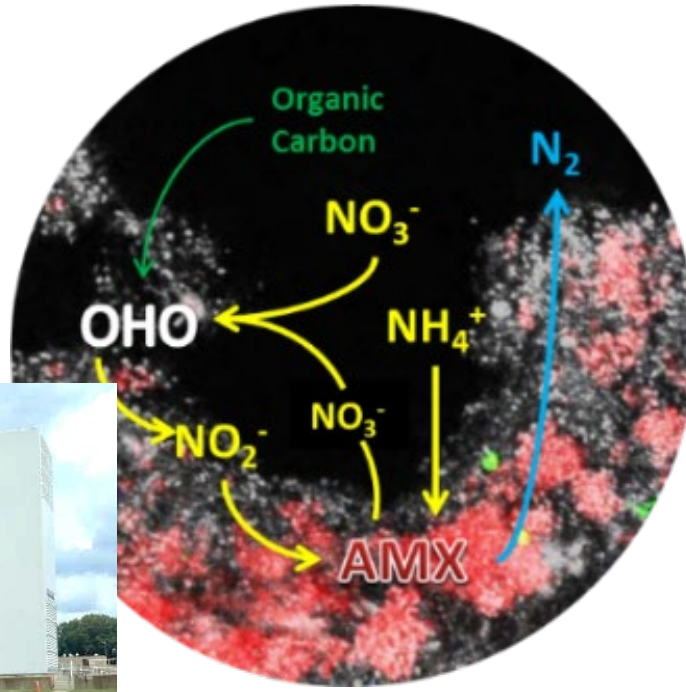
Implementation of Digital Water at HRSD

Problem → Solution → Repeat

Charles B. Bott, PhD, PE, BCEE

Chief Technology Officer
Hampton Roads Sanitation District

Adjunct Professor
Departments of Civil and Environmental Engineering
Virginia Tech & Old Dominion University



HRSD

swift Sustainable Water Initiative for Tomorrow

VIRGINIA TECH

OLD DOMINION UNIVERSITY

UNIVERSITÉ LAVAL

Regional Wastewater Authority for 20 cities and counties

225 MILLION GALLONS PER DAY OF COMBINED TREATMENT CAPACITY

8 MAJOR TREATMENT PLANTS

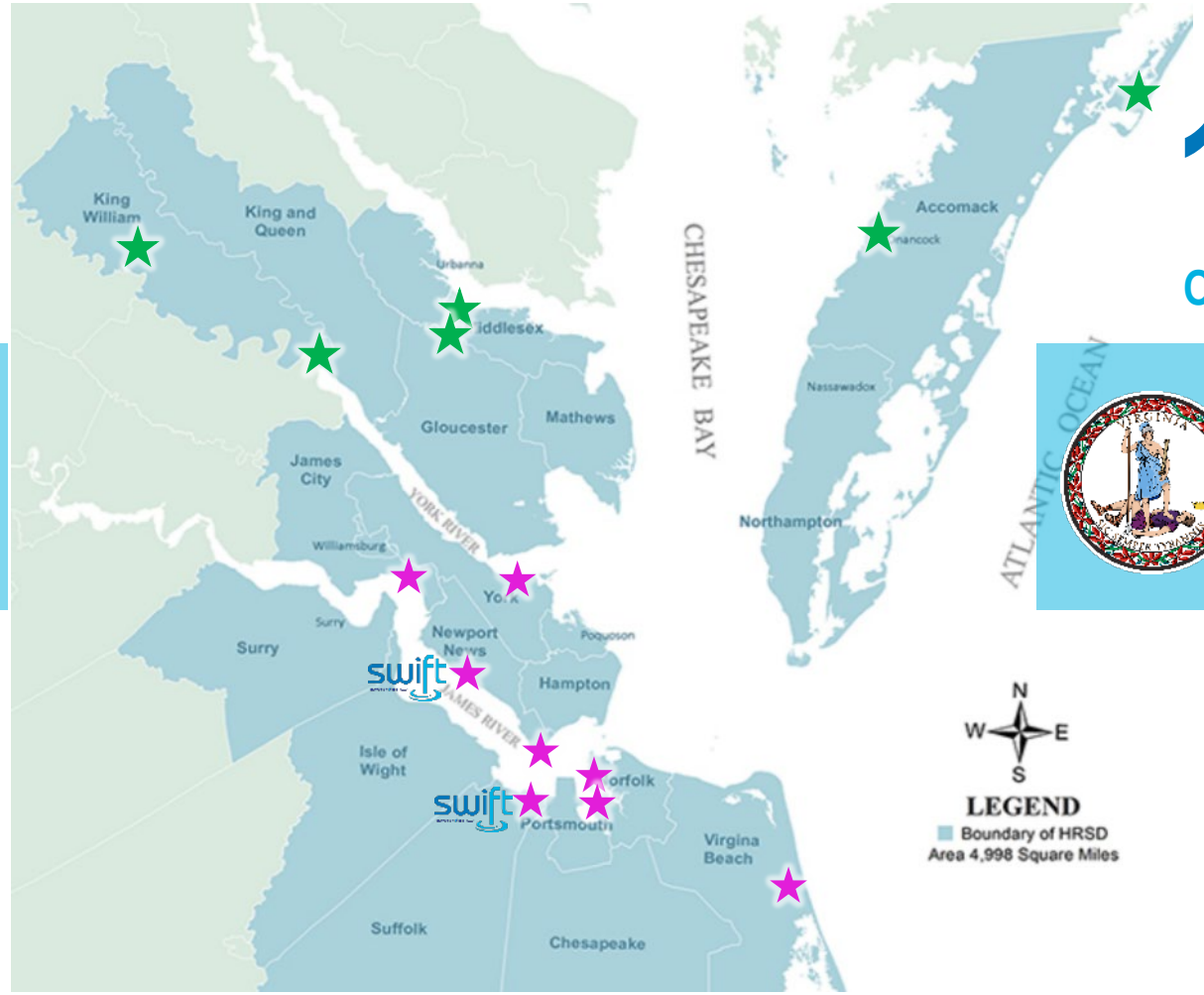
6 SMALL TREATMENT PLANTS

11 Active Patents

5 Patents Pending

THE Water Research FOUNDATION®

32 Active Water Research Foundation Projects



N
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S

LEGEND

Boundary of HRSD
Area 4,998 Square Miles

1.9 MILLION INDIVIDUALS SERVED

Over 20% of all Virginians

POLITICAL SUBDIVISION COMMONWEALTH OF VIRGINIA

10-YR CAPITAL BUDGET **$3.4 BILLION**

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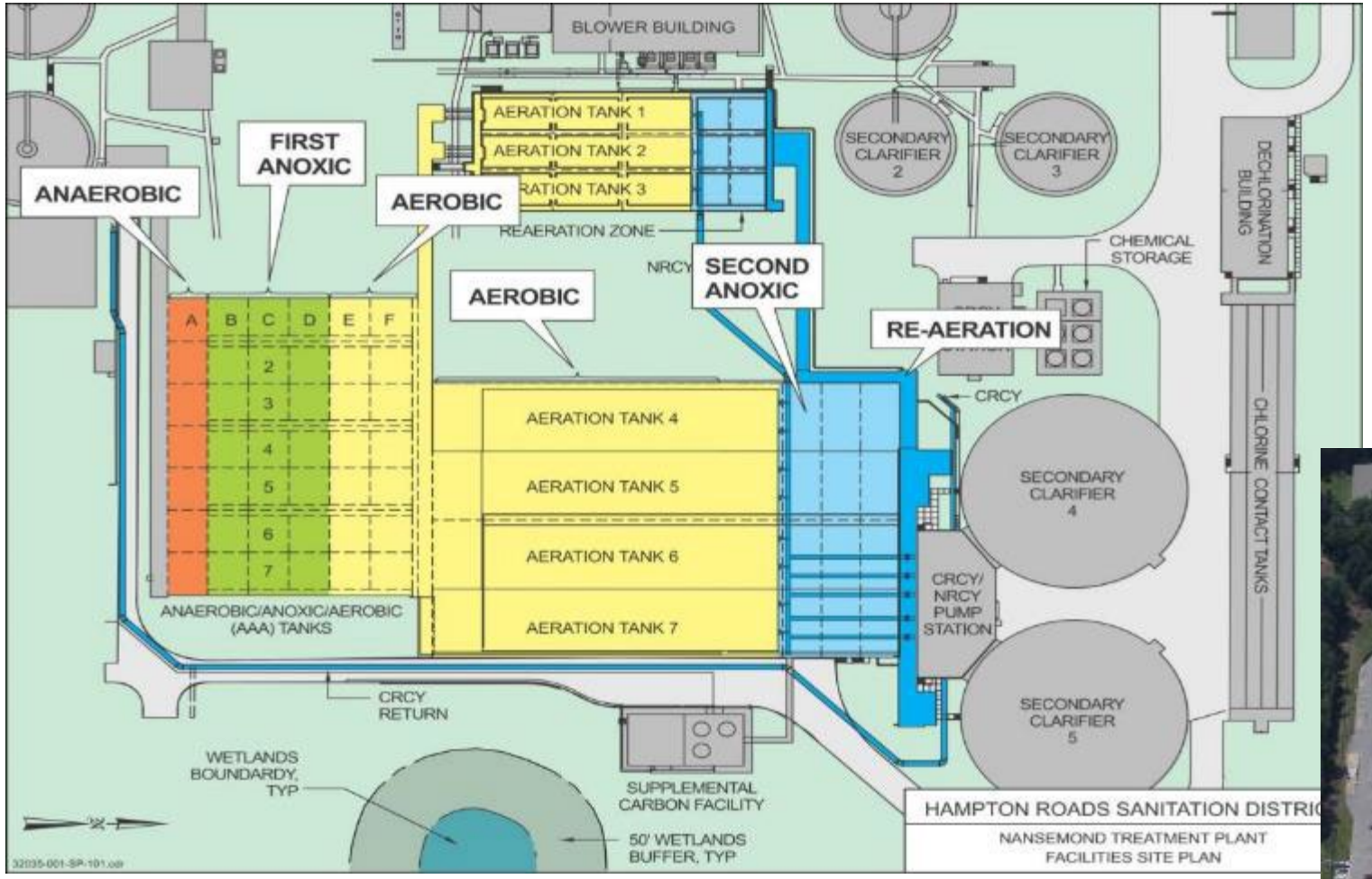
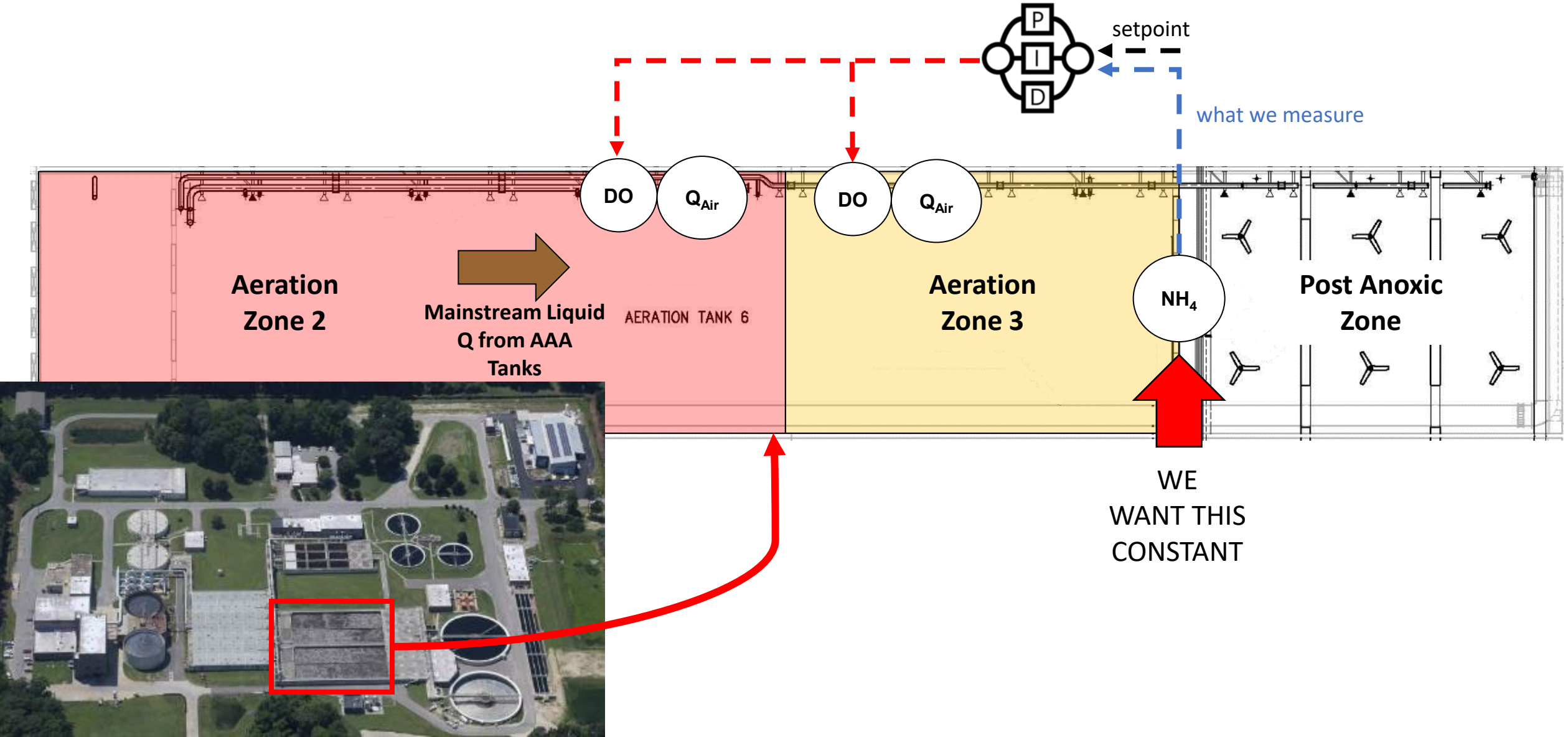
Nansemond Plant - 5-Stage Bardenpho Configuration
Stable and reliable TN removal is a must!



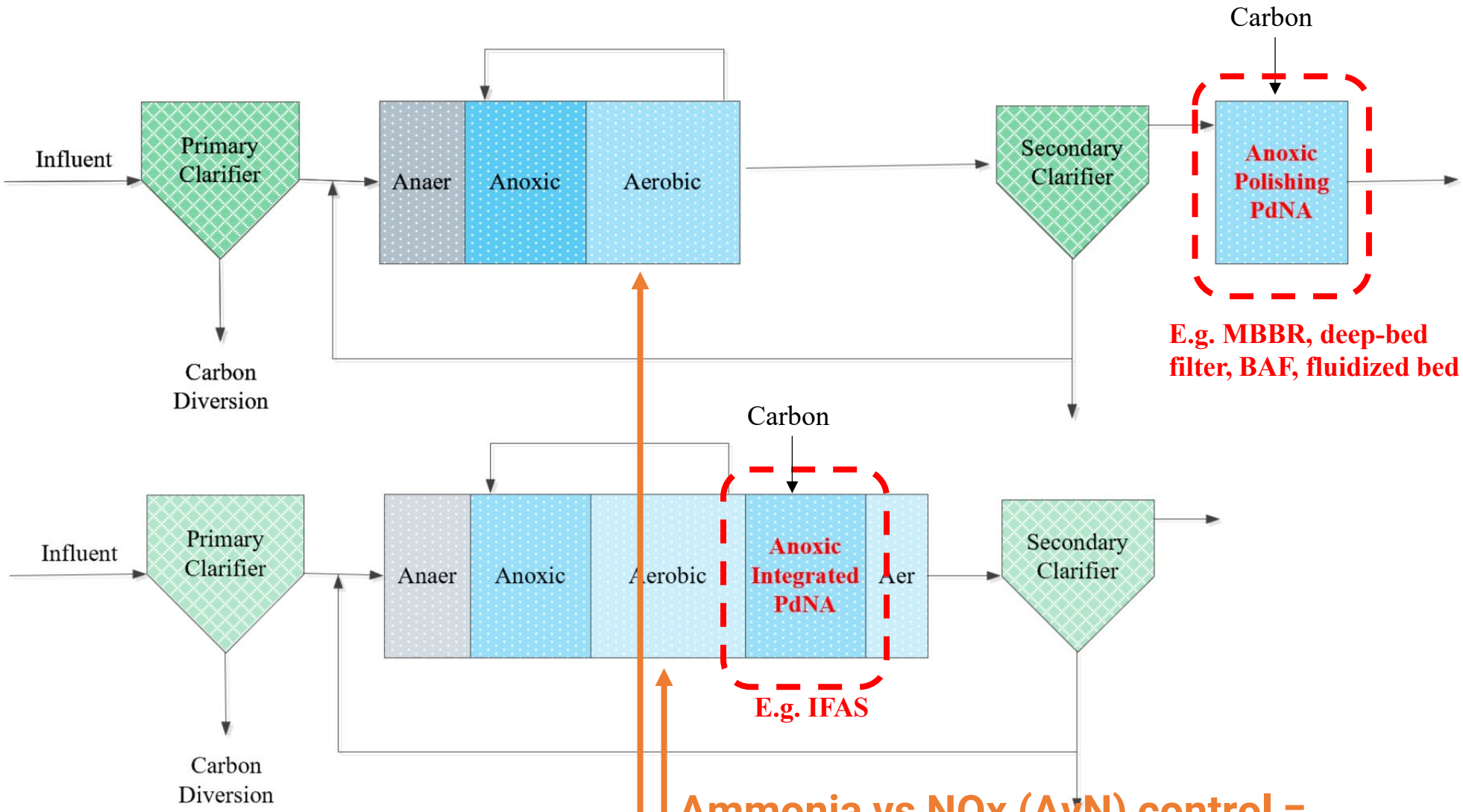
- Feedback ammonia-base aeration control (ABAC)
- Feedback nitrate-based internal mixed liquor recycle (NRCY) flow control
- Feedforward/feedback methanol feed control

Existing ABAC – Feedback only, PI control

(operating at nearly every HRSD BNR plant (7), well established technology)



Polishing Partial Denitrification-Anammox (PdNA) Implementation – Post Anoxic *(stringent TN)* (we know how to do this; now it's just an engineering/control challenge)

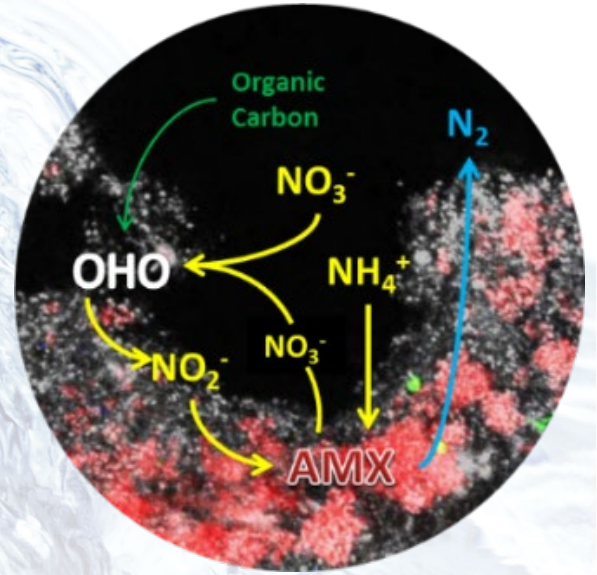


Ammonia vs NOx (AvN) control =
Maintain target NH3/NOx ratio based on controlling:
- **DO, Aeration time, Step feeding, etc**

HRSD Water Technology and Research Department

Dr. Chris Wilson, PhD, P.E. – Director of Process Engineering

Dr. Jeff Sparks, PhD, P.E. – Director of Digital Water



- ✓ 23 Staff
  - 8 Treatment Process Engineers
  - 3 Digital Water Engineers
  - ~15 Graduate Students (majority in Environmental Eng)
- ✓ HRSD provides salary (internship) and tuition support for graduate students
- ✓ Research Facilities:
  - Full-scale plants / collection system
  - VIP BNR Pilot (low DO)
  - James River Mainstream Anammox Pilots
  - SWIFT Research Center
  - Solids Handling and Digestion Pilots

Proportional-Integral-Derivative Algorithm is the backbone of most continuous feedback control systems

Proportional-Integral form is appropriate for first-order systems which can be used to describe most relationship in WRRF.

$$u(t) = K_C e(t) + \frac{1}{T_i}\int_0^t e(t')dt$$

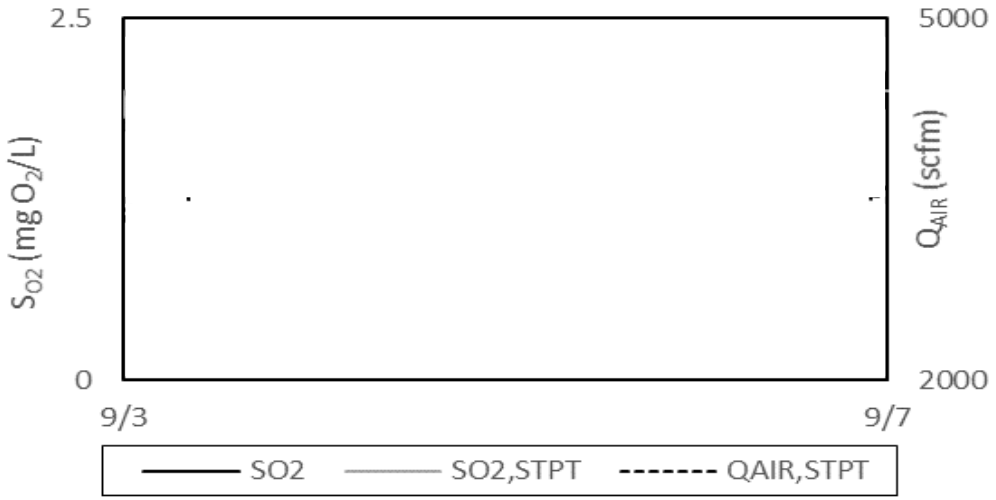
Proportional, K_c - Proportional to the error, gain correction term

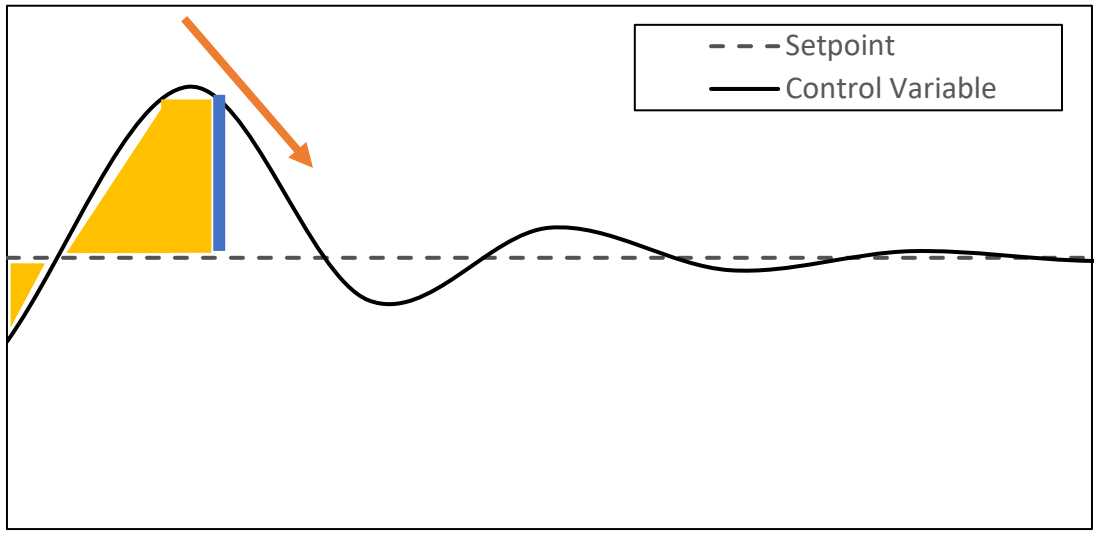
$$P = K_c * Error$$

Integral, T_i, – Accumulated error with time-based correction factor

$$I = I_{previous} + Error * \frac{1}{T_i}$$

State of Process Control In WRRF





Standard PI Controller Tuning: Brute Force Method

- The “trial-and-error” method is:
  - time consuming
  - relies on intuition or feeling
  - typically, no metrics are used for quantitative comparison of previous tuning values

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When a step-response test can be executed: tune from those data.

Water Practice & Technology

IWA PUBLISHING

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Application of step-response lambda tuning to proportional-integral controllers in water resource recovery facilities

Alexandria Gagnon [a,b,*], Kris Villez [c] and Charles Bott [a,b]

[a] Department of Civil & Environmental Engineering, Virginia Polytechnic Institute & University, 200 Patton Hall, Blacksburg, VA 24061, USA
[b] Hampton Roads Sanitation District, 1434 Air Rail Venue, Norfolk, USA
[c] Oak Ridge National Laboratory, Department of Energy, Oak Ridge, USA
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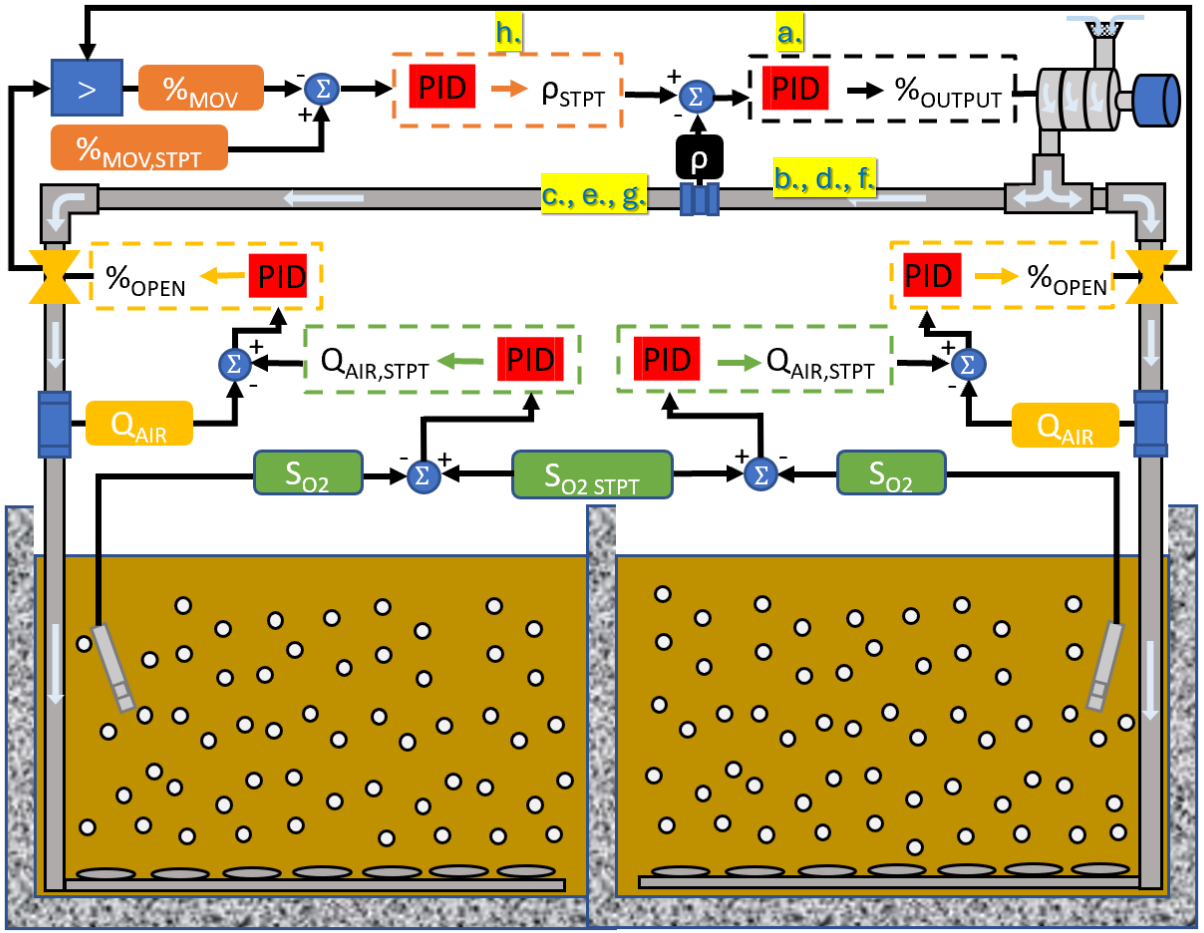
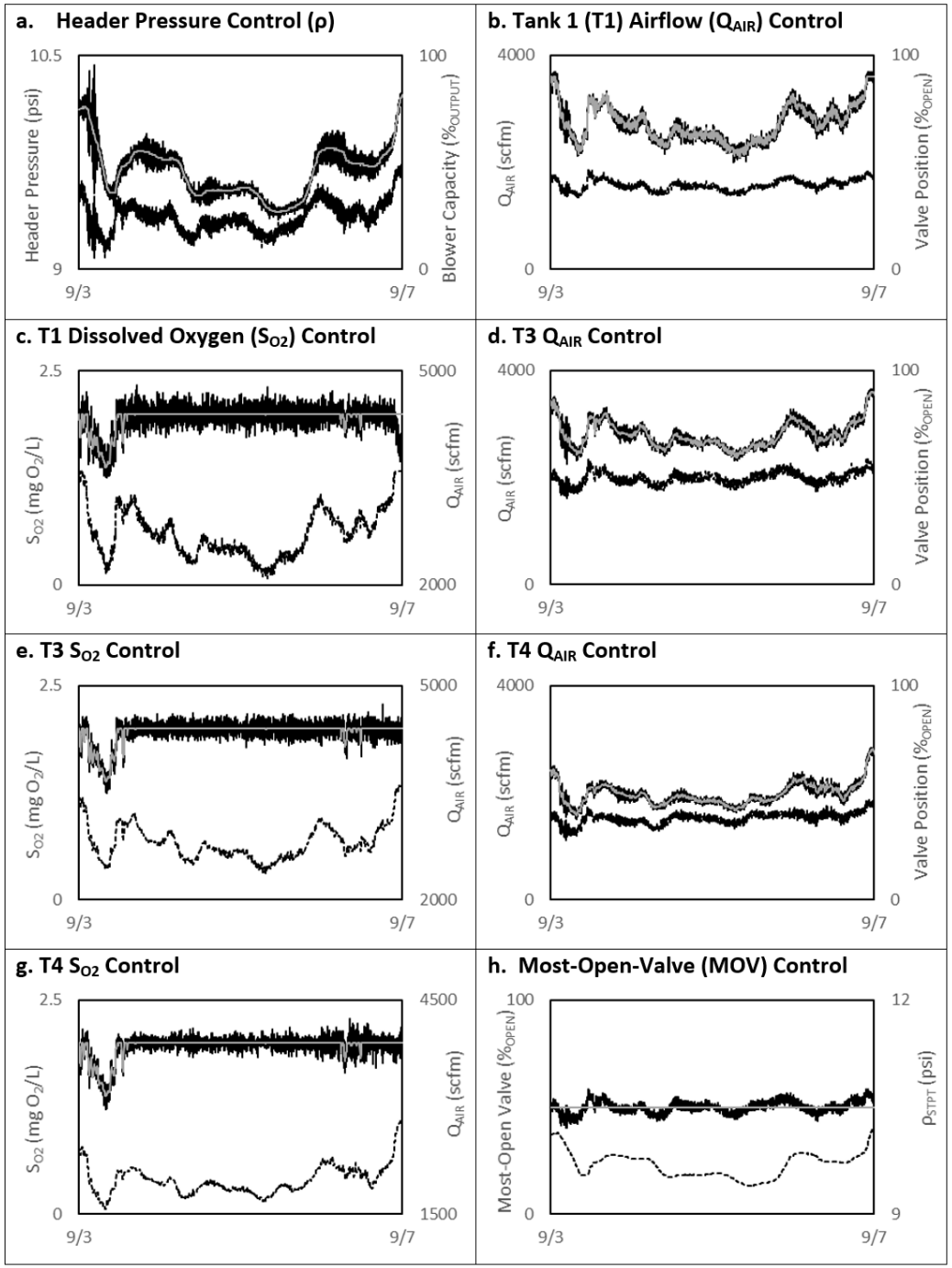
Step-Response Tuning with Lambda produced stable and consistent control of VIP's Aeration Control System





When step tests are impractical, such as with ammonia-based aeration control, tuning can be executed from a reduced-order model.

Water Environment Research

RESEARCH ARTICLE OPEN ACCESS

Development of a Reduced-Order Model to Identify Ammonia-Based Aeration Control Proportional–Integral Tuning Parameters and Improve Performance

Alexandria Gagnon[1,2] | Kester McCullough[2,3] | Charles Bott[3]

[1]Department of Civil & Environmental Engineering, Virginia Polytechnic Institute & University, Blacksburg, Virginia, USA | [2]modelEAU, Département de génie civil et de génie des eaux, Université Laval, Quebec, Québec, Canada | [3]Hampton Roads Sanitation District, Virginia Beach, Virginia, USA

Correspondence: Alexandria Gagnon (gagnonaa@vt.edu)

Received: 5 November 2025 | **Revised:** 3 March 2026 | **Accepted:** 5 March 2026

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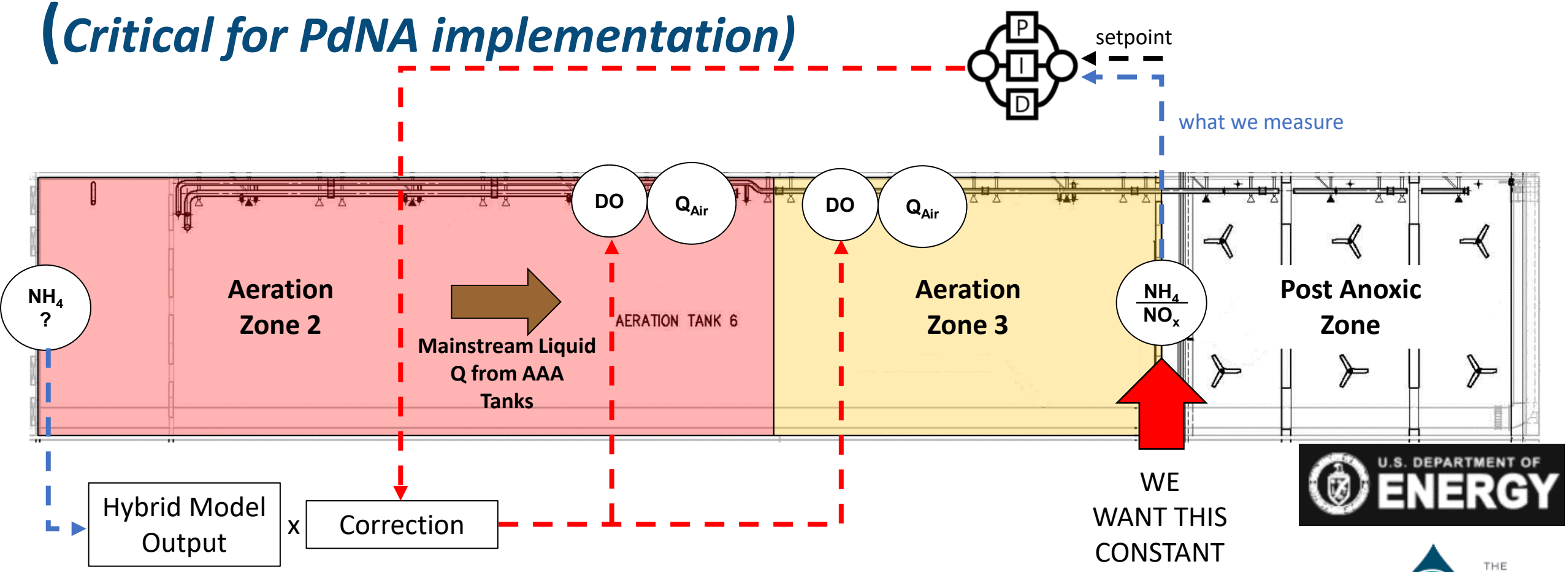
Upgraded ABAC & AvN (with Feedforward)

(*Critical for PdNA implementation)*



U.S. DEPARTMENT OF ENERGY

THE Water Research FOUNDATION

Feedforward – three approaches being evaluated at HRSD:

1. Controller adjusts for changes in influent flow only (already applied to AvN) – Mike Parsons, James River
2. Feedforward model predictive controller from regression analysis of calibrated process model simulations (no additional sensors) – Ali Gagnon, VIP (ABAC now, soon to AvN)
3. Hybrid mechanistic and data/ML model with added NH4 sensor – Jeff Sparks, Nansemond (ABAC, soon to AvN)

HRSD Digital Water Org

Jeff Sparks, PhD, PE

Director

The director is responsible for leading a team of academics, consultants, and practitioners towards a common goal.

Henry Croll, PhD, PE

Consultant

Henry is bringing Reinforcement Learning to HRSD's wastewater treatment controllers and DTs.

Keaton Lesnik, PhD

Solution Provider

Keaton is building an LLM solution for HRSD Operations that integrates with wastewater treatment plant DTs.

Peter Vanrolleghem, PhD

Academic Advisor

The academic advisor provides high-level oversight and supervises graduate students conducting research for HRSD.

Nicholas Badillo

PhD Student

PhD students are expected to perform research related to data-driven / mechanistic modelling, and/or DTs.

Jean-David Therrien, PhD

Post-Doc

Focused projects for the Post-Doc include MPC for disinfection, self-tuning PIDs, Swift projects, data pipelining, etc.

Clay Wise

Digital Water Eng.

Clay specializes in ETL, database management, and GIS.

Kester McCullough, PhD, PE

Digital Water Eng.

Kester specializes in Large Language Models, computer vision, and treatment plant optimization.

Steven Poe, PE

Digital Water Eng.

Steven specializes in time series forecasting, hydraulic modelling, and HRSD Interceptor System optimization.

Elliot Hong

Undergrad. Intern

Elliot is a computer science major at UVA and is currently building a computer vision application for HRSD.

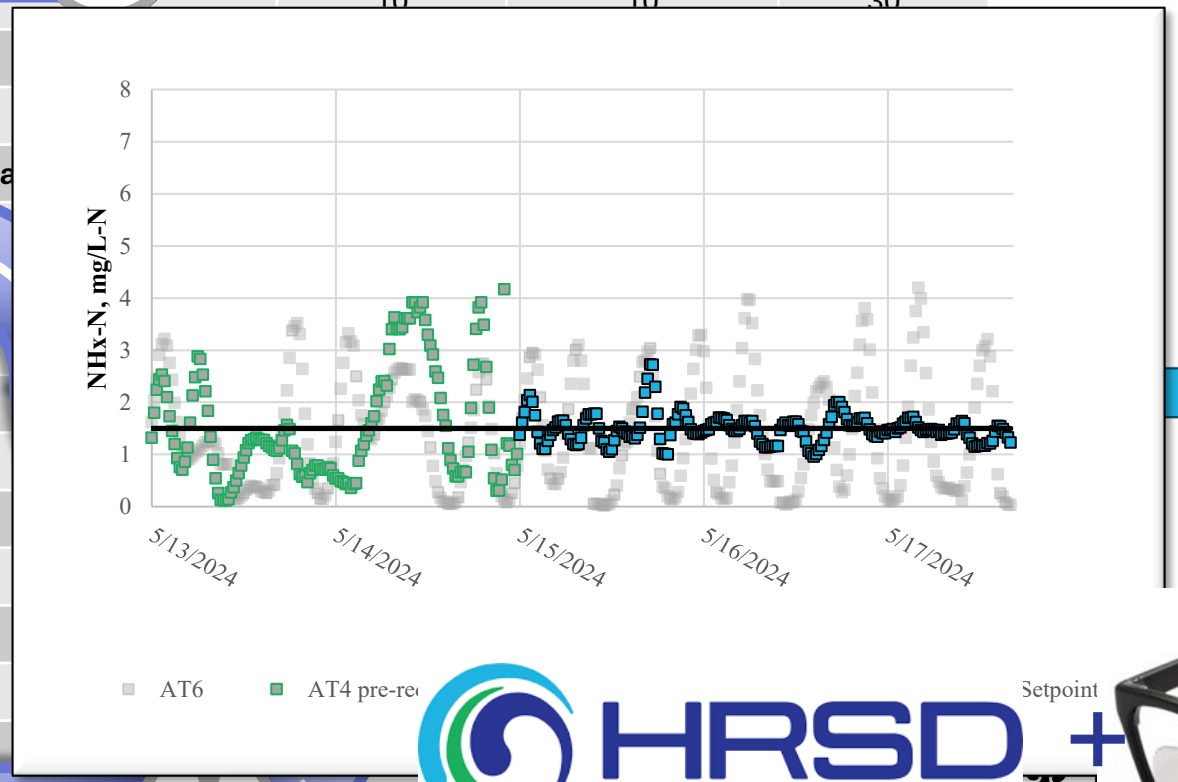
Digital Water Roadmap

01

Identify “Low-Hanging Fruit”

Develop a structured framework that ranks use

Project/Location	Data	Feasibility	Potential ROI	Ranking
		eployments		
		10	10	30
	emond SWIFT			
Y	r Treatment Plant			
	Flow Foreca			
Virg				
Nansemond Plant				
Urbanna Plant				
FM Pressure Forecasting				
FM Break Detection				
PS POR Operation				
Hydraulic Model DT (Smart Sewer)				
Industrial Waste Tracking				
PID Self-T		3		
Disinf		5	10	23
Feedforward	ck ABAC/AvN	10	10	30
NOB	ection	5	3	10	18
Total So	ft Sensor	6	6	8	12
Critical Ser	ult Detection	8	10	8	26



03

Operationalize

Implement an MLOps framework to deploy, monitor, and retrain AI models.

Track use and added value as defined by the end user.

Microsoft Azure Blob Storage → Power BI

Data Pipeline for

HRSD +

hands-free access to SOPs and real-time data. Pilot with small groups to improve productivity and safety in the field.

06

AI Monitoring of Critical Spaces

Introduce AI-enabled cameras in areas with critical equipment and/or elevated risk of failures. These cameras will support operators by providing continuous monitoring during periods when plants are unattended.

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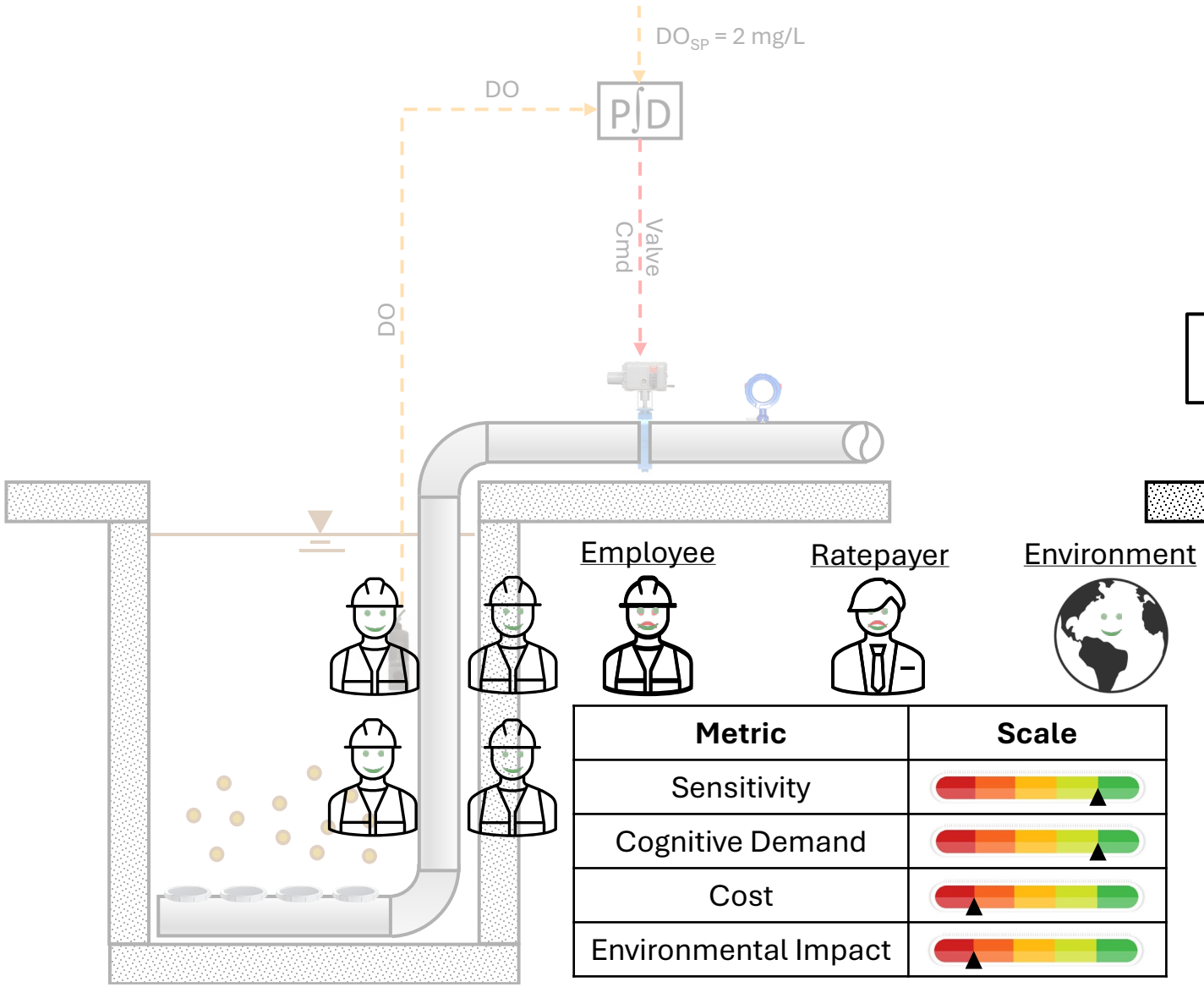
Implementing SOA/complex processes to manage costs

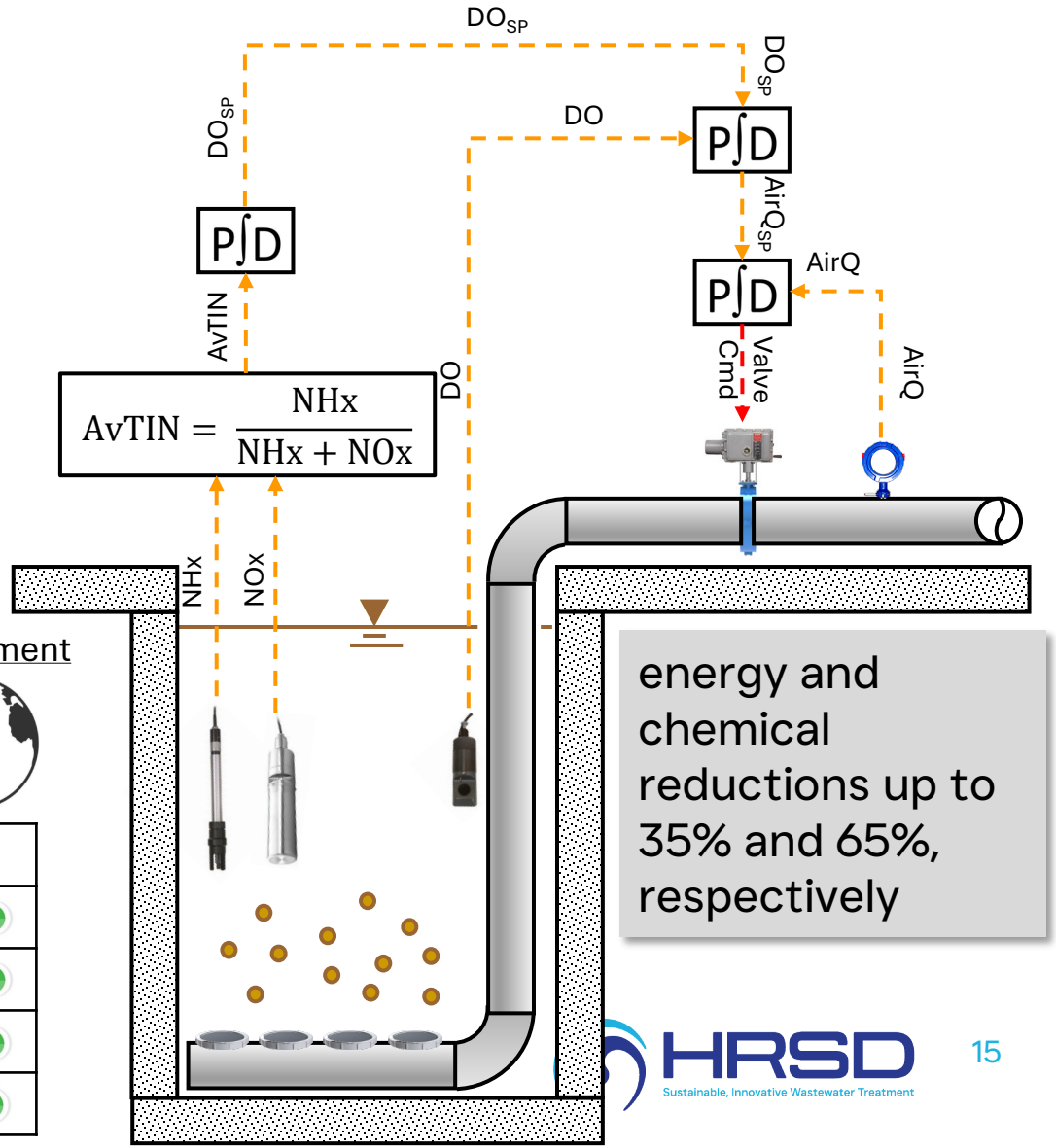


Employee

Ratepayer

Environment

Metric	Scale
Sensitivity	
Cognitive Demand	
Cost	
Environmental Impact	



energy and chemical reductions up to 35% and 65%, respectively

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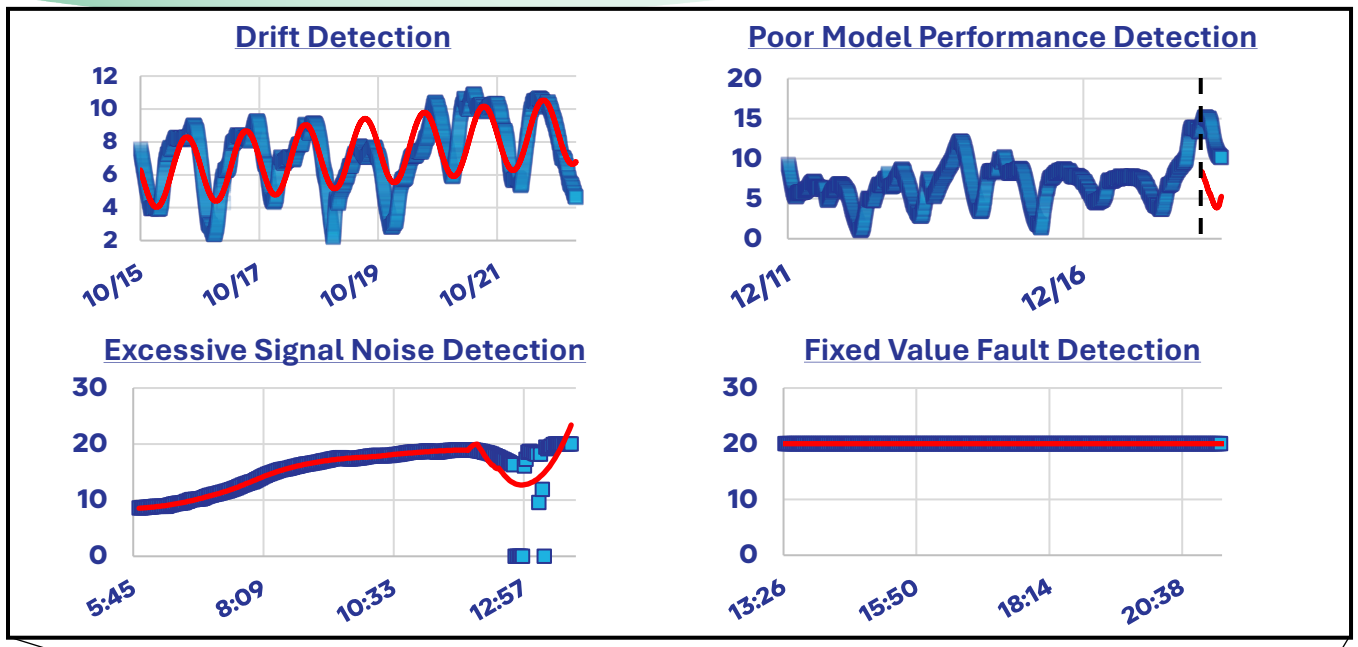
AI is the solution to complexity, not the source of it



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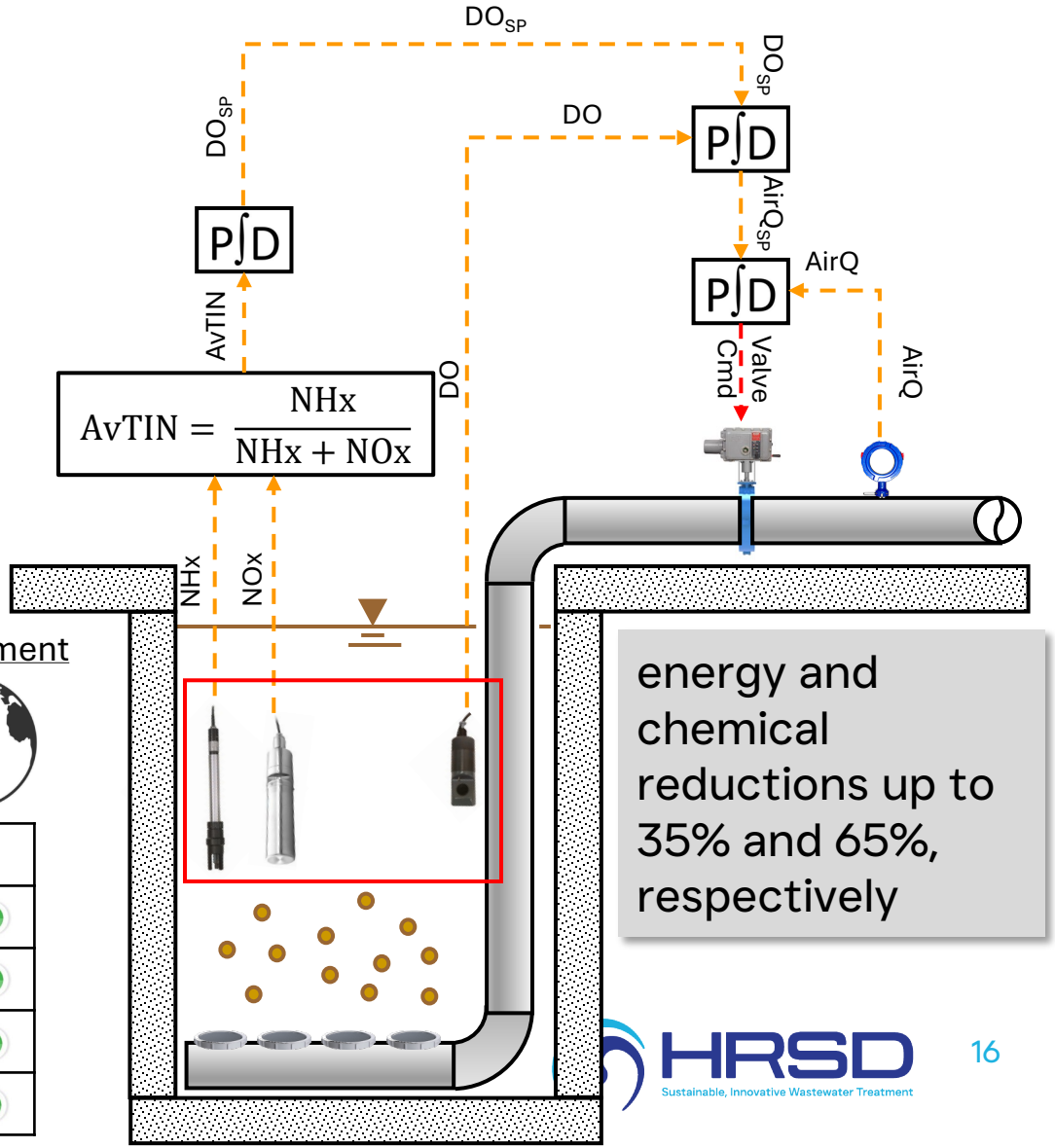

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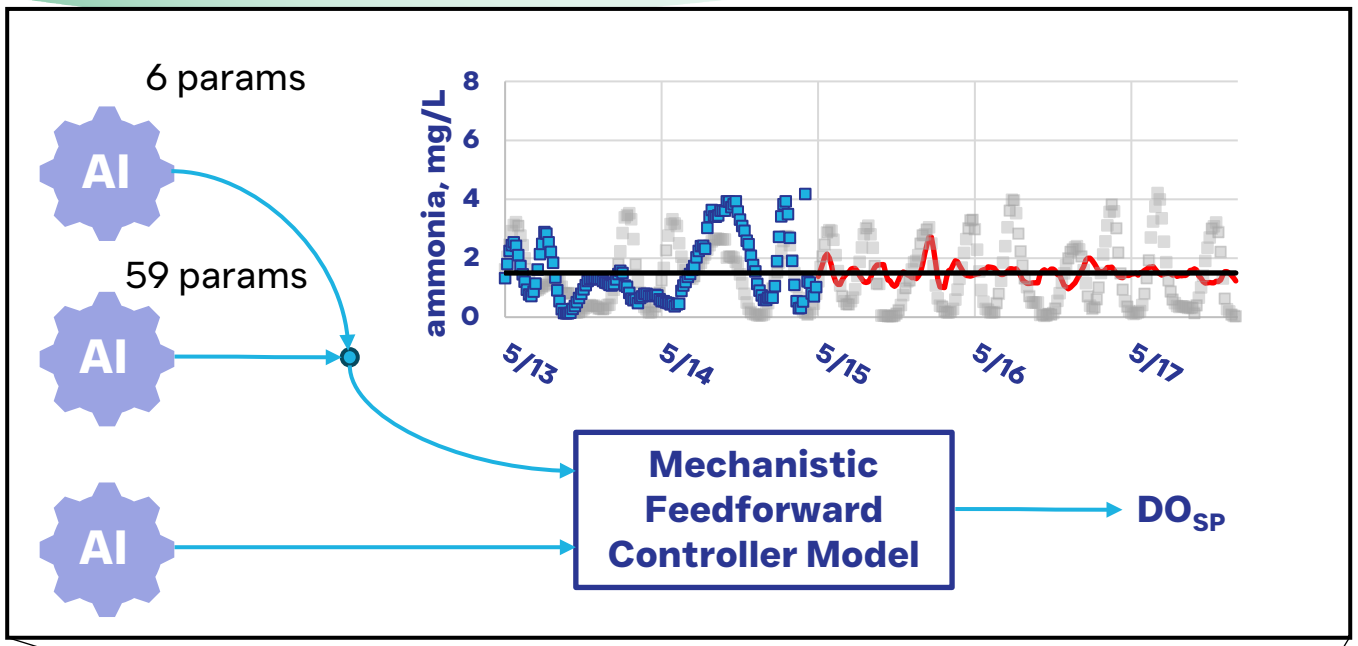

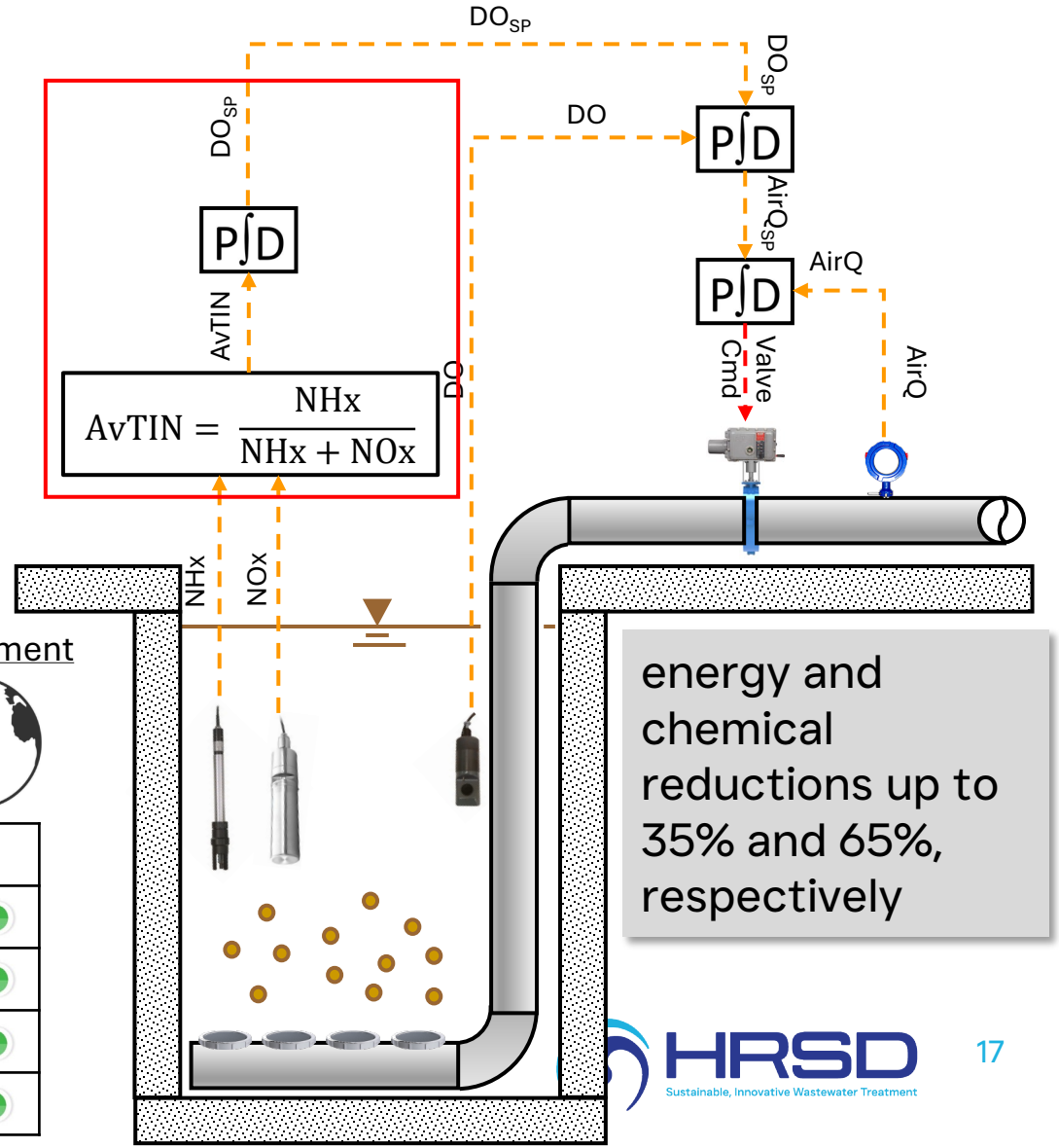

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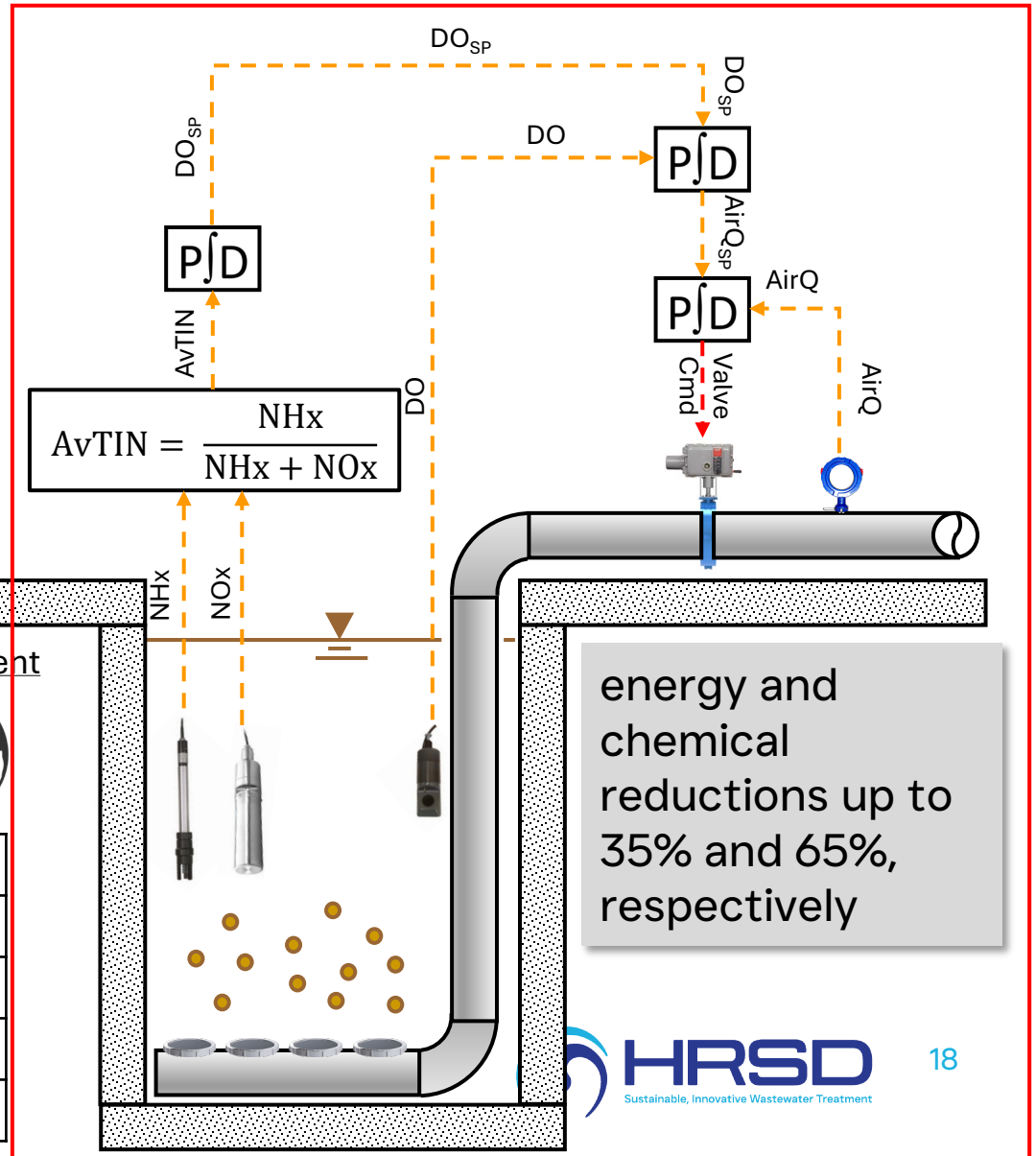

energy and chemical reductions up to 35% and 65%, respectively

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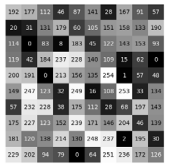
Automating Facility Monitoring – Operator rounds



Anomaly Detection Model

Anomaly Detected?

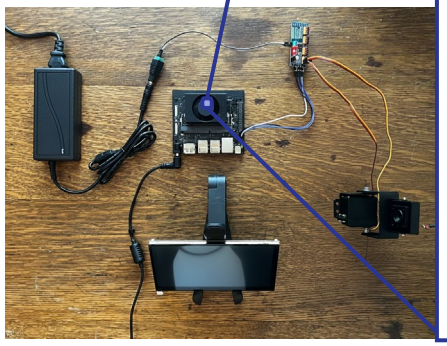
Y

N

No Action

modifications currently in development:

1. **thermal imaging**
2. **sound**
3. **integration of a multimodal LLM**



Employee

Ratepayer

Environment

Metric	Scale
Sensitivity	
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Classification Model

Smoke/Fire

Results in alert and requires immediate response. High criticality.

Human

Potential security threat if room should be unoccupied. Results in alert and requires immediate response. High criticality.

Leak

Most leaks will be minor, e.g. pump packing. Medium criticality depending on anomaly score & leak confidence.

Corrosion

A catastrophic failure due to exterior corrosion will take time to develop. Medium criticality.

Unknown

There is no predefined bucket for the anomaly. Low criticality depending on anomaly score.

New Goal – eliminate plant operator shift work….

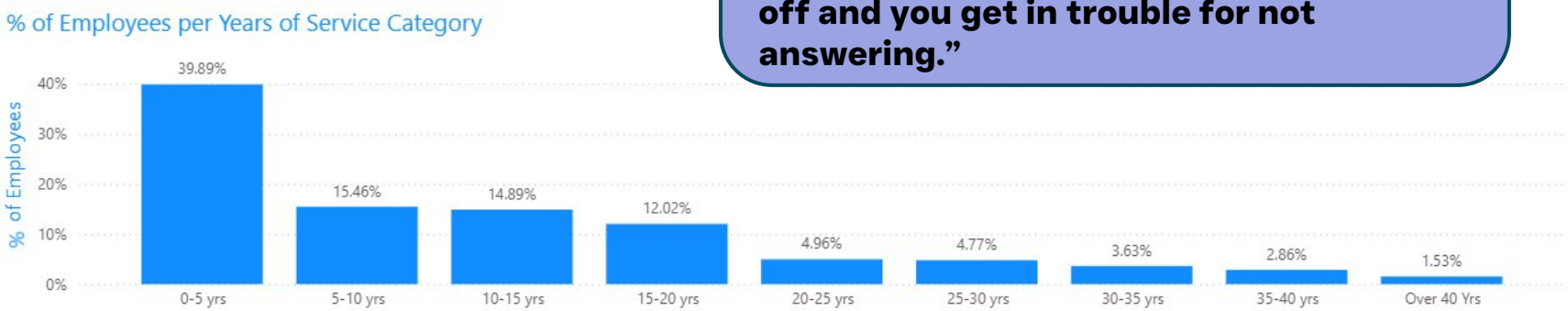
"The only issue as a plant operator is the rotating shift schedule, but honestly if you can get past that, I would highly recommend …"

"Cons: … shift schedule is hard to get used to"

"It's shift work… which I was expecting but having to work 7 days straight to get 3 days off sucks. …"

"You will work day shift, second shift, midnight shift, 2 weekends every 6 weeks, getting woken up while on midnight shift by supervisors who have questions about your shift, text messages, emails on days off and you get in trouble for not answering."

"…Rotating shift work is tough…"



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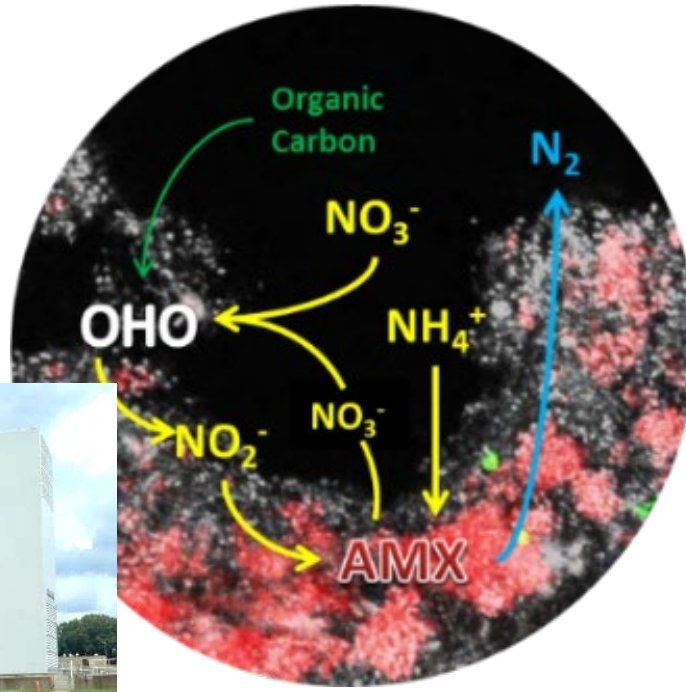

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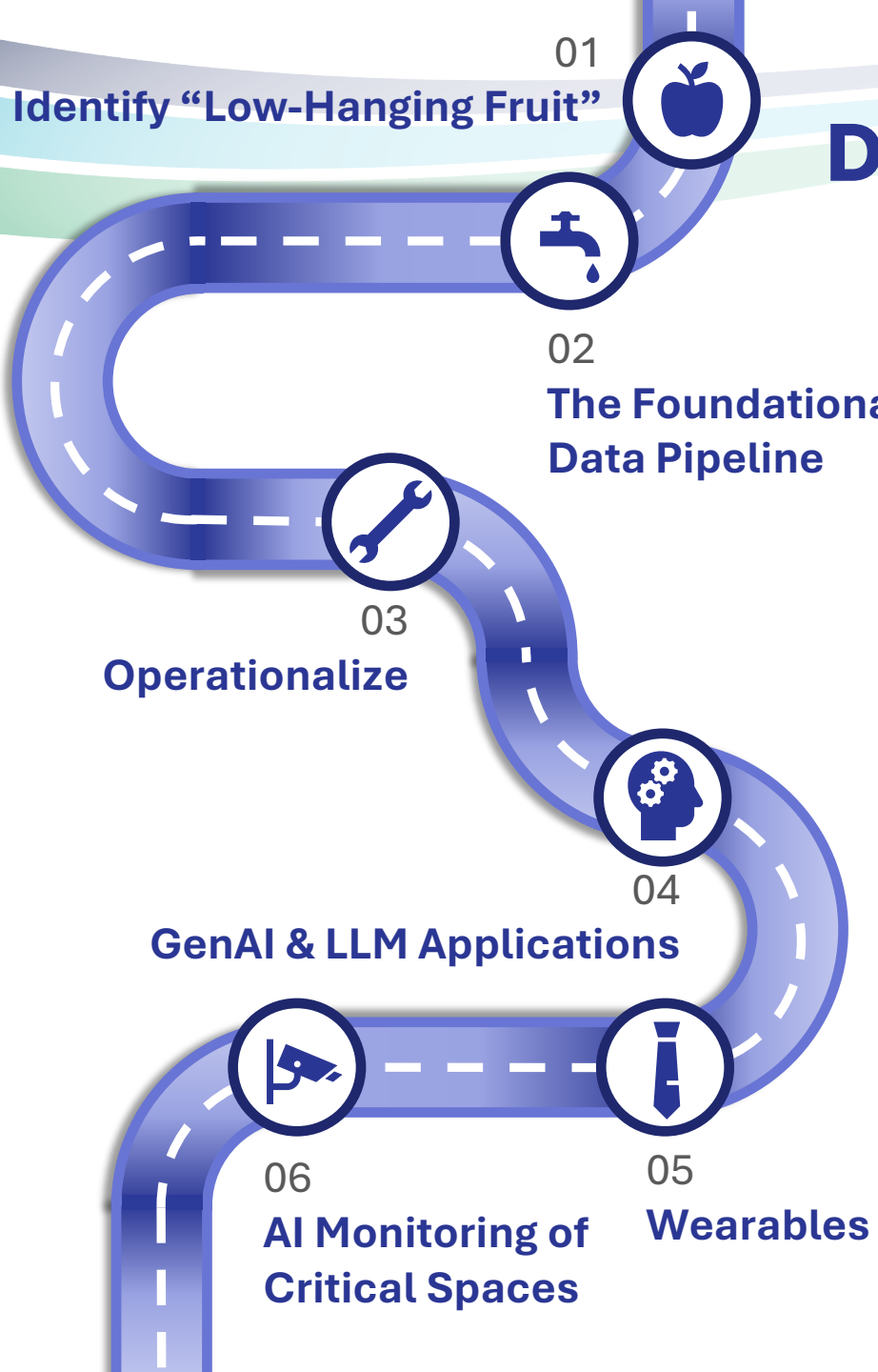
Digital Water Challenges Ahead



- **Cybersecurity** – continuing active control safely and securely
- **Data Pipeline Maturity** – addressing silos and cleaning challenges
- **Cultural Readiness** – achieving curiosity and comfort
- **Fragmented Intelligence** – moving beyond one-off models

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HRSD's Online Analyzer – "Jarbalyzer" NH4, NO3, NO2, OP