LEADING UTILITIES OF THE WORLD

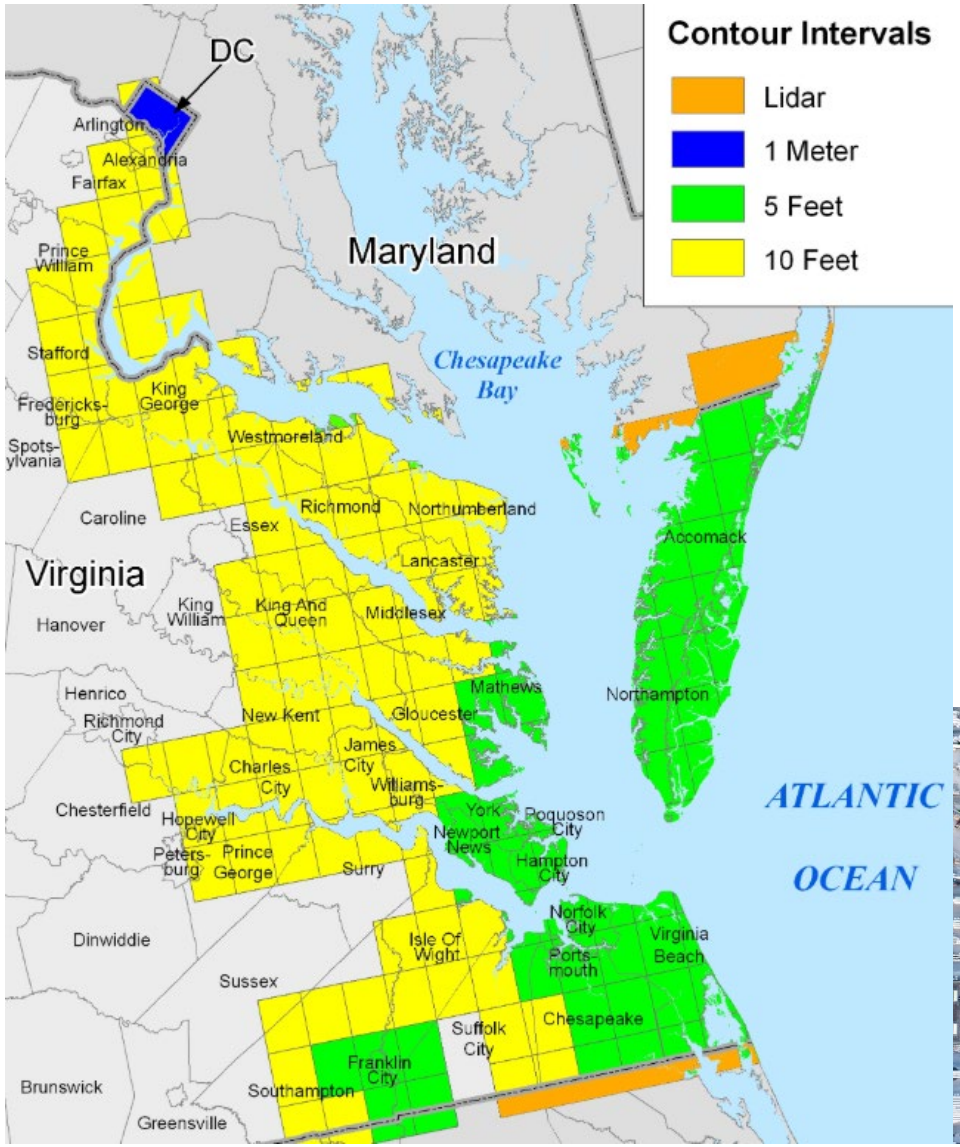
HRSD

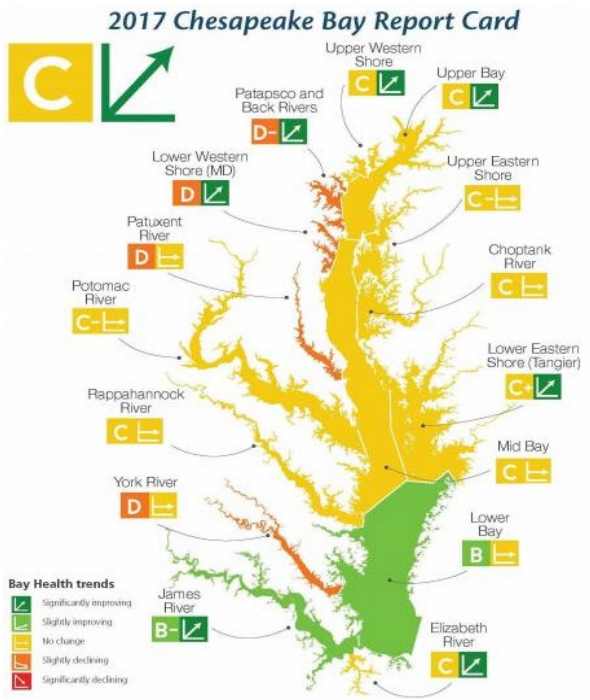
Sustainable, Innovative Wastewater Treatment

May 2026

The Water Challenge We Face

- ✓ Increased regulatory pressure
- ✓ Rising cost of treatment and conveyance
- ✓ Climate and water supply risk
  - ➢ *Utilities are being asked to do more with less under increasing pressure*





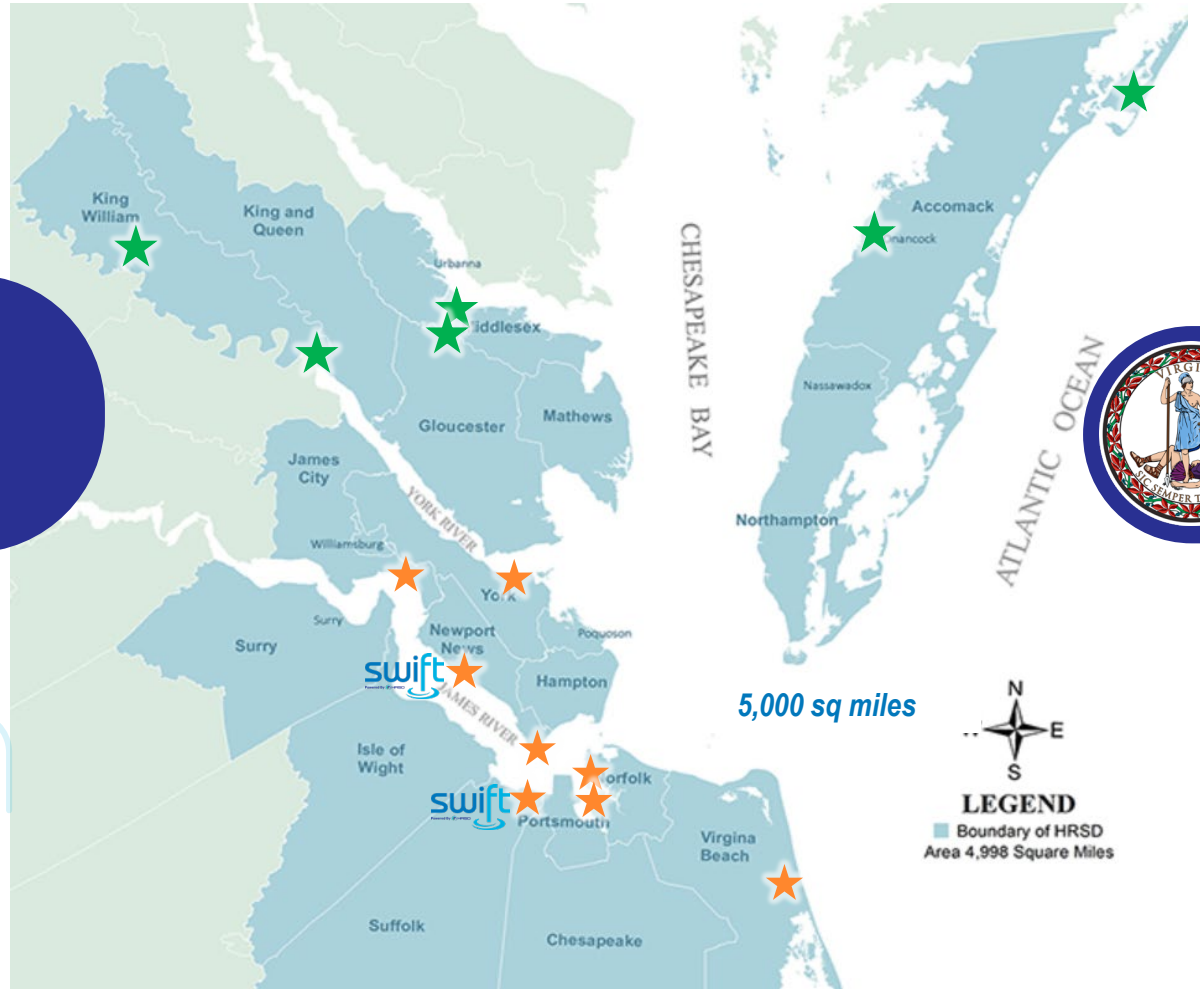
Hampton Roads Sanitation District (HRSD)

Conveyance and treatment to 20 cities and counties in SE Virginia

225 MILLION GALLONS / DAY OF COMBINED TREATMENT CAPACITY

8 MAJOR TREATMENT PLANTS

6 SMALL TREATMENT PLANTS



1.9 MILLION INDIVIDUALS SERVED

Over 20% of all Virginians

POLITICAL SUBDIVISION COMMONWEALTH OF VIRGINIA

10-YR CAPITAL BUDGET

$3.4 BILLION

11 Active Patents

5 Patents Pending

THE Water Research FOUNDATION®

32 ACTIVE Water Research Foundation Projects

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Innovation Areas

WASTEWATER TREATMENT AND ENVIRONMENTAL IMPACT

Innovations in wastewater treatment systems, improving usable biomass output, and/or developing creative methods of obtaining quality measurements for wastewater reuse to support public health goals, odour control, landfill reductions, and the overall environmental sustainability of the local and surrounding areas.

SEE MEMBERS INVOLVED IN THIS INNOVATION AREA

IT & SMART WATER SYSTEMS

Innovations in smart and/or digital platforms which create improvements in any strategic or operational area of a water/wastewater utility.

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RESPONSE TO DROUGHT OR SCARCITY

Innovations which promote the conservation of water, including building short term resilience to extreme events and/or planned long-term responses to climate change and variability.

SEE MEMBERS INVOLVED IN THIS INNOVATION AREA

Challenge → Solution → Outcome

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Wastewater Treatment & Environmental Impact

Challenge: Nutrient Limits

Challenge: More stringent effluent nutrient requirements while influent loads increasing. Targeting lower operating costs (chemical & energy) and limited footprint available for expansion = intensification.

Why this matters:

- Protect public health and the waters of Hampton Roads, while reducing nutrients to local rivers and the Chesapeake Bay.
- Treatment costs rise as nutrient removal requirements become more stringent.

High aeration energy

- Energy-intensive oxygen demand for nitrification and polishing.

High chemical / carbon use

- External carbon and supporting chemicals for full denitrification.

Large expansions

- Conventional upgrades can require major capital and space.

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Solution: Development of PdNA

Partial Denitrification-Anammox (PdNA) = DETOUR®

DETOUR partial denitrification anammox

dc water is life®

Biofilm-based PdNA

- Partial denitrification: convert nitrate to nitrite
- Anammox: convert nitrite + ammonia to nitrogen gas
- Large aeration energy and chemical savings; significant intensification benefit

Anammox required for success – need for retaining slow-growing organisms

- Moving bed biofilm reactors (MBBR) or Integrated fixed film activated sludge (IFAS) or post denitrification filter
- Control strategy required for stable and consistent operations (AvN)
- Eliminates additional footprint requirement by utilizing existing infrastructure

1. Set the right influent ratio (AvN)

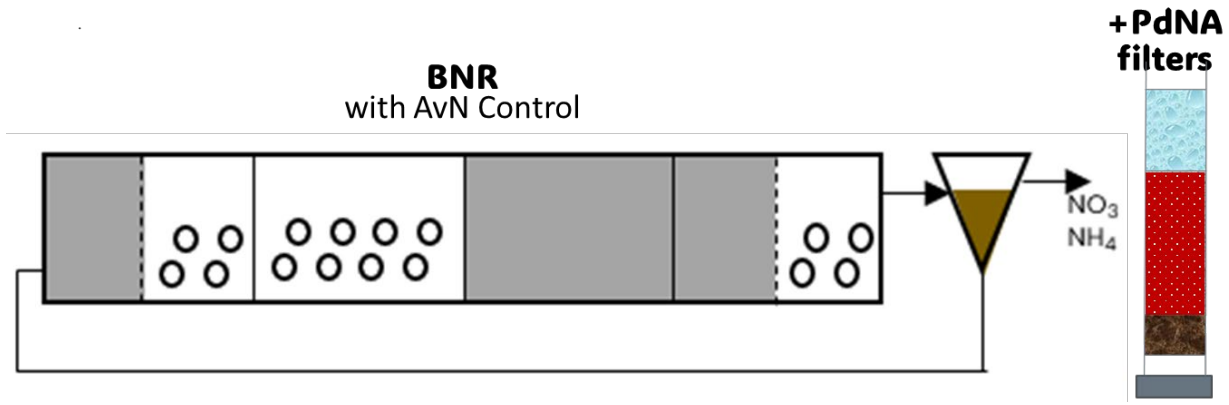
Control upstream ammonia vs NOx to feed the PdNA zone stable nitrogen balance.

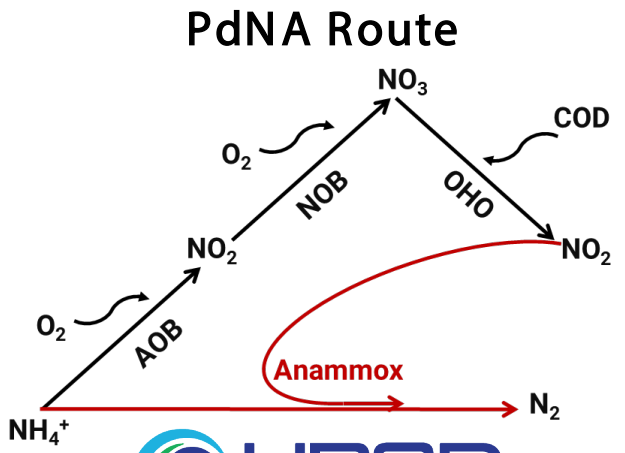
2. Dose carbon by nitrate residual

Maintain a small nitrate residual (>1.5-2 mg N/L) to hold partial denitrification.

3. Retain anammox in biofilm

Use MBBR/IFAS or filter approach to retain anammox.





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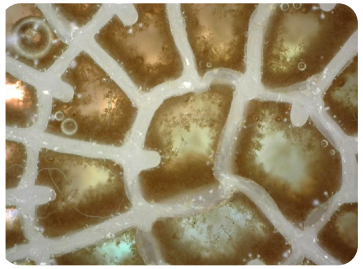
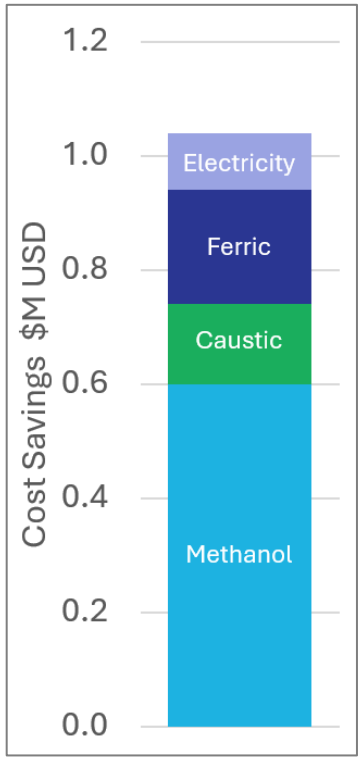
Outcome: Development of PdNA

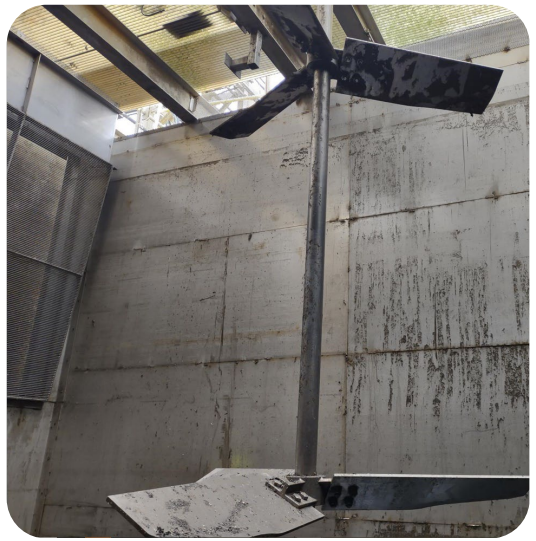
< 3 mg/L*	> $1M/year*	~$100M*
• Effluent TIN	• O&M Savings	• Capital project avoided



*HRSD York River TP – 13 mgd capacity

- Mainstream PdNA full-scale at 3 facilities (2018) in 4 configurations
- **More nutrient removal with less resource demand**
- Performance, sustainability, and cost benefits
- Carbon footprint reduction





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IT & Smart Water Systems

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Challenge → Solution → Outcome

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Challenge: Reliable Controls

Challenge: Keep effluent ammonia on target (and TIN reliably low) in a dynamic process with long response delays and large daily load swings, while reducing aeration energy and chemical use and safeguarding downstream water reuse.

Why this matters:

- Stability needed in effluent for SWIFT indirect potable reuse
- PdNA requires accurate AvN control
- Simplify operations

Long Process Delay

- In plug-flow tanks, upstream DO changes at the outlet NHx ~2.5 hours later (avg HRT).

Big diurnal load swings

- Diurnal TKN load varies ~4× from valley to peak: feedback-only ABAC couldn't anticipate swings.

High-consequence excursions

- Downstream SWIFT IPR has an instantaneous TIN limit (5 mg/L N); excursions can pause recharge.

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Solution: Digital Water - Leveraging AI for ABAC

Digital Twin (DT) + Ammonia Based Aeration Control (ABAC)

Purpose-built Digital Twin

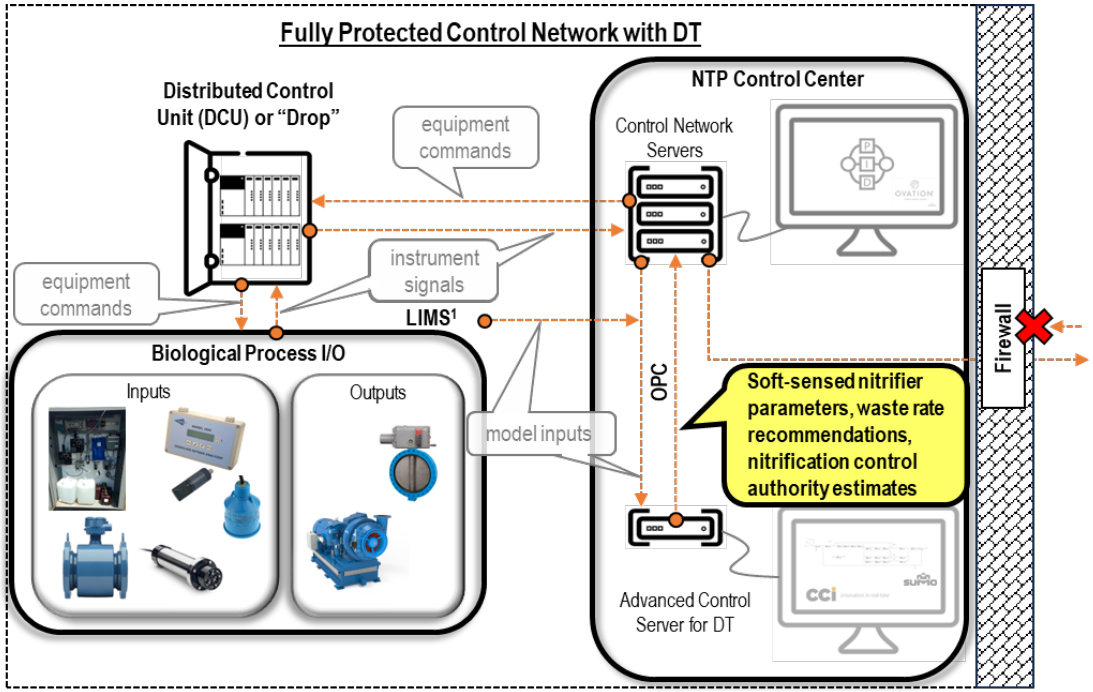
- Updates every minute; soft-senses nitrifier kinetics and recommends wasting to preserve control authority.

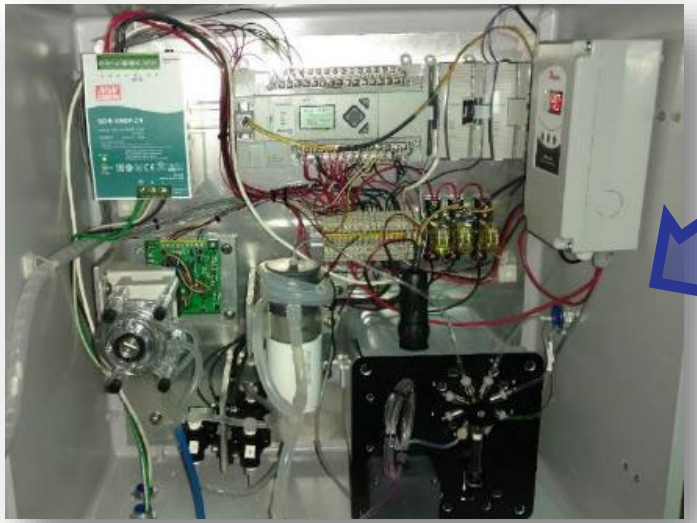
Hybrid feedforward-feedback ABAC

- Mechanistic oxygen demand equation + lightweight AI error forecasts set forward-looking DO setpoints.

Operator-first smart deployment

- HRSD-built analyzers ("Jarbalyzers"), mixing upgrades ("Minions"), SCADA integration, and fail safes.





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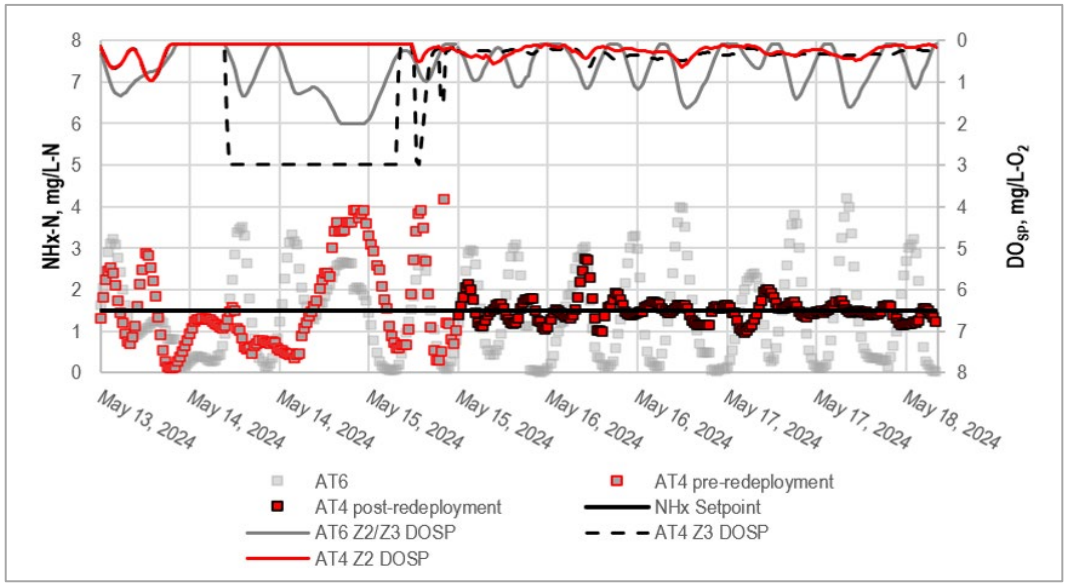
Outcome: Digital Water - Leveraging AI for ABAC

- Consistent effluent quality
- DT updates every minute; soft-senses nitrifier activity and recommends wasting strategies
- Hybrid ABAC flattened NHx peaks/valleys and removed DO setpoints riding bounds
- Operator-friendly and auditable: clear graphics, AI toggles, and fail safes
- **Bringing AI to WWRFs doesn't have to be mysterious or complicated**
- **First full-scale Digital Twin deployed solely for nitrification control**



Catalyst for HRSD's NEW
Department of DIGITAL WATER

94% ↓
- Controller error (MSE)
- vs feedback-only ABAC

Smoother DO Setpoints
- No bound-riding

Reuse + PdNA Readiness
- Steady NHx ratio

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Response to Drought or Scarcity

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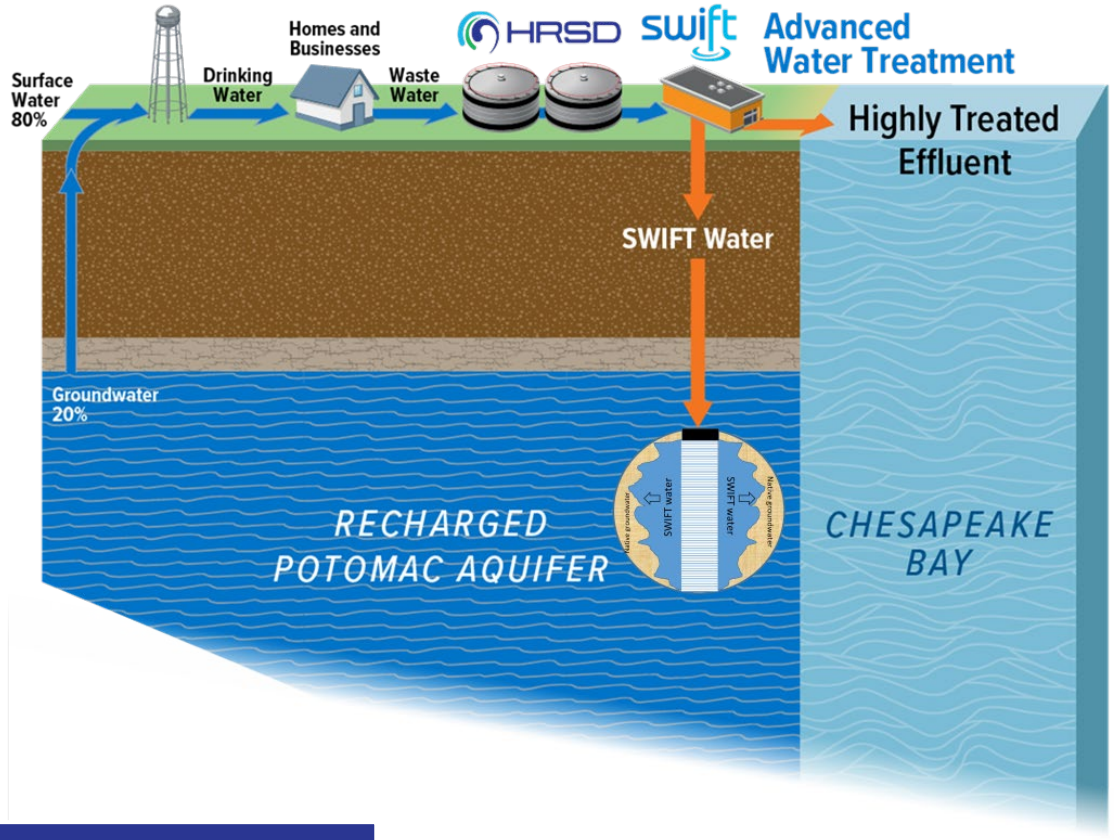
Challenge: Water Supply

Challenge: Securing groundwater in Eastern Virginia.

Why this matters:

- Eastern Virginia's Potomac Aquifer is a confined, limited resource with limited natural recharge - withdrawals have lowered pressure for over a century.
- Groundwater is used faster than it can be naturally recharged, contributing to land subsidence and greater vulnerability to sea level rise.
- Saltwater intrusion and climate variability amplify scarcity risk - communities need reliable water resources for generations.



Overdrawn aquifer

- Confined geology limits recharge; withdrawals reduce aquifer pressure.

Coastal pressures

- Land subsidence + sea level rise heighten flood risk and saltwater intrusion.

Reliability expectations

- A drought-resilient supply is essential for households, industry, and the regional economy.

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swift
Powered By HRSD
Sustainable Water Initiative for Tomorrow

Solution: HRSD SWIFT

SWIFT – Managed Aquifer Recharge

- Recycle highly treated wastewater instead of discharging
- Apply advanced treatment to produce SWIFT Water® (drinking-water quality)
- Managed aquifer recharge into Potomac Aquifer System – strengthening long-term groundwater supply

Co-benefits that strengthen sustainability

- Helps slow land subsidence and reduce saltwater intrusion risk
- Continuous monitoring and a USGS extensometer track performance
- Supports Chesapeake Bay goals through nutrient reductions

Drinking Water Quality Effluent

Carbon-based advanced water treatment produces SWIFT Water® to drinking-water standards and matches aquifer chemistry.

Recharge the Aquifer

Highly treated water that would be discharged is further treated and added back to the Potomac Aquifer.

Phased, Monitored Rollout

1 MGD Research Center (2018) informs full-scale facilities.

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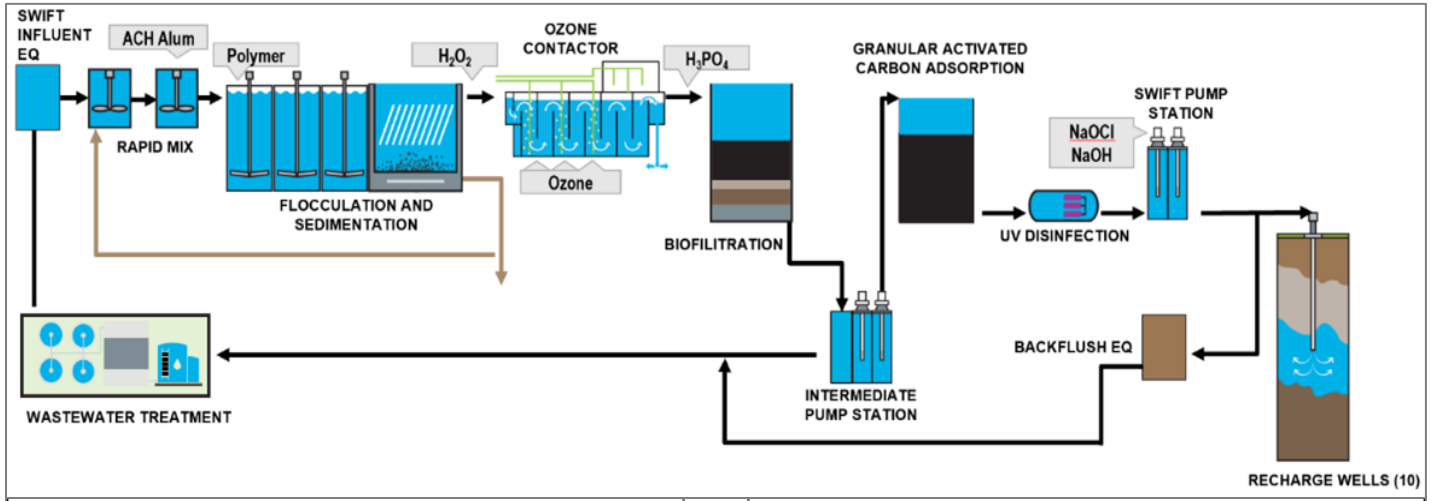
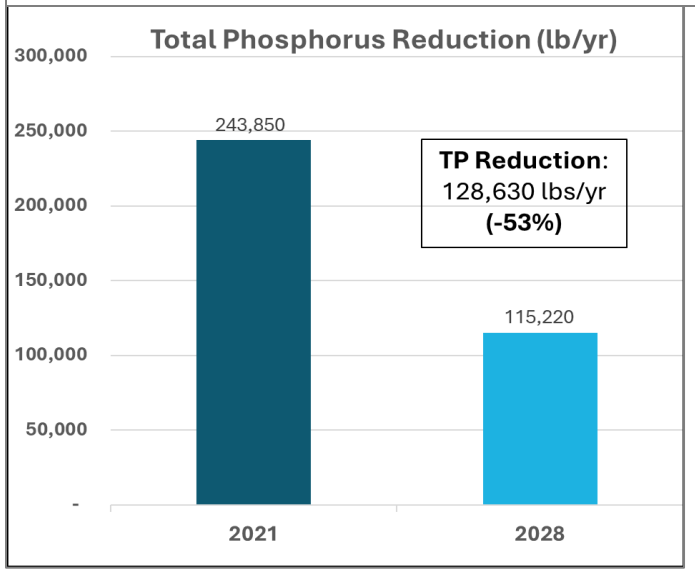
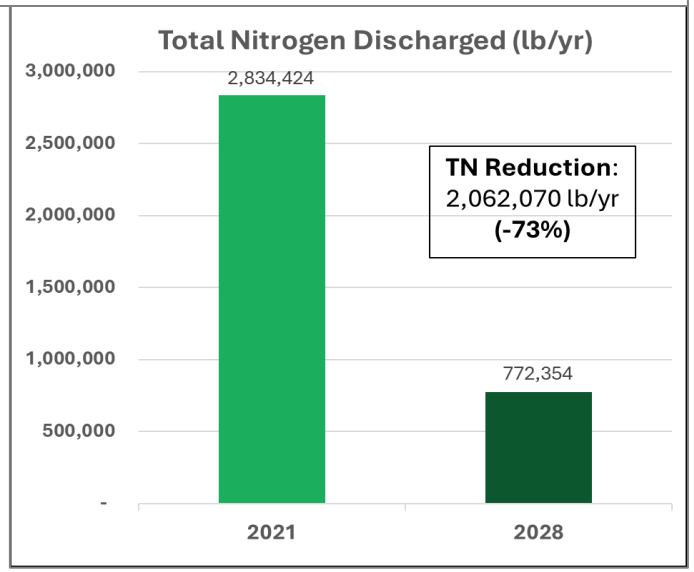
Outcome: HRSD SWIFT

- Full-scale SWIFT facilities at James River & Nansemond Treatment Plants with managed aquifer recharge wells
- 50 mgd SWIFT Capacity by 2030
  - 2018: Nansemond Research Center
    - 1 MGD
  - 2026: James River SWIFT
    - 16 MGD
  - 2029: Nansemond SWIFT
    - 34 MGD
- Reduced TN & TP discharge into Chesapeake Bay







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HRSD's 5 Year Lookahead

Expand Partial Denitrification-Anammox (PdNA)

- Startup HRSD James River Treatment Plant MBBR polishing PdNA system
- Complete HRSD Nansemond Treatment Plant second anoxic zone IFAS PdNA
- Advance HRSD Army Base Treatment Plant second anoxic IFAS PdNA implementation

Digital Water

- Scale AI-enabled tools across HRSD
- Complete the Digital Water enterprise data pipeline
- Pilot wearable technologies for field staff
- Introduce AI-enabled camera monitoring in select locations

Expand SWIFT

- Commission the HRSD James River Treatment Plant and Nansemond Treatment Plant SWIFT facilities
- Expand aquifer and land subsidence monitoring

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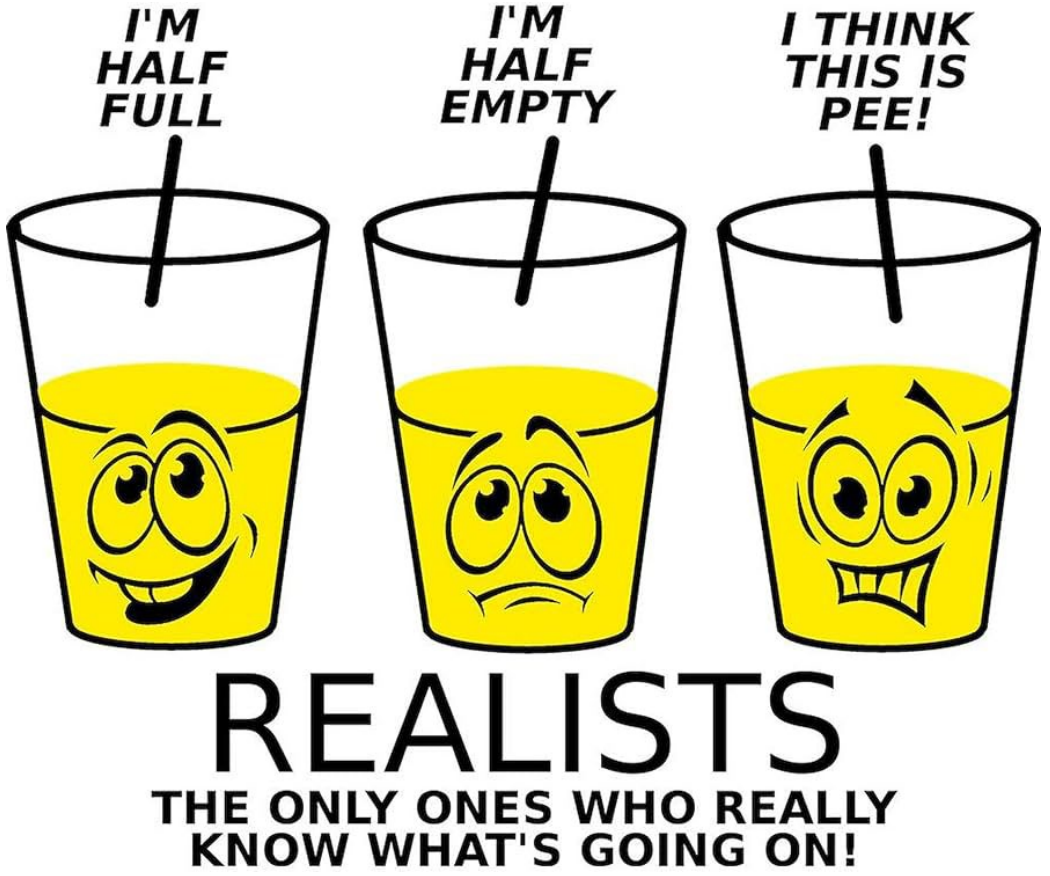
In Closing

Key Takeaways

Utilities around the world face the same challenge: tighter regulations, rising costs, and climate pressure.

Innovation is not optional, it is essential.

At HRSD, we believe the future of water lies in combining advanced treatment, digital intelligence, and sustainable water supply solutions



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