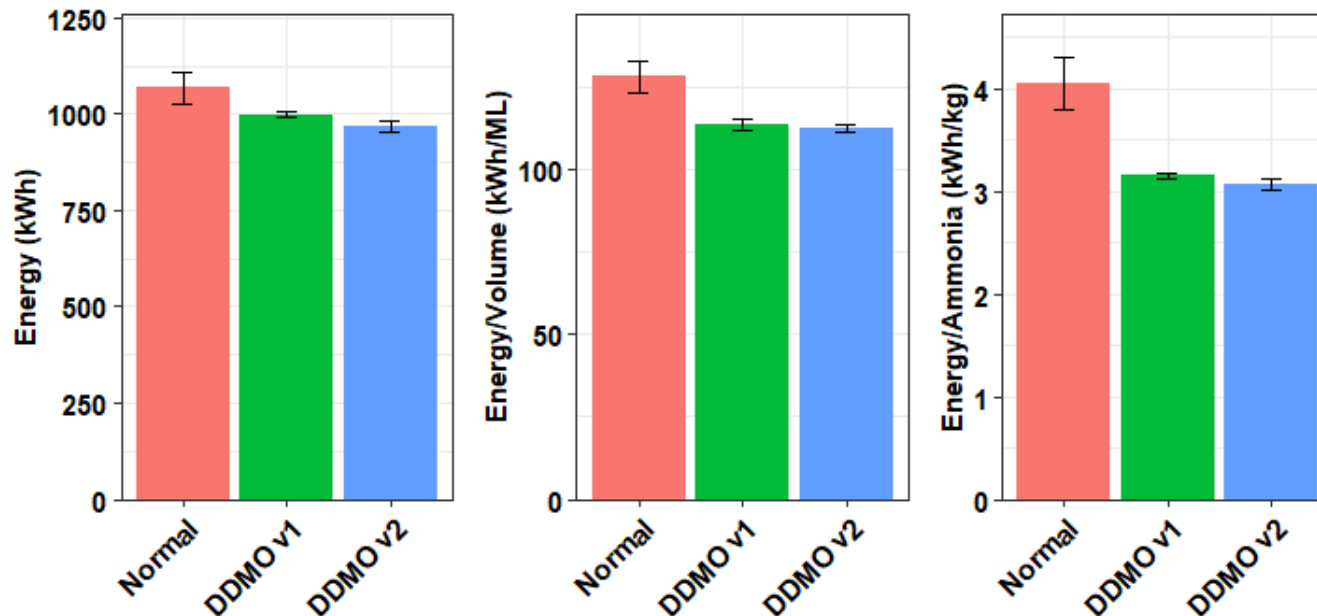


# Real Time Tracking of Adjustment Effectiveness



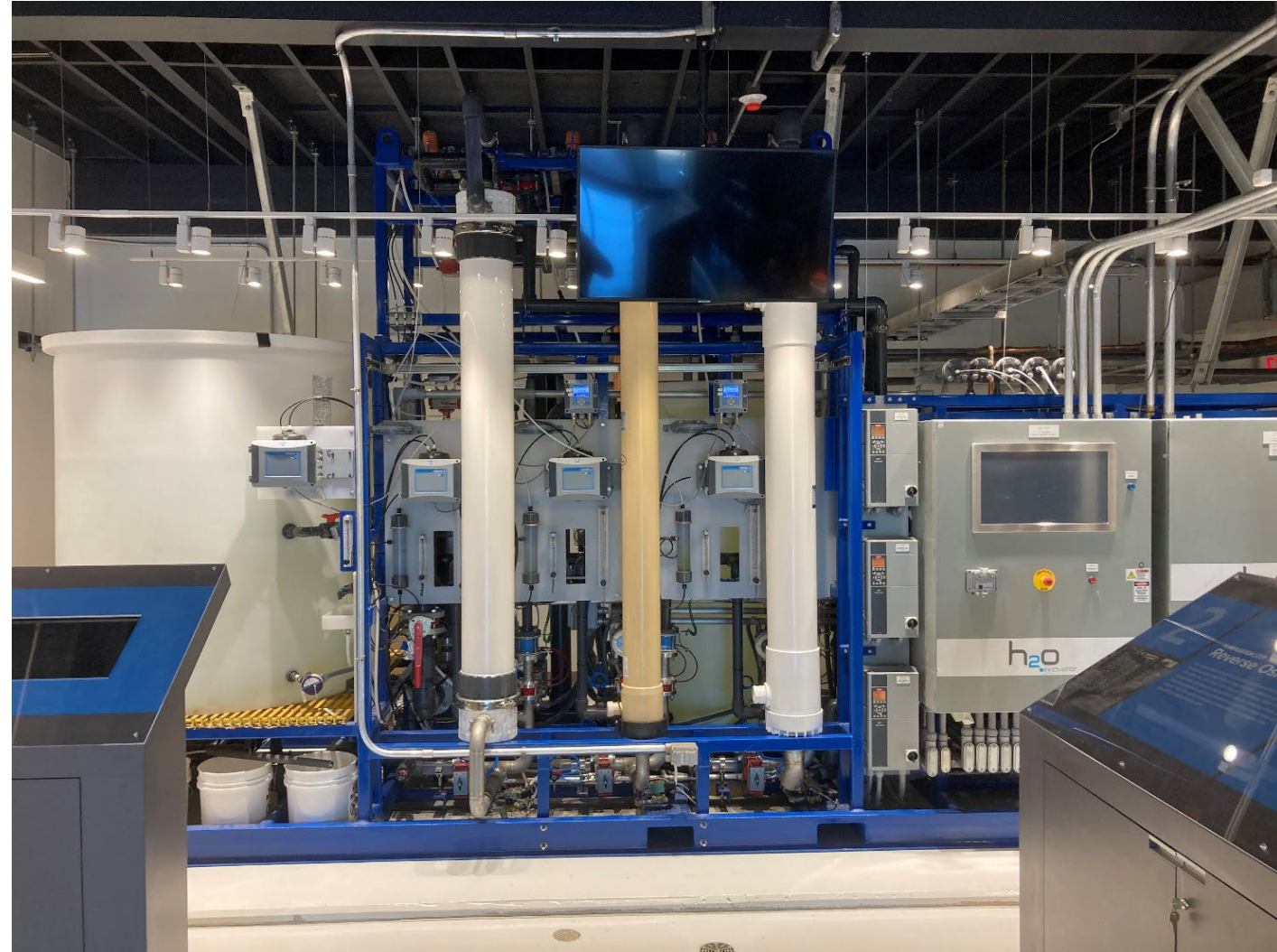
# Significant Improvement with No Additional Hardware Compared to the Status Quo

- A ML based solution kickstarted from the foundations of this grant for aeration optimization was implemented.
- The solution required no hardware changes and was set up in the existing data management program (IOsight).
- Modest but significant savings relative to implementation costs could be achieved.
- Potential for follow up testing and evaluation post Tapia SCADA upgrade.

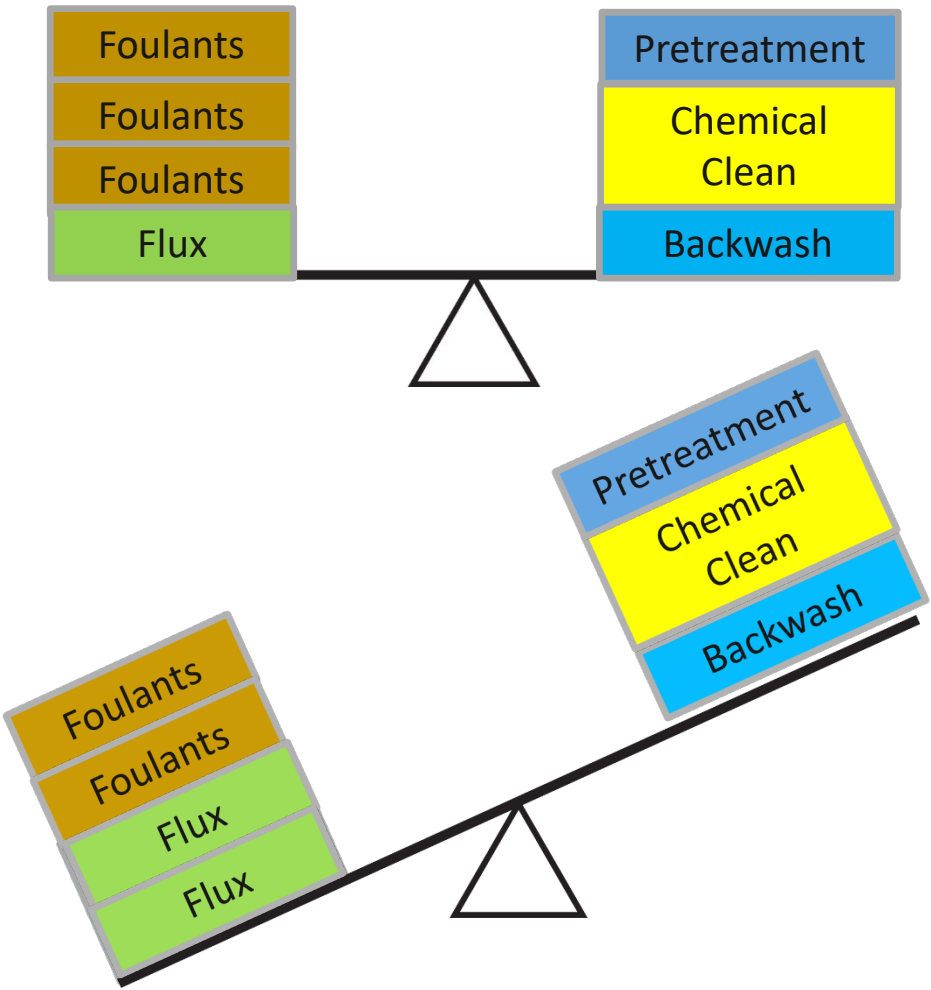


# Moving Down the Treatment Train to the AWPf MF/UF

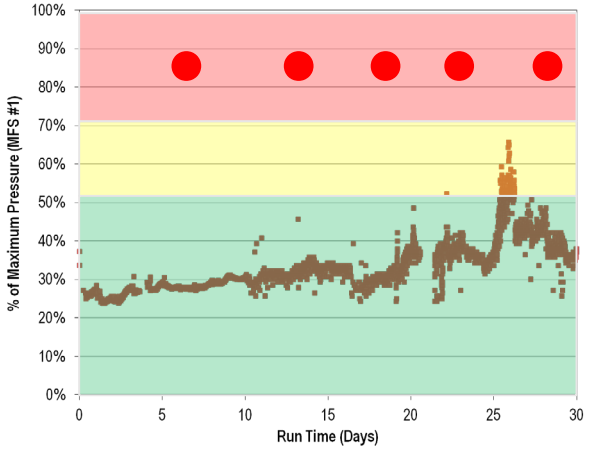
- Max Total Feed Flow 100 gpm
- Open-platform - 3 vendors with independent monitoring and operation
  - UF1 - Dow SFD-2880XP (0.03  $\mu\text{m}$ )
  - UF2 - Pall UNA 620A (0.1  $\mu\text{m}$ )
  - UF3 – Toray HFUG Type 2020AN (0.01  $\mu\text{m}$ )
- UF Feed Chemical Dosing
  - Chloramine (Ammonium Sulfate + Sodium Hypochlorite)
  - Flow Paced Set Point – 2.5 – 3.0 mg/L
  - Targets –
    - 2 – 2.5 mg/L total Cl<sub>2</sub> in UF filtrate
    - 0.5 mg/L free ammonia in UF filtrate



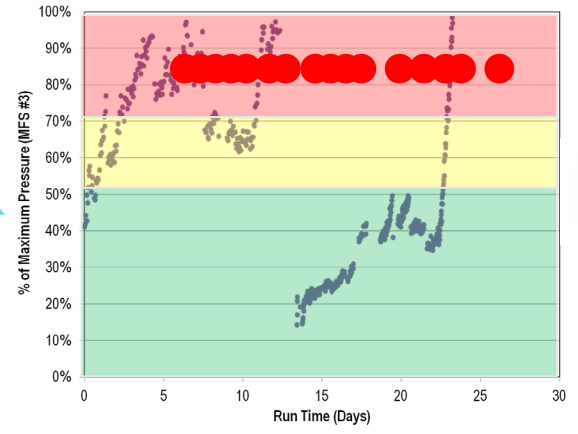
# Micro- and Ultra-Filtration Sustainable Operation



TMP  
↑

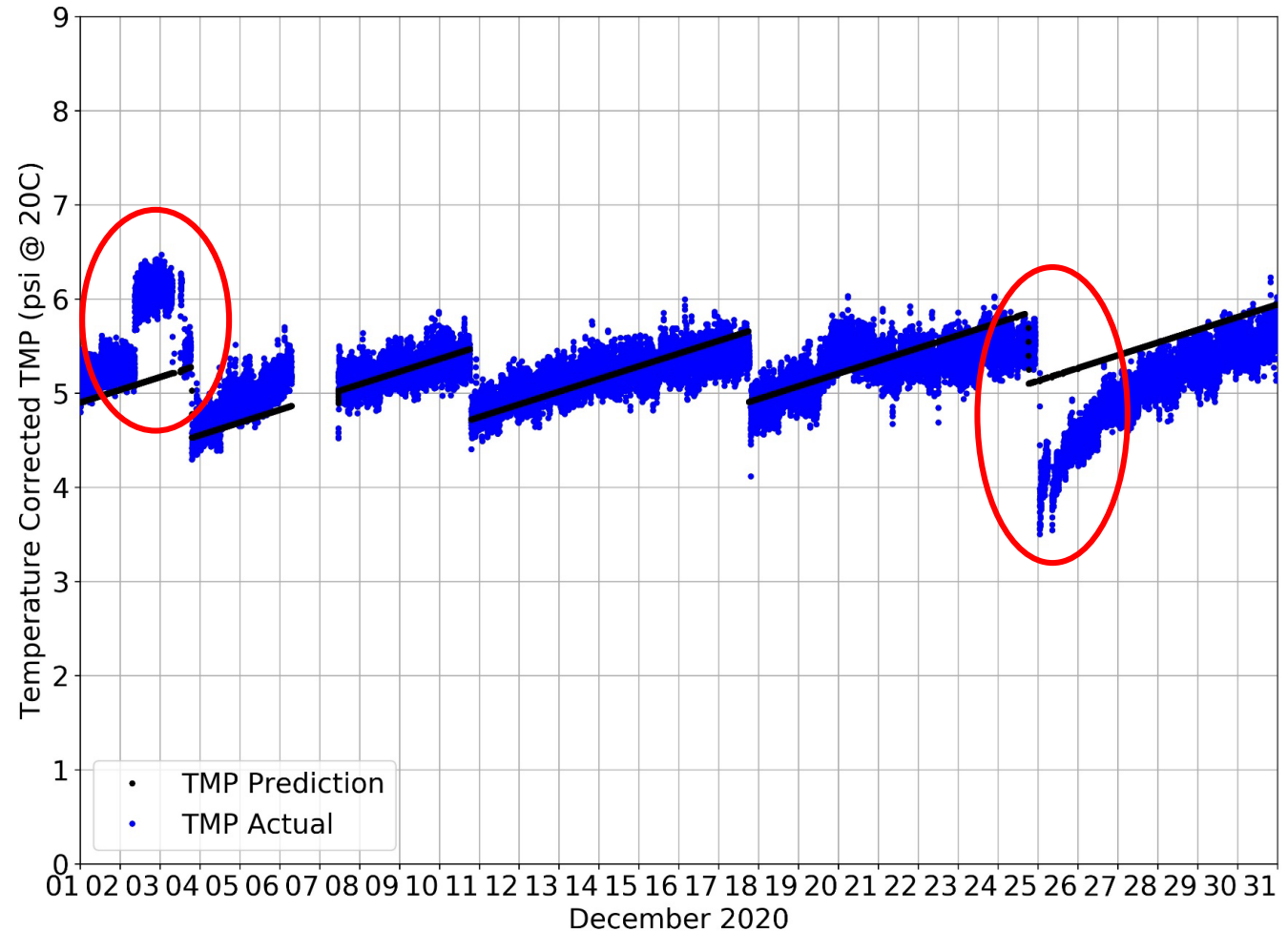


TMP  
↑



# Initial Work, Offline Data Analysis and Blind Prediction of the Future

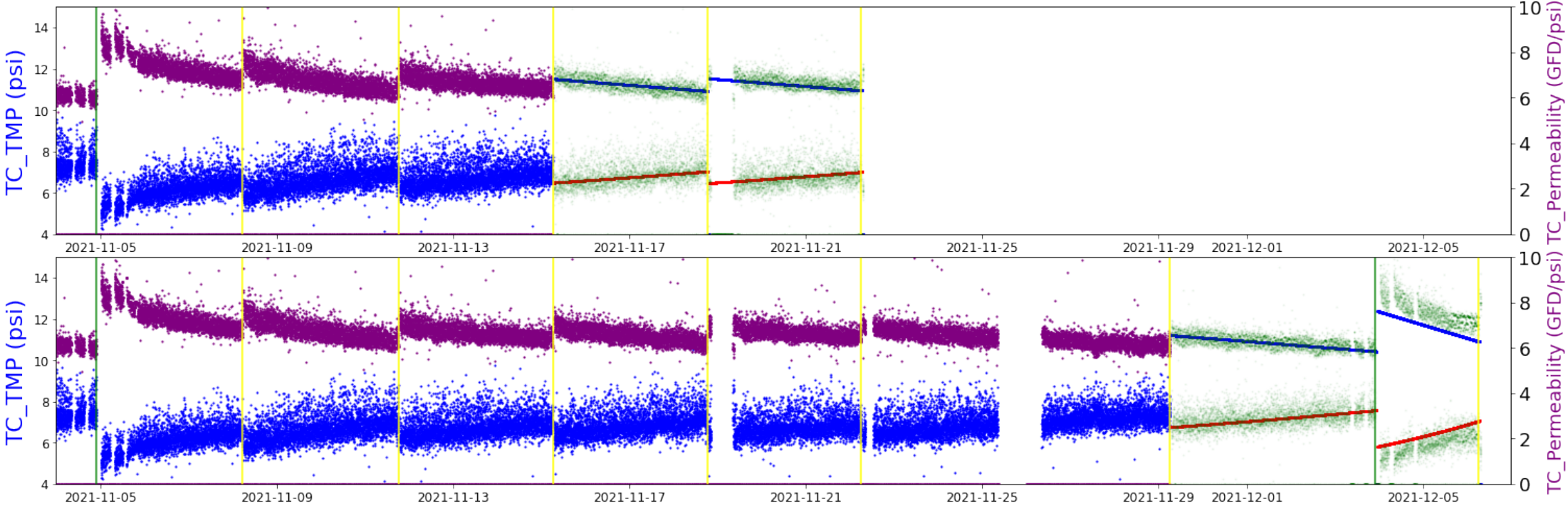
- Explored at desktop-scale.
- 1-month blind trial.
- Generally accurate except for two excursions.
- These excursions were caused by changes in cleaning procedure that were not communicated to the model



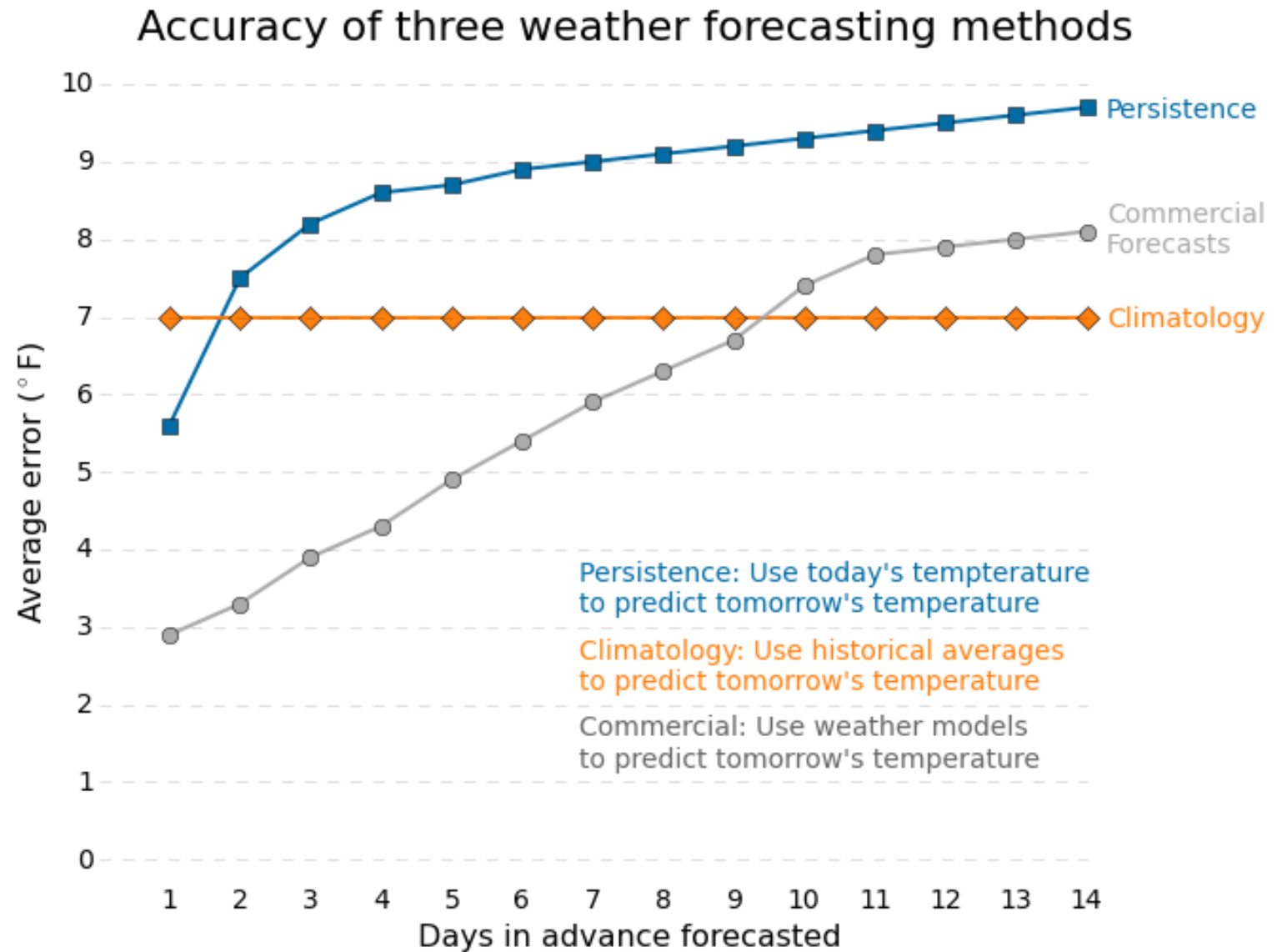


# Initial Modelling Work Revised and Improved.

- Model 1 = fouling rate during operation
- Model 2 = change in fouling during clean
- Model 1 + Model 2 + cleaning schedule = long-term forecast!

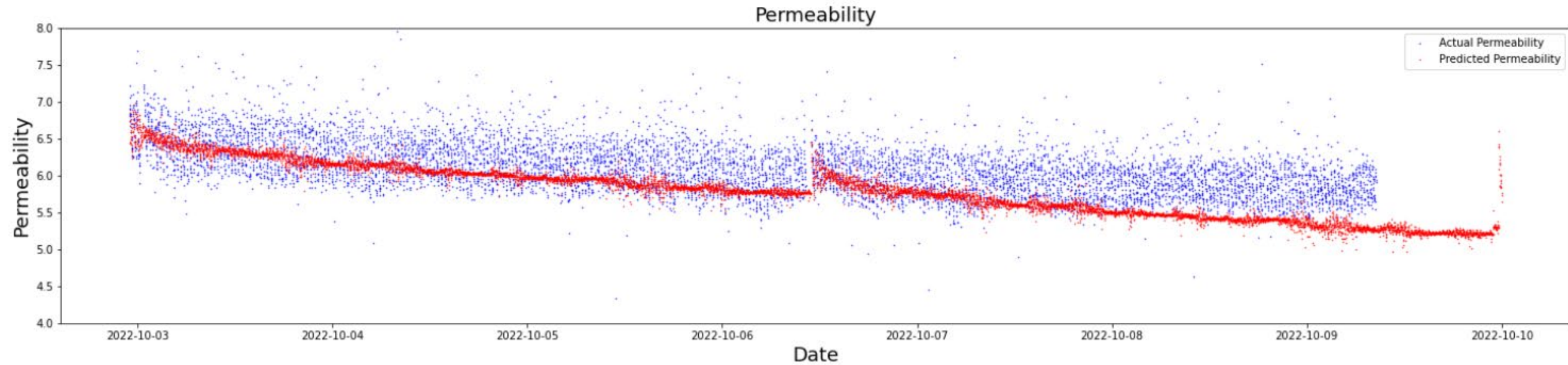


Making accurate predictions gets more difficult further into the future.



Source: "The Signal and the Noise" by Nate Silver | Author: Randy Olson (randalolson.com / @randal\_olson)

# Predictions: first week



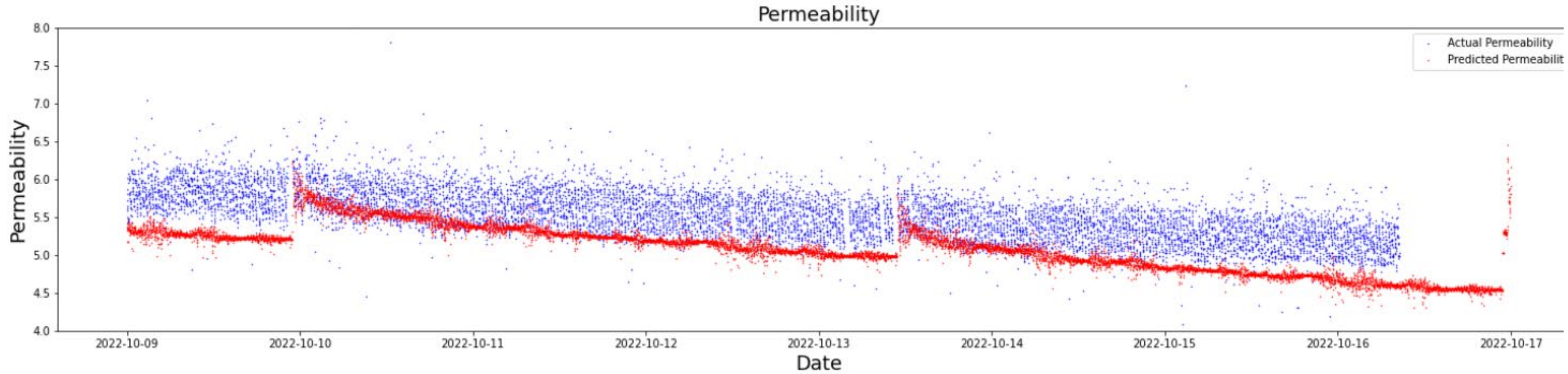
**MAPE (%)**

4.84

**RMSE**

0.31 gfd/psi

# Predictions: second week



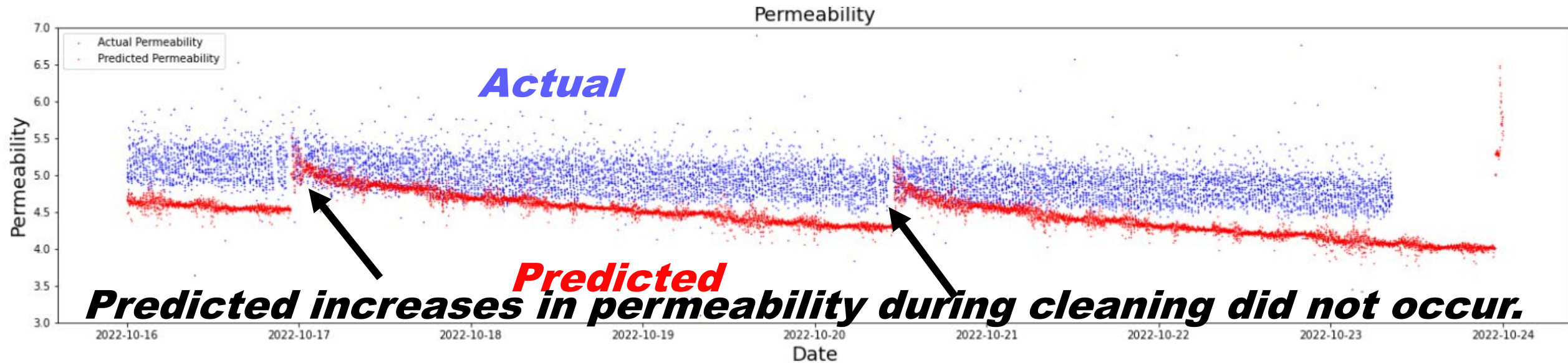
**MAPE (%)**

7.55

**RMSE**

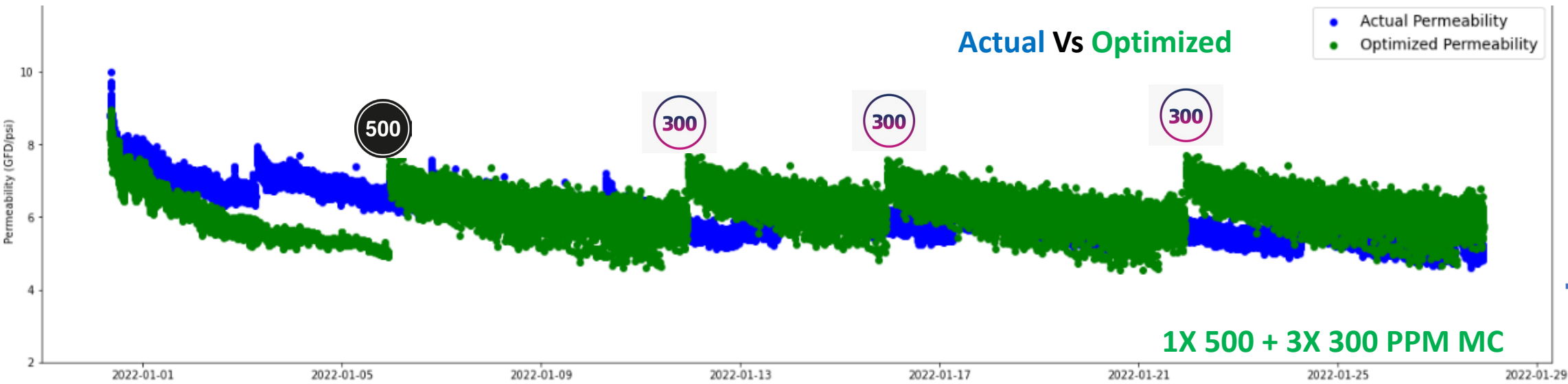
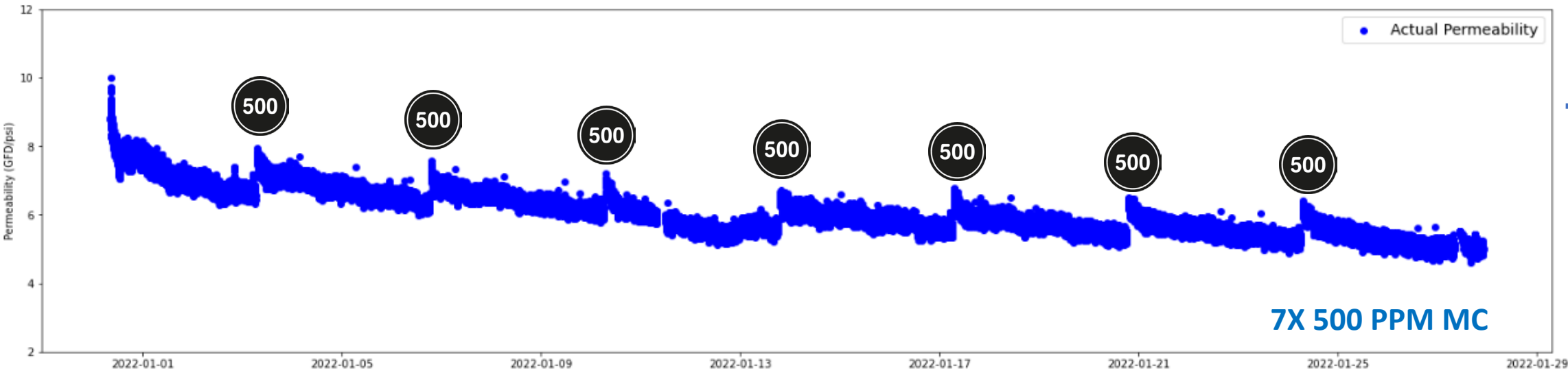
0.44 gfd/psi

# Predictions: third week



MAPE (%)	RMSE
9.49	0.44 gfd/psi

# Most Promising Optimization – Chemical Usage



60% Less Cleaning

# What if interface – What will occur if I operate like this, How and when should I clean?

VTScada
UF2 Optimization Dashboard
10:43 AM Mar 21  
Sign in

MC Interval 1 (DAYS)	MC Interval 2 (DAYS)	MC Interval 3 (DAYS)	MC Interval 4 (DAYS)	RC Interval 1 (DAYS)	RC Interval 2 (DAYS)	RC Interval 3 (DAYS)
1	3	5	7	2	4	6

UF2 Optimized Setpoints
MC Cl2 Strength: 500.0 PPM
RC Cl2 Strength: 2000.0 PPM
RC Citric Strength: 2000.0 PPM

MC Tank Volume (GAL)	RC Tank Volume (GAL)	MC Cl2 Strength (PPM)	RC Cl2 Strength (PPM)	RC Citric Strength (PPM)
100.0	99.0	98.0	97.0	96.0

[Simulate](#)

[Optimize](#)

Production Durrantion (DAYS)	Flux Planned (GFD)	Cost Power (\$USD)	Cost CL2 (\$USD)	Cost Citric (\$USD)
5.0	4.2	4.3	4.4	5

UF2 Optimized Setpoints	
MC Cl2 Strength	500.0 PPM
RC Cl2 Strength	2000.0 PPM
RC Citric Strength	2000.0 PPM

UF2 Simulated MC Schedule	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	

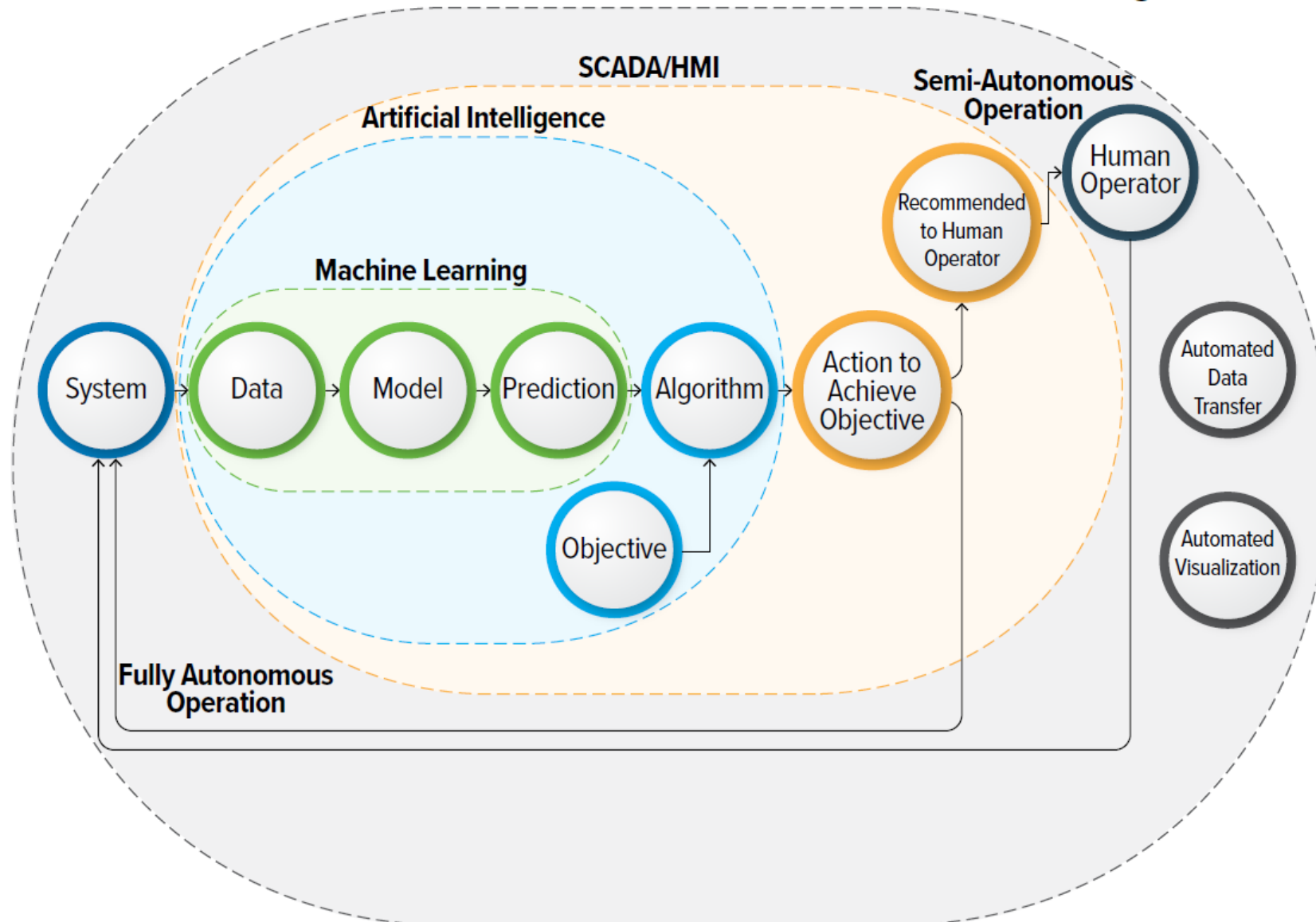
UF2 Optimized MC Schedule	
1	2022-03-20 09:23:00
2	2022-03-31 09:23:00
3	2022-04-04 09:23:00
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	

UF2 Simulated RC Schedule	
1	2022-03-18 09:23:00
2	

UF2 Optimized RC Schedule	
1	2022-03-18 09:23:00
2	

# Where do we think we are headed?

## Intelligent Water





# The FSA Research Activities Paved The Way for Development of a SAO Interface

**VTScada** Home 01:52 PM Mar 19 Sign in

**VTScada** Pure Water Project 09:21 PM Dec 28 Sign in

**VTScada** Performance & Production 01:50 PM Mar 19 Sign in

**Water Quality Safety**  
Advanced purification of recycled water requires multiple treatment barriers to remove biological and chemical contaminants, producing a purified water that exceeds potable water quality requirements and is protective of public health. Confidence in water quality is continuously monitored by the OPTICS platform and verified by certified operations staff.

**CA Requirements**  
The State of California requires 12-log reduction of virus and 10-log reduction of protozoa (both Giardia and Cryptosporidium), with each treatment process contributing to the overall performance. Note that 1-log reduction is a 90% reduction, 2-log reduction is a 99% reduction, etc.

**Membrane Filtration**

Solids Reduction - NTU  
Threshold: < 0.2

Pathogen Log Reduction\*  
Threshold: ≥ 4

25.0  
4.2

**Tapia Water Reclamation Facility**

Solids Reduction - NTU  
Threshold: < 2

0.1

**Reverse Osmosis**

Chemical Reduction - mg/L  
Threshold: < 0.3

Salts, Pathogen Log Reduction\*  
Threshold: ≥ 1.0

0.1  
1.5

888825 Gallons of purified new water produced at the Pure Water Demonstration

888825 Total Energy savings - \$USD

888825 Total Energy savings - kW

888825 CO2 Footprint Reduction

888825 Minutes to Next Update

**Ultraviolet Light Advanced Oxidation**

Chemical Reduction - %  
Threshold: < 66

Pathogen Log Reduction\*  
Threshold: ≥ 6

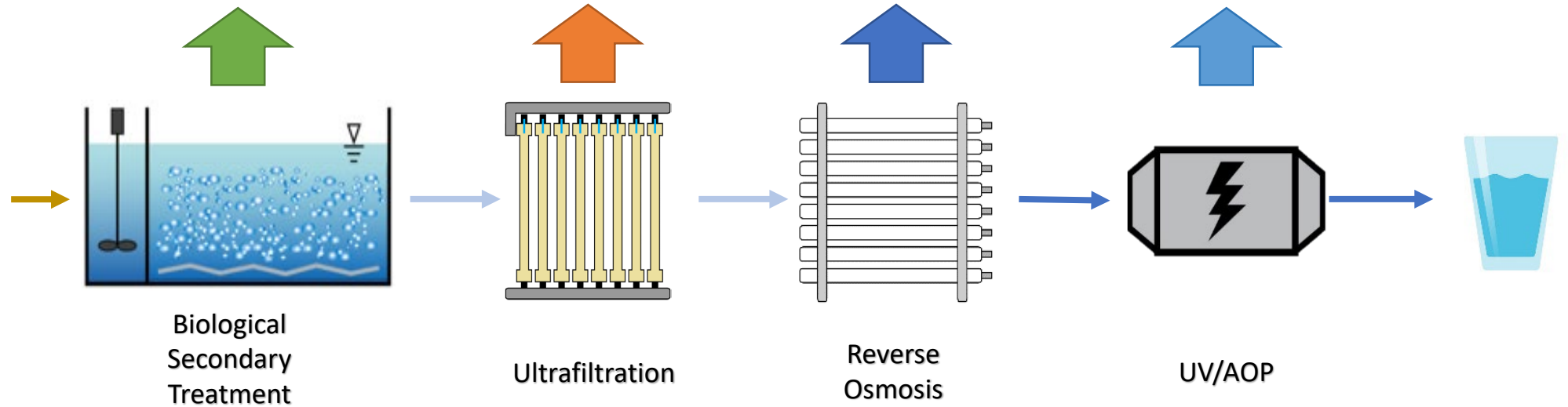
77.0  
6.0

**PURE WATER PROJECT LAS VIRGENES-TRIUNFO**  
Bringing Our Water Full Circle

# What else is in the pipeline stemming from the FSA project?

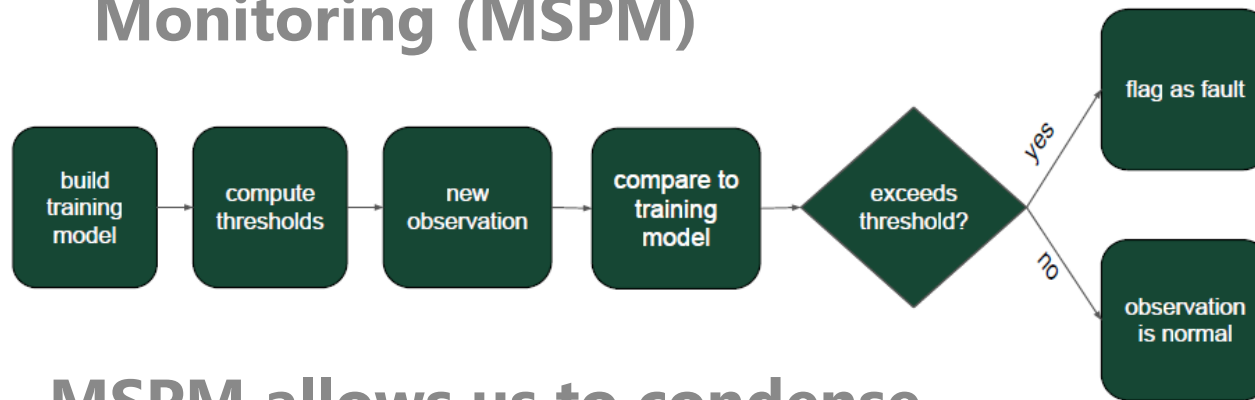


Pilot/Full-Scale Demonstration study	METI ('21)	USBR ('22)	USBR ('23)	NAWI ('23)
Desktop Feasibility study	MWD & METI ('19 & '20)	METI ('21)	USBR ('22)	NAWI ('22)

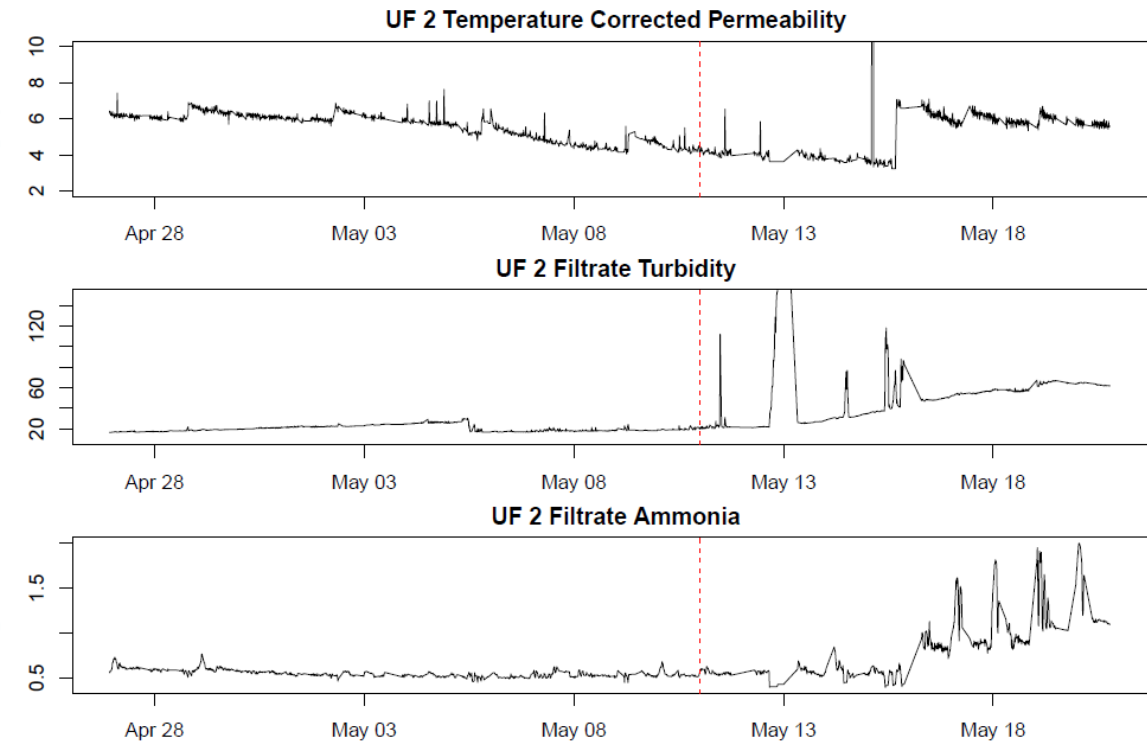


# Developing a Method for Real Time Detection of Abnormal Behavior

## Multivariate Statistical Process Monitoring (MSPM)

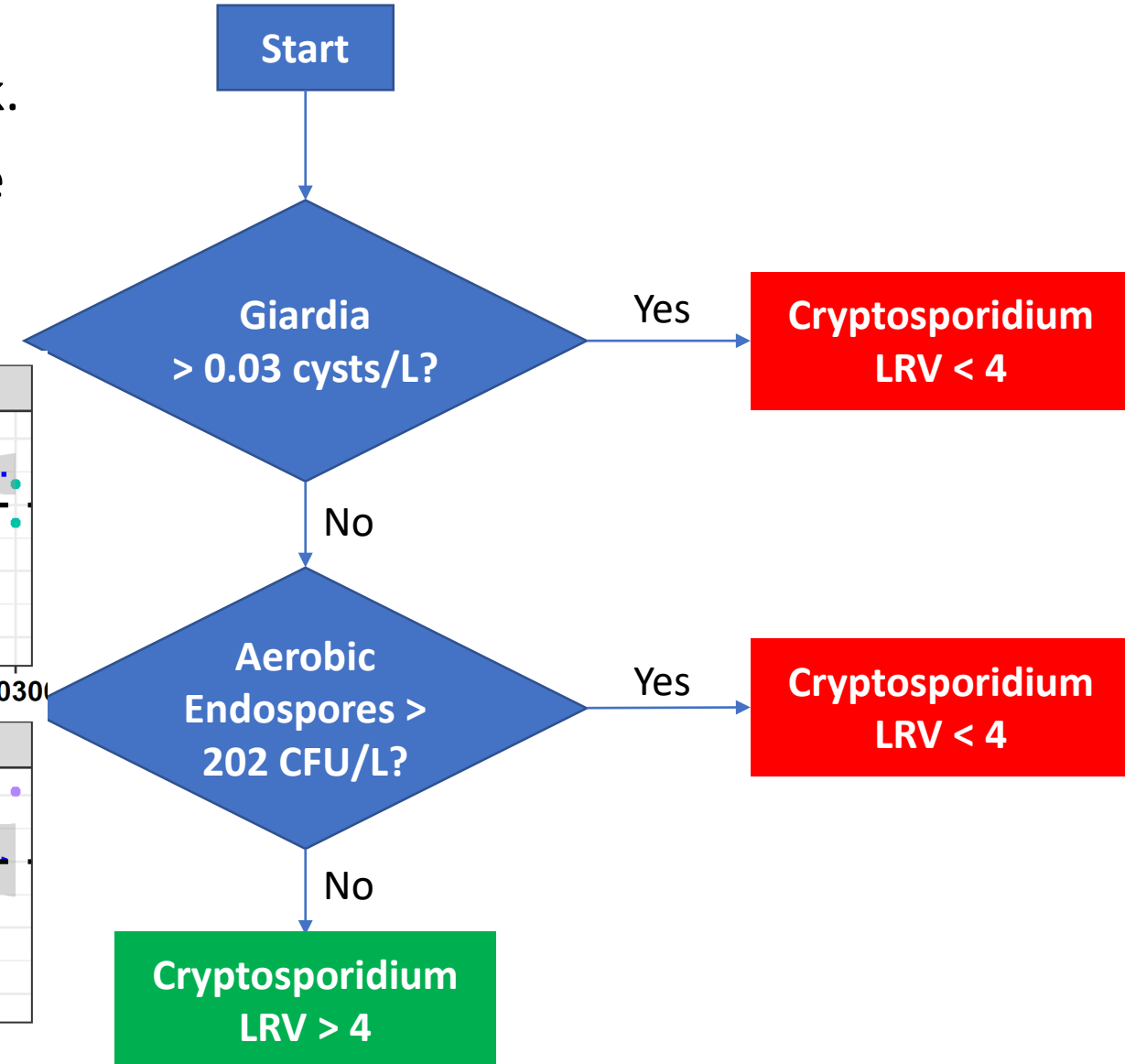
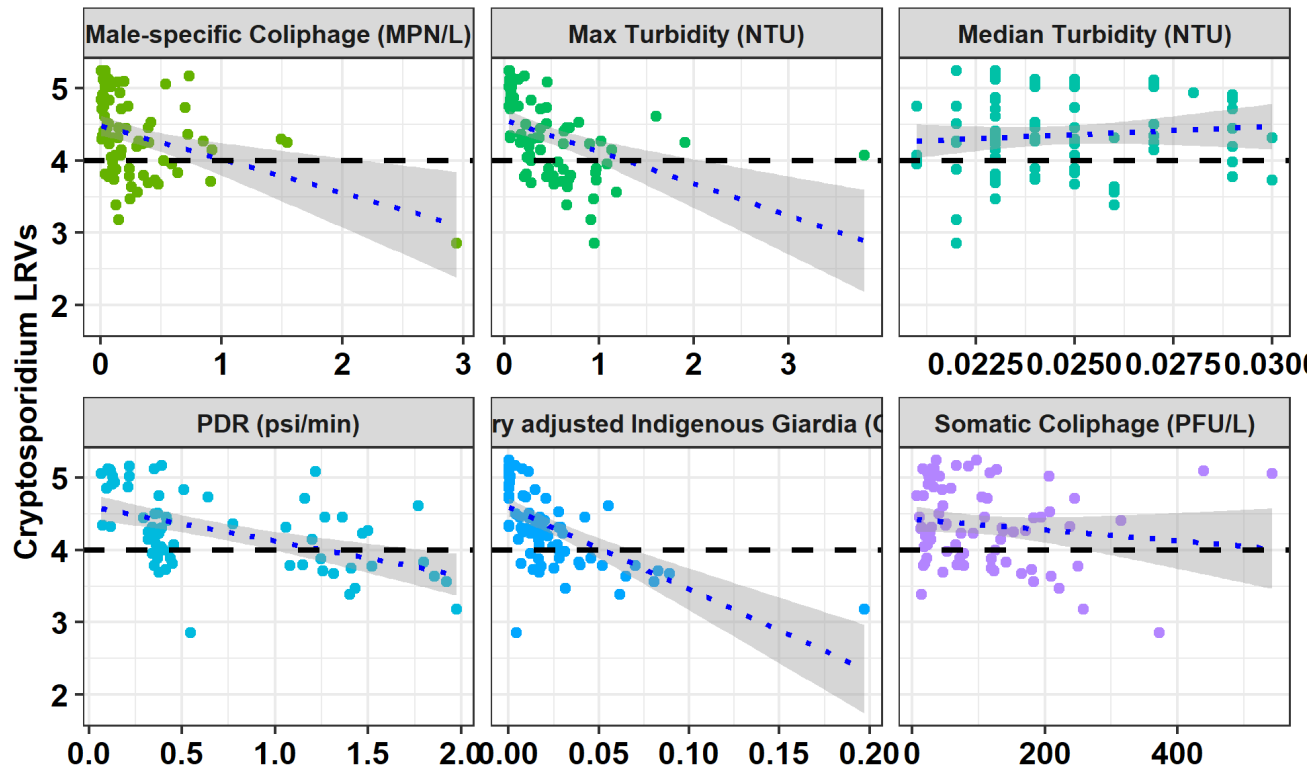


MSPM allows us to condense information from several variables into 2 monitoring statistics (T2 and SPE)



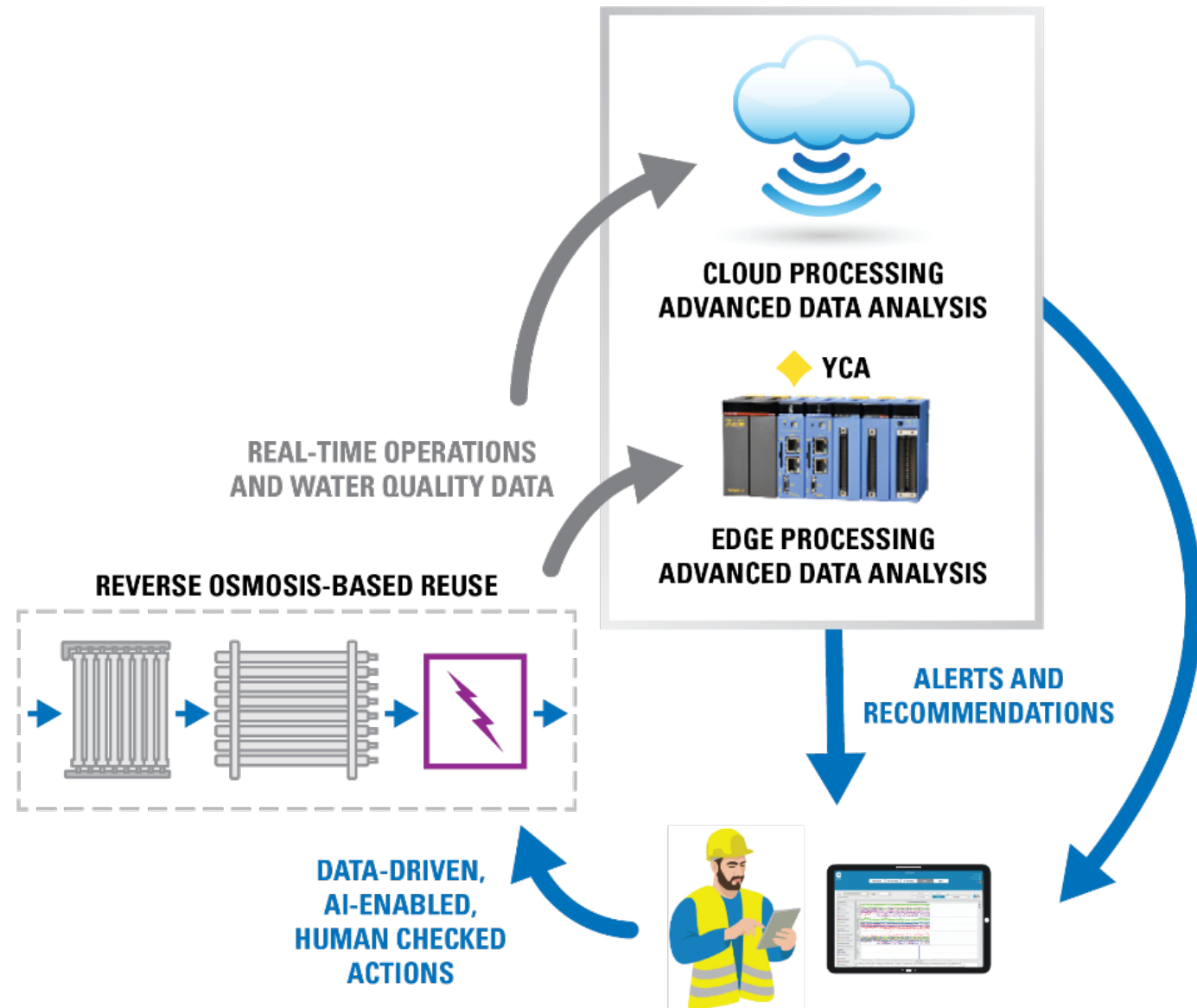
# Initial Decision Trees for Better Pathogen Reduction Verification (C5.0Rules)

- Direct correlation exists but strength is weak.
- Machine learning shows promise to improve prediction significance across multiple variables



# Research to Date Stemming from Initial FSA Efforts Shows Promise

- Regulatory Confidence
- Operational Support
- Data Security





# Questions and Discussion