LIFT/RMWEA Intelligent Water Systems Webcast Series – Day 2

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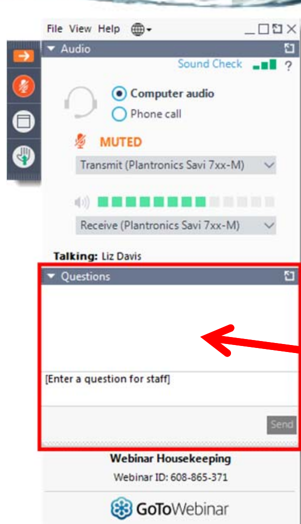
How to Participate Today

- This webcast will be recorded and available afterwards
- PDH instructions will be sent to all attendees 24 hours after the webcast has ended



Audio Modes

- Listen using Mic & Speakers
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Submit your questions using the Questions pane.

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Tanja Rauch-Williams, Carollo Engineers

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Morgan Brown, Barry Liner, Lisa MacFadden – WEF
Walter Graf, David Morroni, Stephanie Fevig, Frank Blaha, Mary Smith - WRF
Erica Bailey - City of Raleigh

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Today's Presentations

- Where are intelligent water systems going in the future; smart water networks, **Ken Thompson, Jacobs**
- The Journey of Transforming Information Technology to Digital Solutions, **Ting Lu, Clean Water Services**
- Case Illustrations of Predictive Operations at Resource Recovery Facilities, **Kate Newhart, Metro Wastewater Reclamation District; Ali Gagnon, HRSD; Jeff Sparks, HRSD; Katya Bilyk, Hazen and Sawyer; Erika Bailey, Raleigh Water**
- Implementing Cloud-Based Process Management at a Small Water/Wastewater Utility, **Barbara Biggs, Roxborough Sanitation District**
- The Role of Digital Twins in our Water Sector, **Gigi Karmous-Edwards, Karmous-Edwards Digital Consulting**
- Data as a Service and other IWS transformations: Learning from Data Scientists and Outside the Water Industry, **Meena Sankaran, Ketos**

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Where are intelligent water systems going in the future; smart water networks

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Lift/RMWEA Intelligent Systems Webinar
Thursday, June 18, 2020
Ken Thompson, Jacobs Engineering Group

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The Digital Water Utility

AKA:

- Smart Water Grid
- Smart Water Utility
- Intelligent Water Utility
- Intelligent Water System
- Data Driven Water Utility

Aligns with the "Digital Organization" in other industries

- Overlays data collection, information creation, and insight to improve efficiency and decision making

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Characteristics of a Digital Water Utility

- **Strategy & Vision:** The approach and foresight for development of a digital water utility
- **Data Management:** How data are collected, quality and security is maintained, its transmission to proper points of analysis
- **Analytics & Information Use:** Methods used for analysis of the data to produce useful, actionable information and the ways that information is used within the organization
- **Integration & Interoperability:** Whether systems managing the information are integrated across the organization and the information is available in a timely manner to all members of the organization who can make use of that information
- **Workforce & Asset Management:** The way information is being used to optimize the workforce and manage assets across the asset lifecycle
- **Resiliency:** The way the utility uses the information to enhance resiliency

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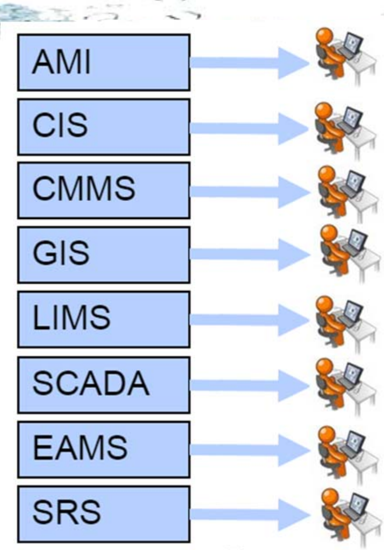
Current Water Utility

Water utilities have often introduced digital systems such as:

- Advanced metering infrastructure (AMI)
- Customer information system (CIS)
- Computerized maintenance management systems (CMMS)
- Geographic Information Systems (GIS)
- Laboratory information management systems (LIMS)
- Operational optimization tools
- Supervisory control and data acquisition (SCADA) system
- Enterprise asset management system (EAMS)
- Surveillance and Reponses System (SRS)
- Any other applications?



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These rarely share information, producing separate outputs

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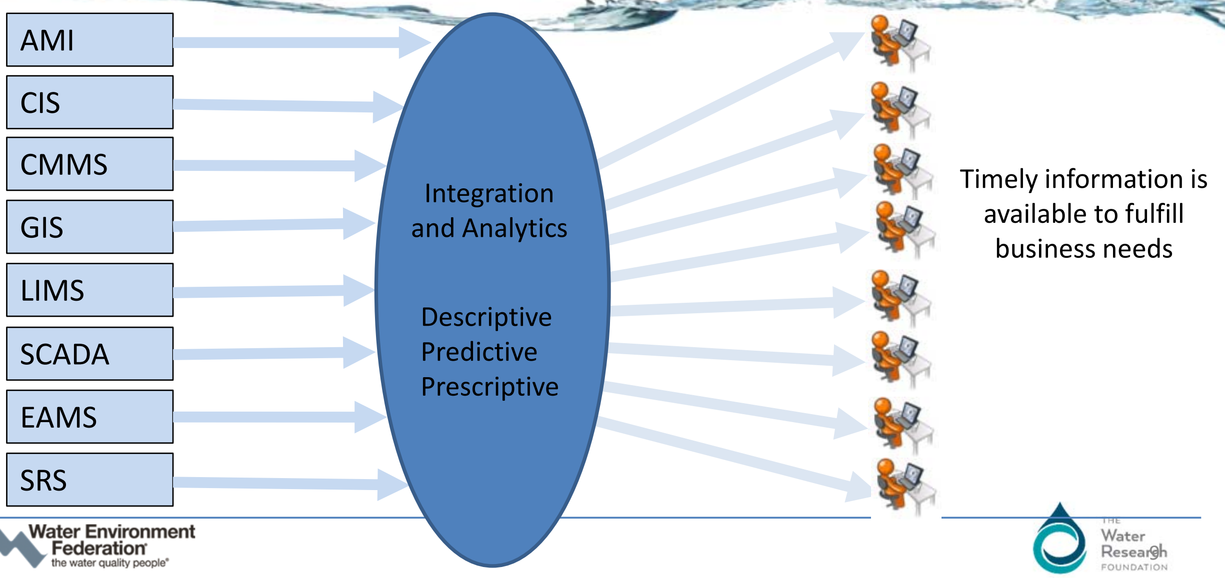
Digital Water Utility Information Architecture



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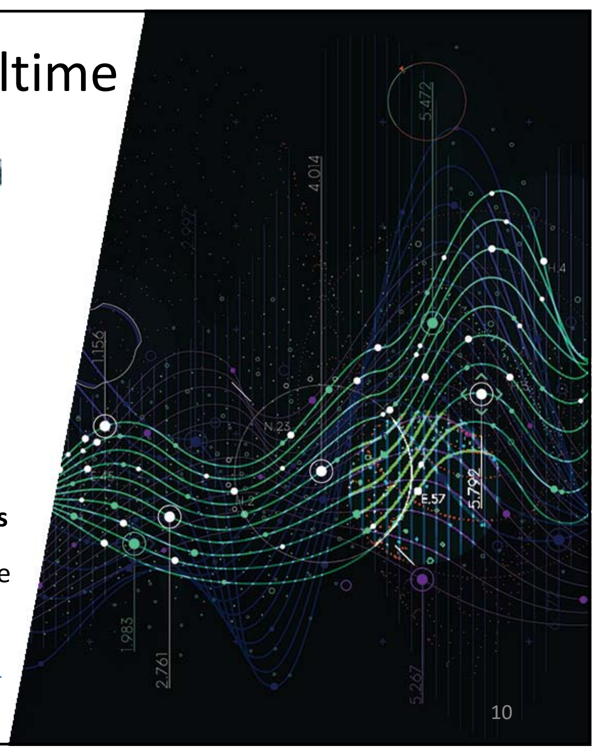
Applying Smart H2O in Realtime

- Data challenges facing water utilities

- The value of now
  - There is certain information whose **value decays exponentially over time**. Perform realtime analytics on data to provide realtime intelligence



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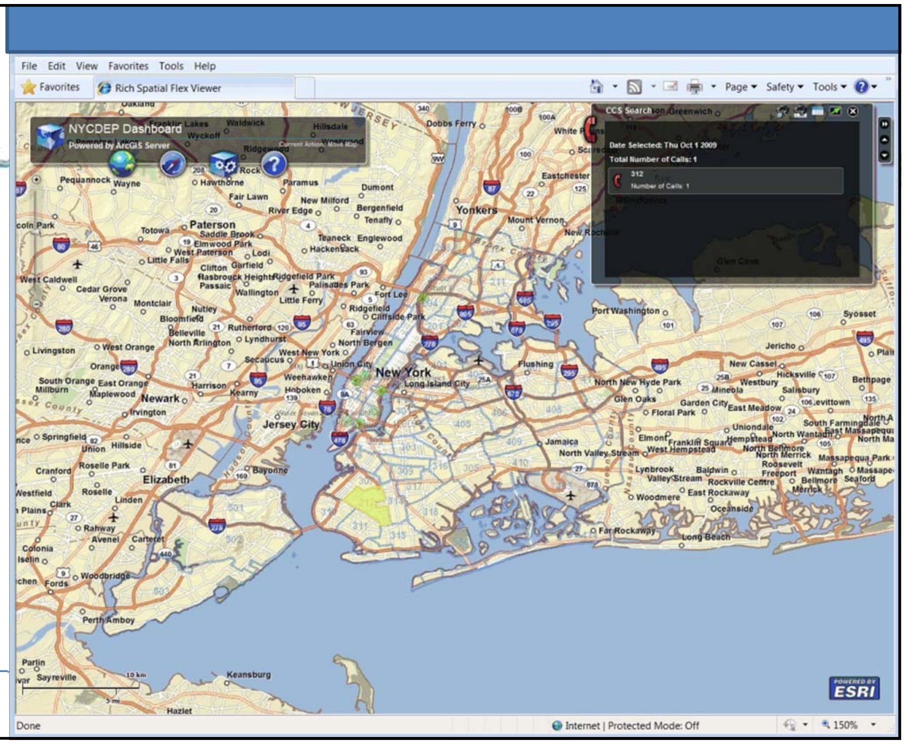
Real-time Dashboard



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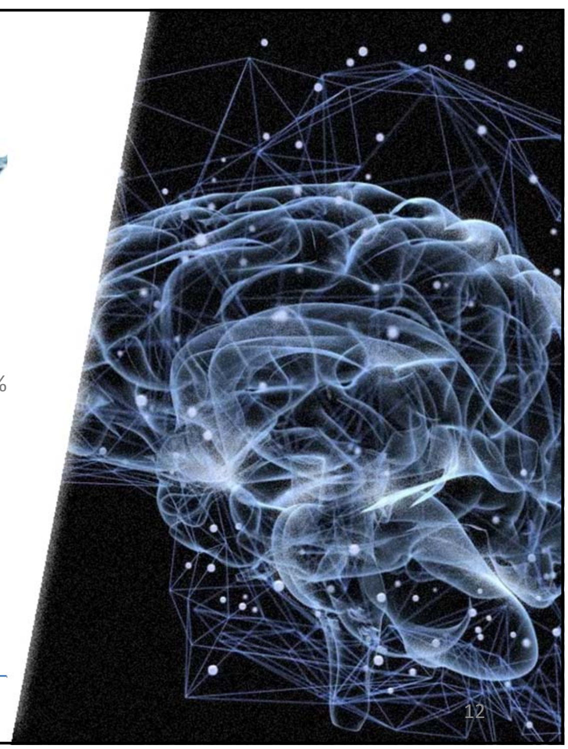
Digital Expectations

- Benefits of implementing smart water solutions

- Digital twin
  - Definition: A digital **replica** of physical **assets**, **processes** and **systems** that can be used for **synthetic data** generation, **prediction**, **optimization** through **scenario analysis**



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Wastewater treatment plant operational resiliency

- 2017 plant failure, led to multi-week, multi-million recovery effort
  - Power failure cascaded into multiple issues
  - Operators did not respond correctly to the initial failures
- Use a digital twin to develop operational scenarios
- Develop operator training “flight simulator”
  - Link digital twin to DCS to provide realistic situational training

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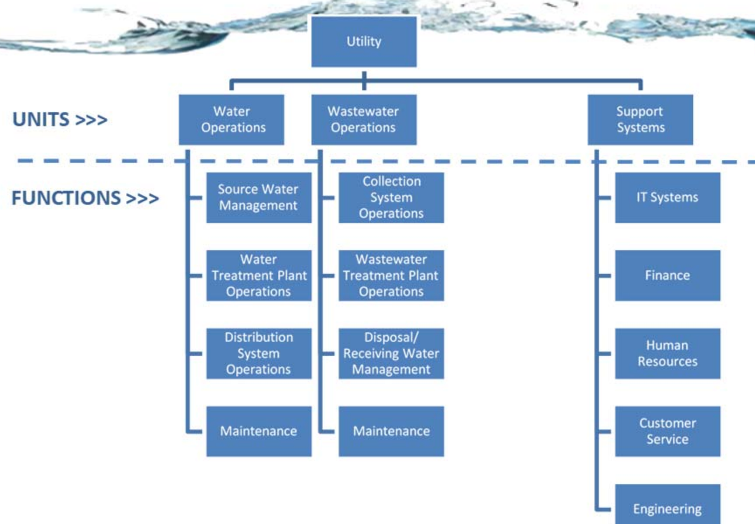
The Digital Water Utility Maturity Framework

- Framework was an outcome of WRF project PFA 04714 – “Intelligent Water Networks Summit and Workshops”
- Tailored to water and wastewater utilities
- Operational Units and Functions
- Used for benchmarking



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The Digital Water Utility Maturity Levels

- **Level 0: Baseline.** The level before any significant steps are taken toward implementing digitization.
- **Level 1: Initiating.** Exploring the options, developing a strategy, and conducting isolated pilots to test technology and processes.
- **Level 2: Enabling.** Having a clear utility-wide strategy and investing in pilots based on the strategy.
- **Level 3. Integrating.** Merging technologies and processes across the utility and demonstrating cross-functional measurable benefits.
- **Level 4: Optimizing.** Fusing information across the utility and potentially beyond the utility (e.g., customers, regulators) to increase measurable benefits.
- **Level 5: Pioneering.** Innovating as an industry leader.

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Categories for Assessment

- **Strategy & Vision:** The approach and foresight for development of a digital water utility
- **Data Management:** How data are collected, quality and security is maintained, its transmission to proper points of analysis
- **Analytics & Information Use:** Methods used for analysis of the data to produce useful, actionable information and the ways that information is used within the organization
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Maturity Assessent Results

CATEGORY RANKING

	Strategy & Vision	Data Management	Analytics & Information Use	Integration & Interoperability	Workforce & Asset Management	Resiliency	Average Maturity by Function Across All Categories
Drinking Water/Reuse							
Source Water Management	4	2	2	2	2	1	2.2
Water Treatment Plant Operations	4	3	3	2	2	3	2.8
Distribution System Operations	4	2	3	2	2	2	2.5
Maintenance	4	1	2	2	1	2	2.0
Average Maturity Across All Functions	*4.0*	*2.0*	*2.5*	*2.0*	*1.8*	*2.0*	2.4 Overall Maturity of Operation
Wastewater/Stormwater							
Collection System Operations	0	0	0	0	0	0	0.0
Wastewater Treatment Plant Operations	0	0	0	0	0	0	0.0
Disposal/Receiving Water Management	0	0	0	0	0	0	0.0
Maintenance	0	0	0	0	0	0	0.0
Average Maturity Across All Functions	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	**0.0** Overall Maturity of Operation
Support Systems							
IT Systems	0	0	0	0	0	0	0.0
Finance	0	0	0	0	0	0	0.0
HR	0	0	0	0	0	0	0.0
Customer Service	0	0	0	0	0	0	0.0
Engineering	0	0	0	0	0	0	0.0
Average Maturity Across All Functions	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	**0.0** Overall Maturity of Operation

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Conclusions

- Digital Transformation is journey and will not happen overnight
- Developing a Digital Utility Strategy is critical first step
- Document the “As Is” and map out the “Future” System Architecture before investing in single point solutions
- Interoperability is essential for a robust and well integrated digital utility
- Data is valuable – Don’t overlook data ownership during the transformation to a digital utility

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The Journey of Transforming Information Technology to Digital Solutions

Ting Lu, Ph.D., P.E.
Business Practice Leader - Digital Solutions
Clean Water Services

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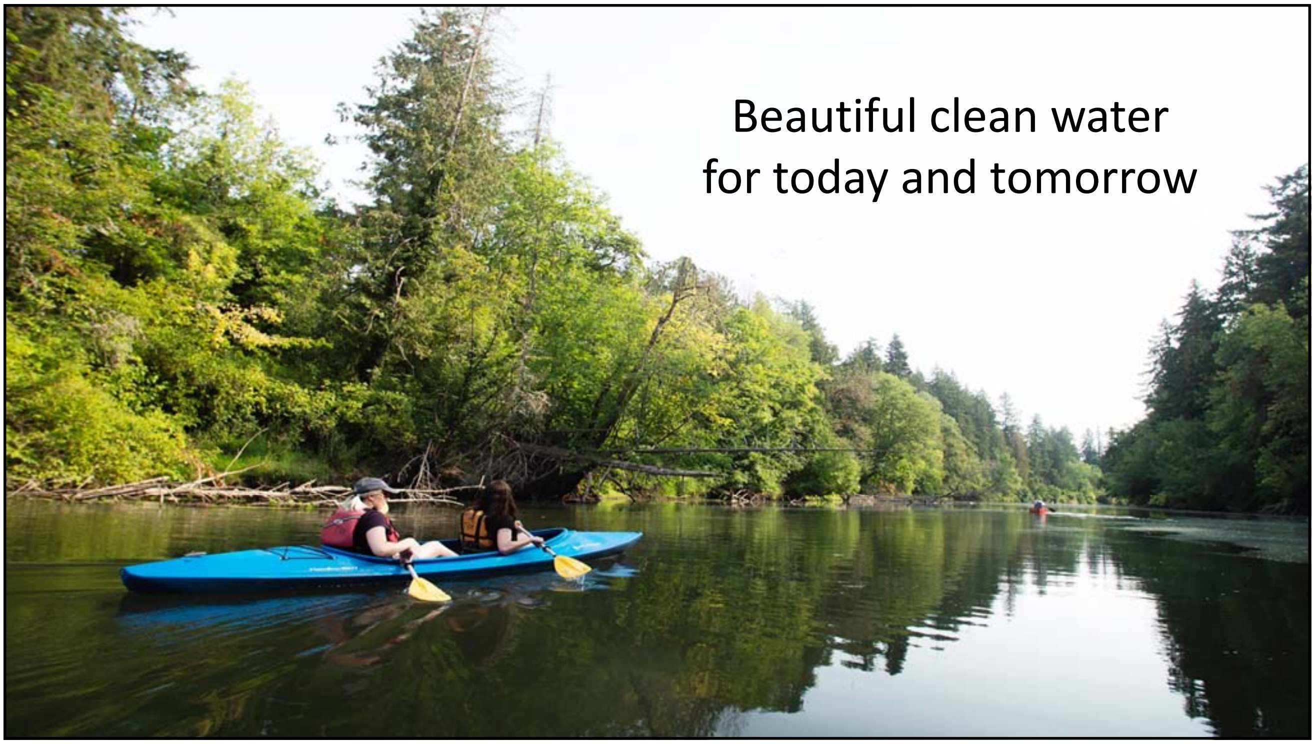

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The Services We Provide

- Water Resource Recovery
- Surface Water Management
- River Flow Management
- Watershed Restoration

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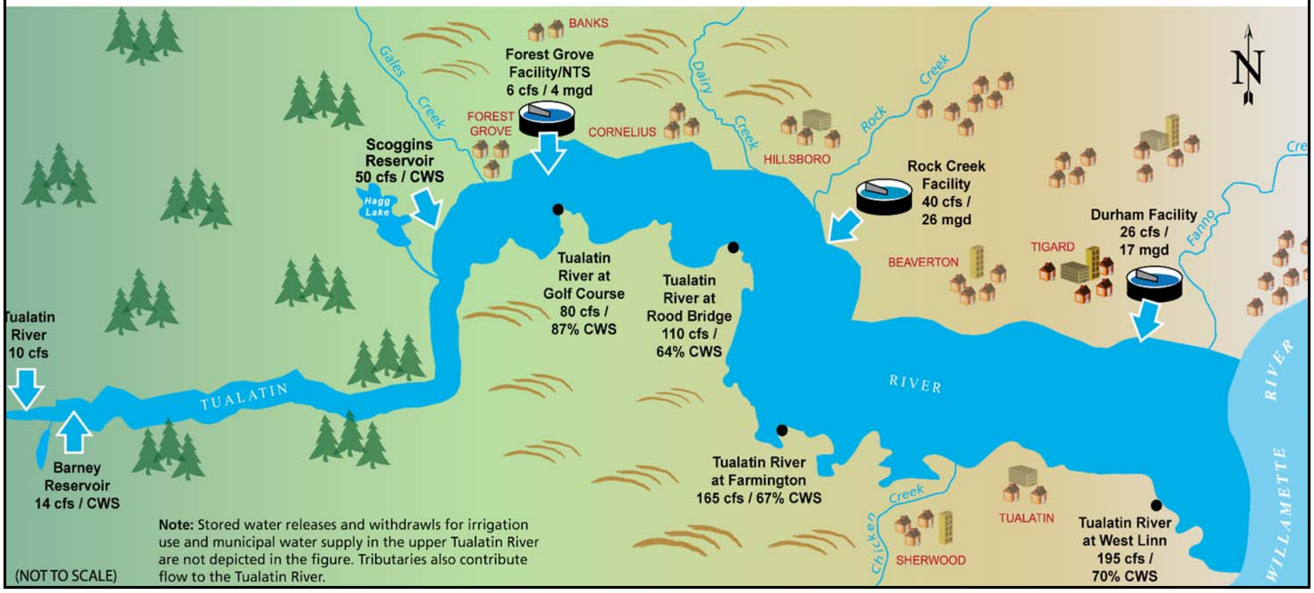
Clean Water Services flow contribution to the Tualatin River during critical Summer flow conditions



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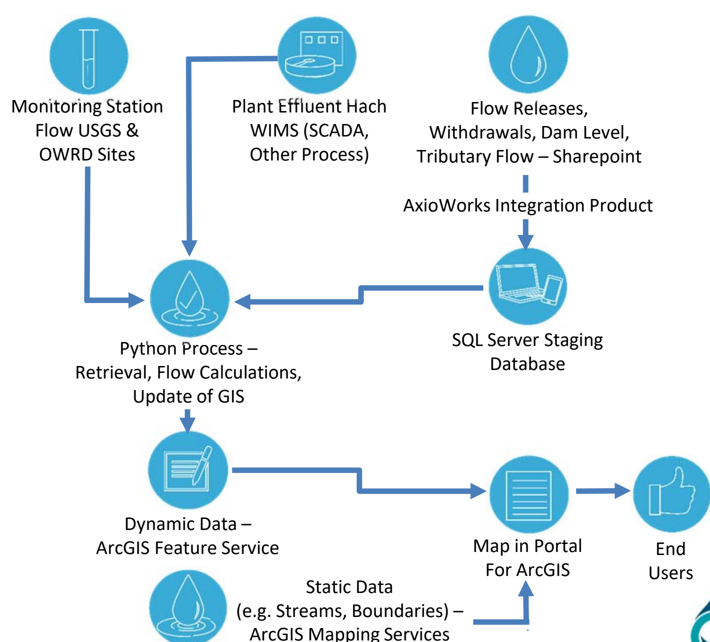
Flow Portal High Level Architecture



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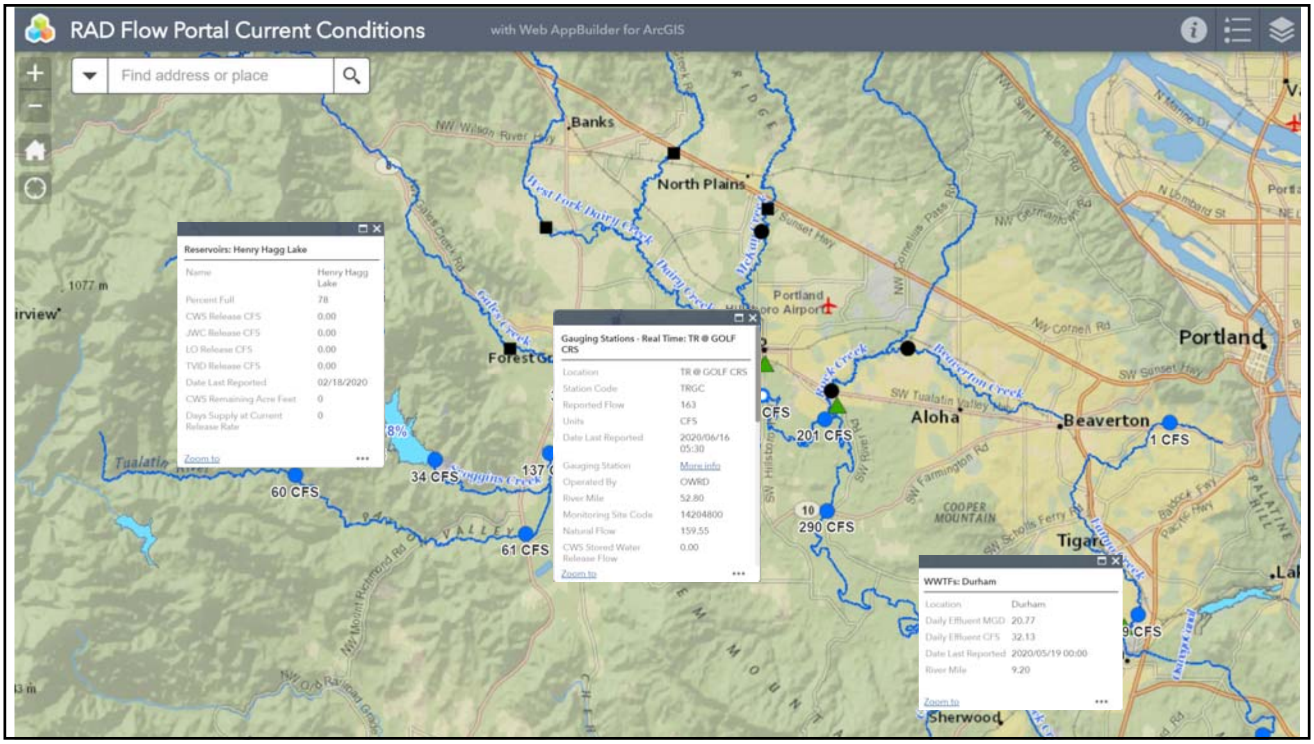

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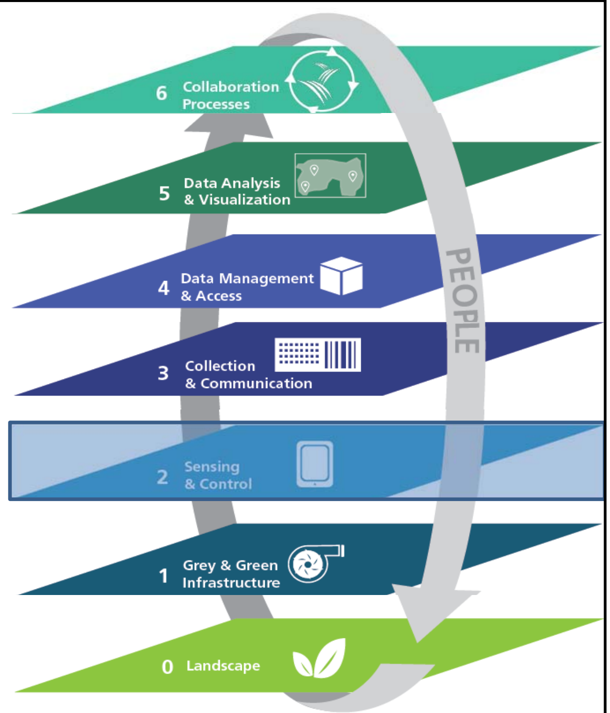
Results

- Automated data gathering and production
- Seamless sharing
- Automated & ad hoc analysis
- Holistic and informed decision making



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EnviroDIY Water Quality Sensors

Open-source data-loggers & radios

EnviroDIY

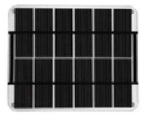
EnviroDIY Mayfly Microprocessor & Datalogger

$60

+

$10

$5



$25

Solar Panel $10-35

Accessories (vary depending on need)

$30-90

+

Cell Phone or Radio Modules

$30-60

Total = $140-$220

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Based on Arduino platform, collaboration with LimnoTech

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Leverage bare-wire Commercial Sensors

Decagon, Sensorex, Vaisala, Keller America, Apogee, Campbell

Soil moisture, conductivity, redox, CO_2, water depth, oxygen, turbidity, CTD

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Data Visualization

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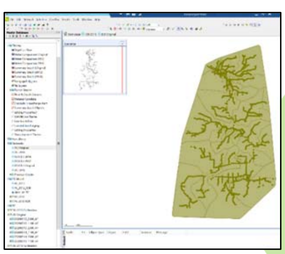
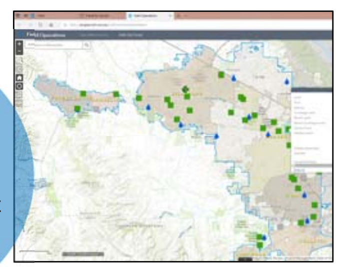
Digital Transformation





Engineering Technology

- Automate Data Retrieval
- Model Integration
- Dashboard prediction

Operation Technology

- Network Security
- Dashboard Development
- System Integration

- Real Time Decision Support

Information Technology

- Security
- Application, Integrations
- Infrastructure
- Capabilities

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Do more with the data you have: neural networks for disinfection control

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Kate Newhart, EIT, CWP
Metro Wastewater Reclamation District
knewhart@mwrd.dst.co.us

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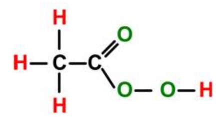
Metro Wastewater Reclamation District

- Largest wastewater treatment facility in the Rocky Mountain West
- Treats and reclaims about 130 million gallons each day (220 MGD capacity)
- Piloting novel disinfection method:
  - Peracetic acid (PAA)
  - Fewer DBPs than chlorine-based disinfection
  - Full-scale disinfection kinetics are not well understood



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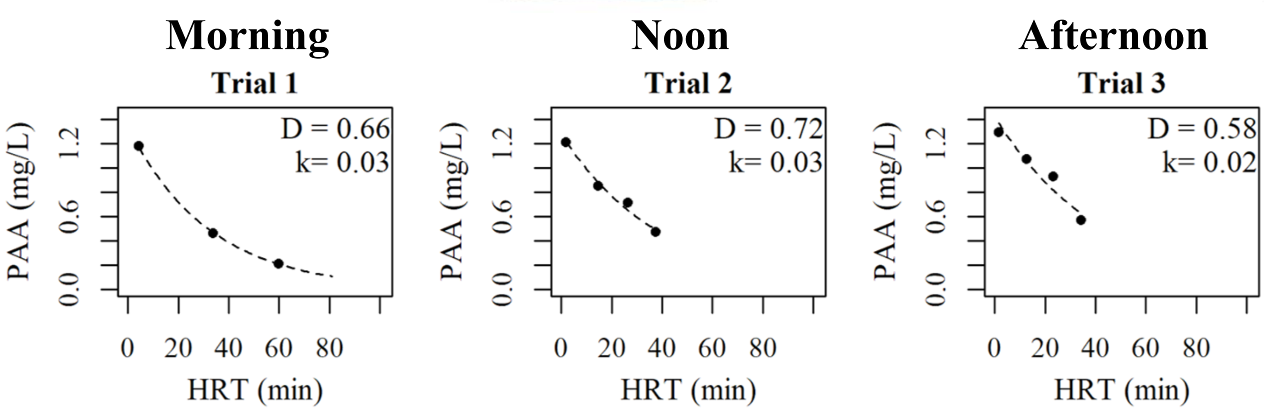
Disinfection kinetics vary with water quality



$$C(t) = (Dose - D)e^{-k \cdot t}$$

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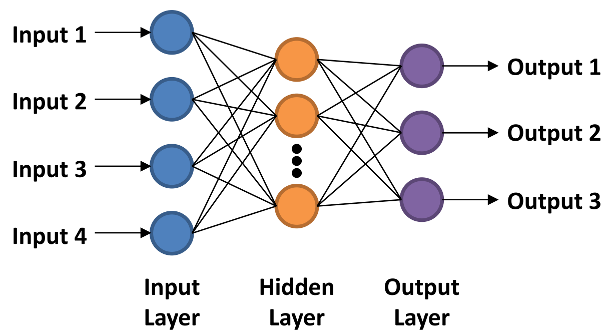
Opportunity

- **Predict PAA disinfection** performance (CT and *E. coli*) from **sensor and lab data**
- Artificial neural networks (**ANN**) and recurrent neural networks (**RNN**)

Example of a single-layer ANN



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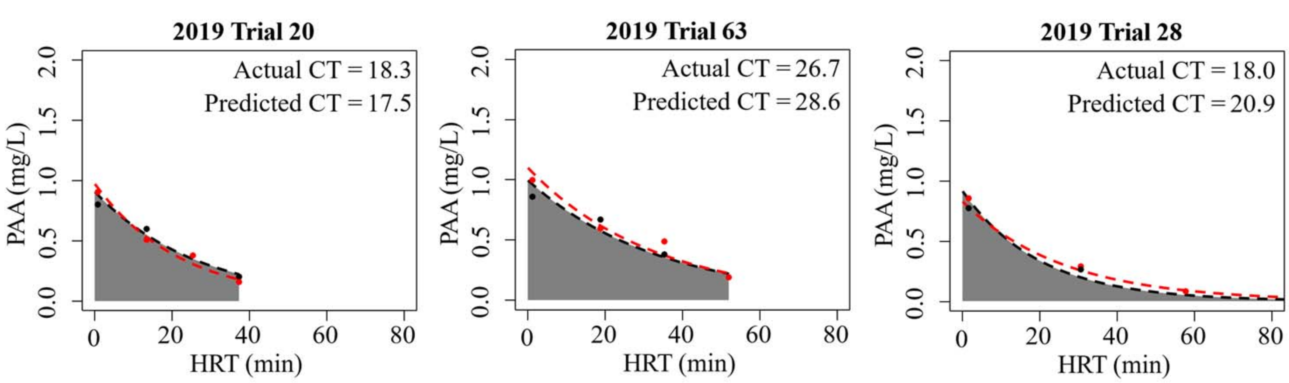
ANN can predict real-time CT



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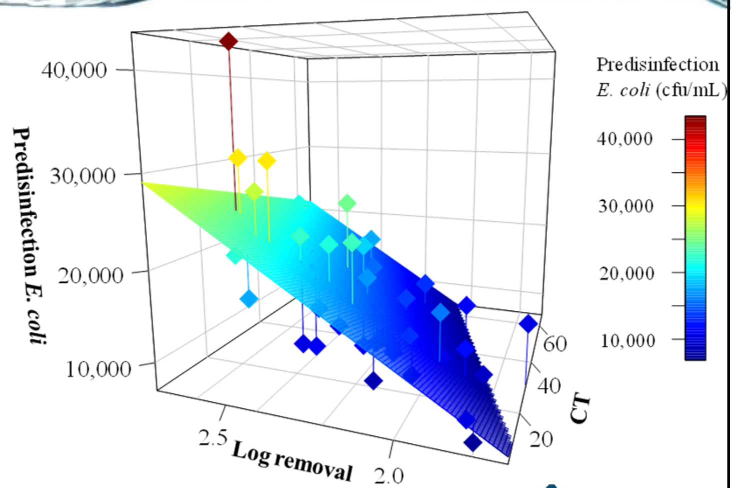
Lessons Learned

- ANN can improve real-time CT accuracy by 30% compared to an analyzer-based method
- RNN can predict *E. coli* within 0.25 log (95% CI)
  - Predictions are more computationally intensive and variable than ANN



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Kate Newhart, EIT, CWP
Metro Wastewater Reclamation District
knewhart@mwrd.dst.co.us

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Implementation

- Data
  - *Online*: Flow, temperature, SRT, nutrients, visual spectrum
  - *Lab*: 24-hour flow composite nutrients and TSS
  - *PAA & E. coli*: 236 sampling campaigns in 2018 and 2019 at multiple locations in the disinfection basin
- Data import → Calculations → Data export
  - OSIsoft PI → R → OSIsoft PI

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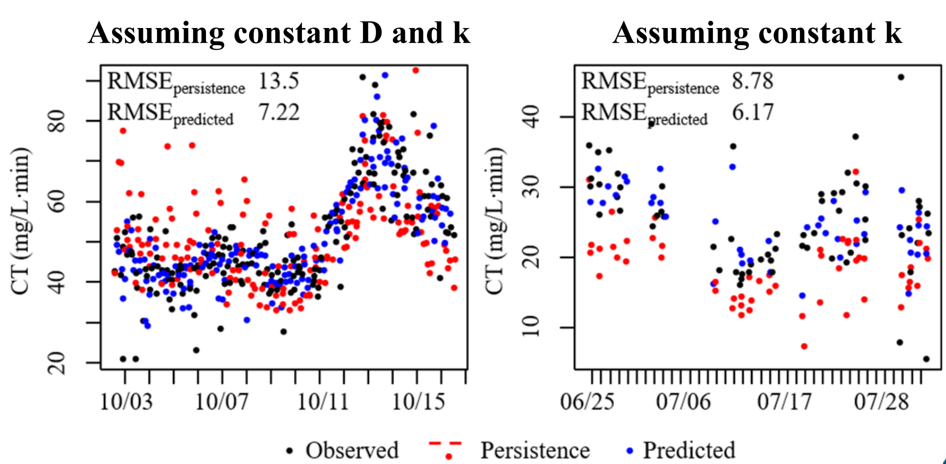
ANN can predict real-time CT



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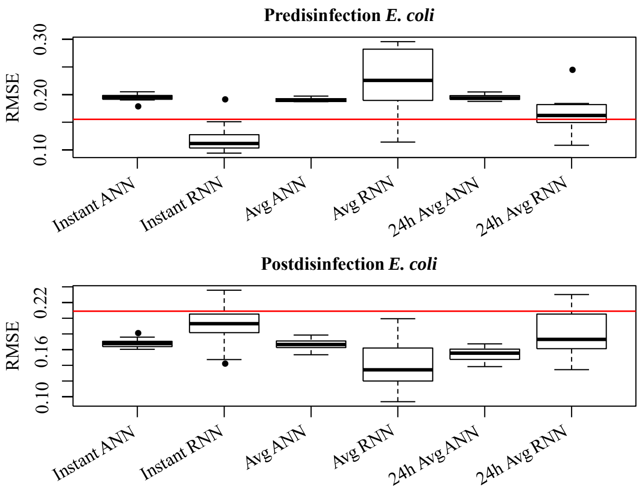
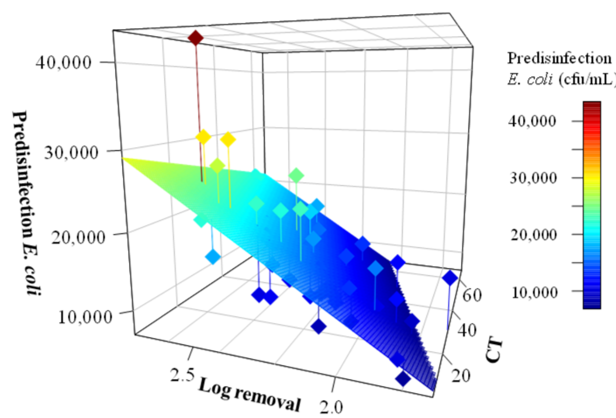
E. coli is dependent on more factors





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Augmentation of Traditional Supplemental Carbon Control with Data-Driven Tools

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Alexandria Gagnon
Treatment Process Engineer
Hampton Roads Sanitation District

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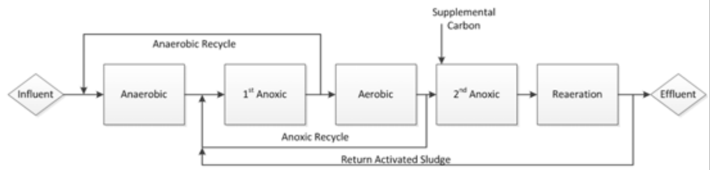
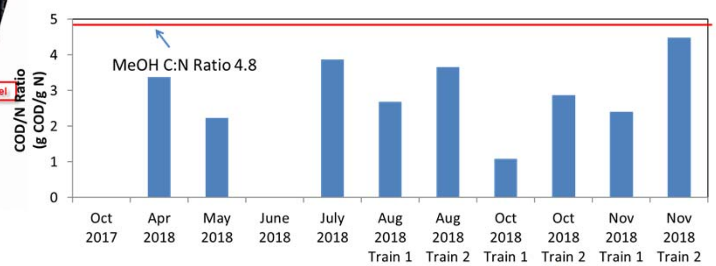
Virginia Initiative Plant Upgrades and Startup (40 MGD) and Traditional Control System Shortfalls





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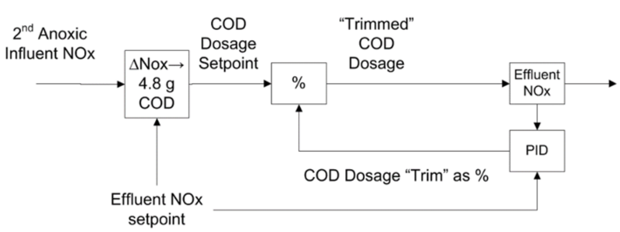
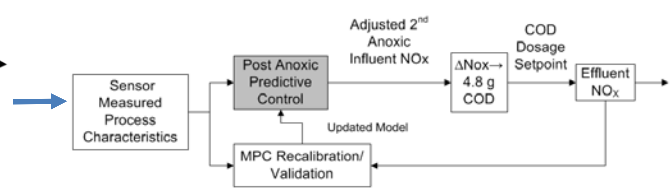
Reducing Controller Reliance on Feedback to Maintain Target Setpoint

Traditional Supplemental Carbon Controller utilizes a stoichiometric feedforward PID feedback control system.



By developing a feedforward data driven model and combining with traditional stoichiometric feedforward controller, the model error is reduced. This reduces the reliance on feedback to maintain effluent setpoint.



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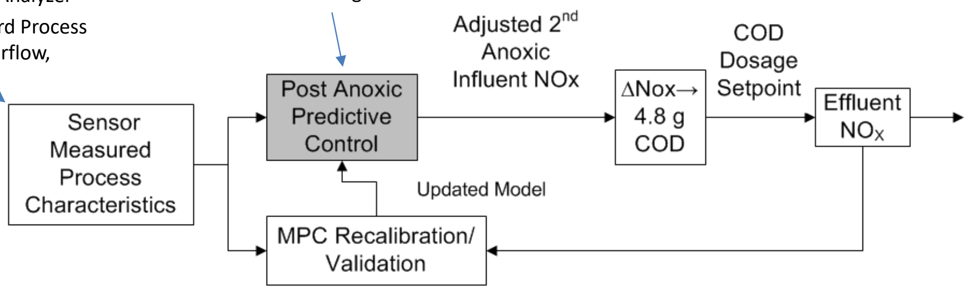
Development of Data-Driven Model

Controller will predict nitrate removal in 2nd anoxic required to hit effluent target.

Raw Influent COD Sensor

P-Uptake Rate Analyzer

Various Standard Process Sensors (DO, Airflow, NH4, etc)



Model will utilize data-driven methods to identify corollary relationships between post-anoxic denitrification and sensors.

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Advancing Ammonia-Based Aeration Control (ABAC)

HRSD · UNIVERSITÉ LAVAL · swift · modelEAU

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Applying Model-Predictive Controllers (MPCs) and Machine Learning Techniques

by: Jeff Sparks, Peter Vanrolleghem, & Charles Bott

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Problem Statement

- PID controllers with delays are problematic.
  - Delays lead to instability of controllers and reduced control authority.
    - Difficulty in tuning the controllers.
    - Industrial slug loads and impacts on IPR/DPR facilities.
    - Slow sensors (analyzers) compound the issues.
- FF MPCs exist, but they are not well known and there is little experience at full scale.

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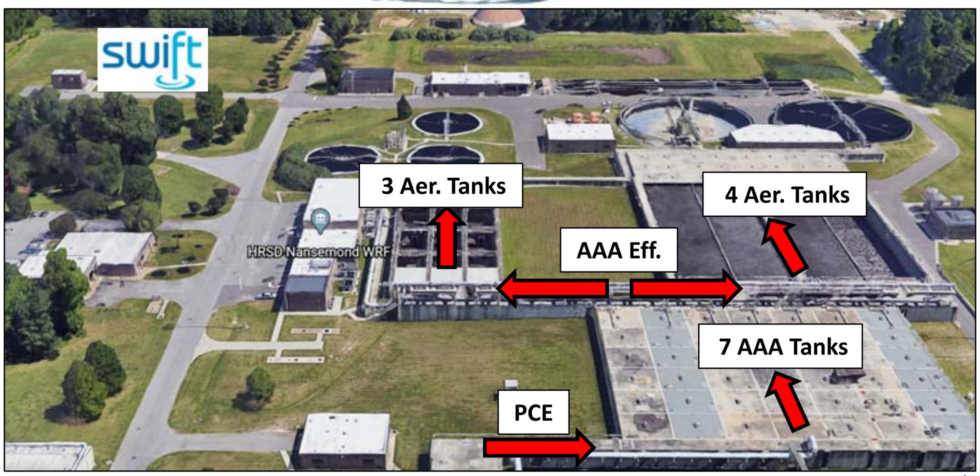
Nansemond Plant



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Nansemond Treatment Plant

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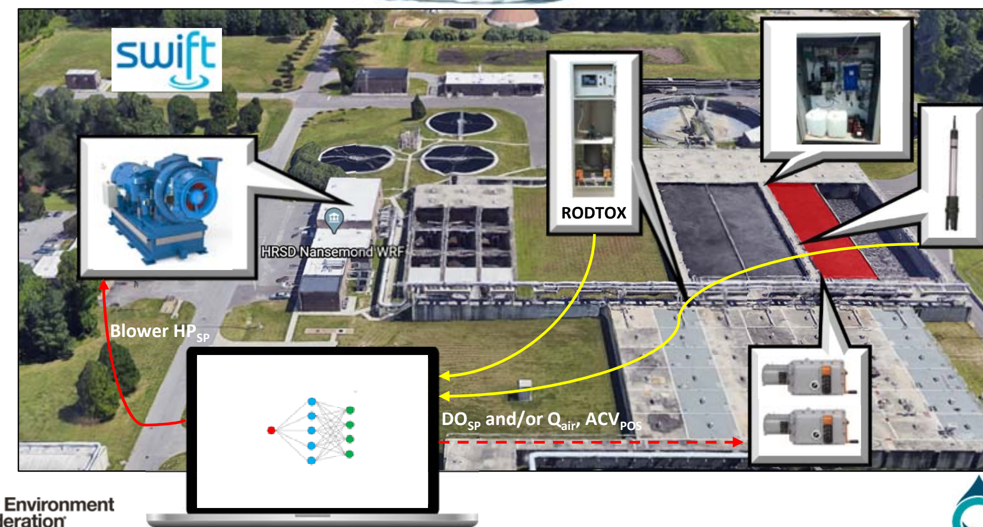
ABAC using MPCs



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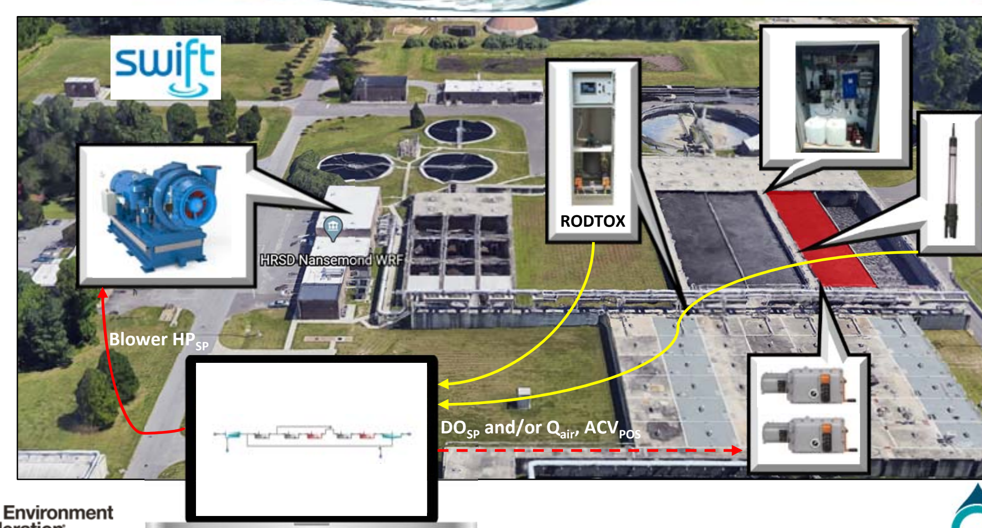
ABAC using MPCs



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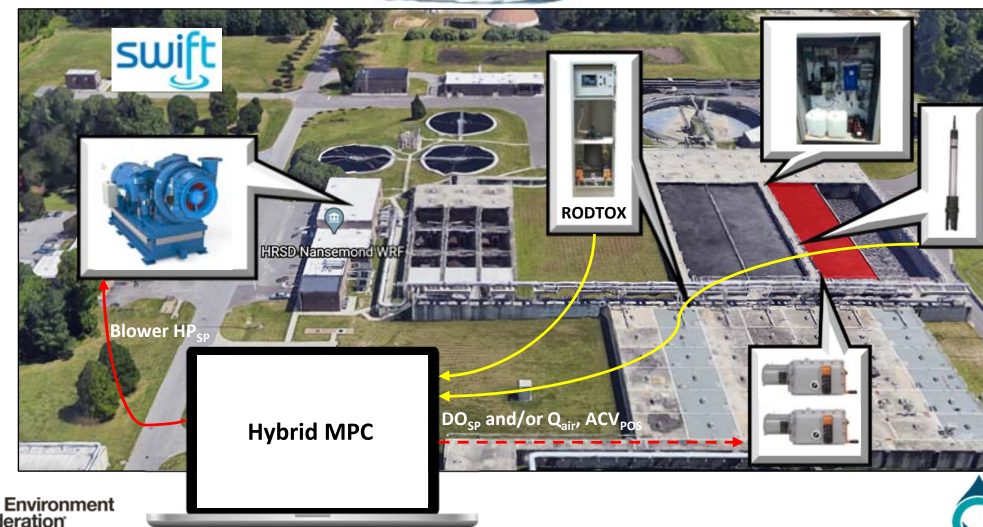
ABAC using MPCs



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Objectives

Best Control

- Quantify using Root Mean Squared Error (RMSE).
- Compare MPCs to feedback-only PID.
- Compare MPCs against each other.
- Find the ideal combination of biological and air flow models.

Lowest Cost

- Consider energy, chemical, and maintenance costs.

Lowest Risk and Best Protection from Slugs

- If slugs naturally enter the plant during data collection, then document performance of controllers.
- For each controller test, simulate a slug with added COD at the head of the plant.

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Neuse River Resource Recovery Facility Wet Weather Flow Prediction and Equalization Basin Guidance Program

Raleigh

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June 18, 2020

Erika Bailey, PE, Raleigh Water
Katya Bilyk, PE, Hazen and Sawyer

Hazen

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Purpose: Predict the Peak Flow and Hydrograph Shape for Each Significant Storm Event and Use that Information to Manage Equalization Storage

- Facility background
  - 75 mgd
  - Average daily flow of 50 mgd
  - Hydraulic capacity of 225 mgd
  - Highest hourly flow recorded 184 mgd
  - Stringent nutrient limits
    - TN 3 mg/L
    - TP 2 mg/L
  - 32 MG EQ basin
- Tie-in with other wet weather management programs like secondary clarifier guidance program
- Deliverable = dashboard

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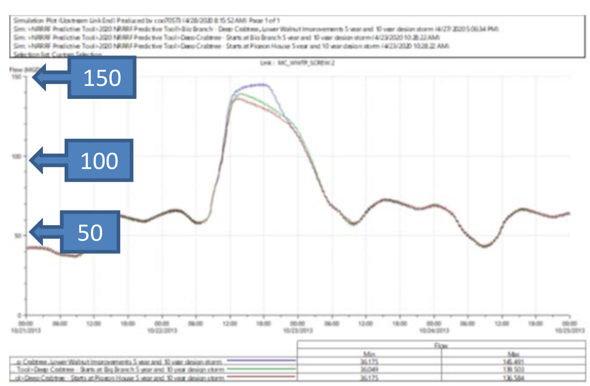
Why do Current Strategies Fall Short?

- Currently staff use pump station data to estimate peak flow and have 30-60 minutes of advance warning
- Flow monitors in collection system aren't predictive
- Doesn't tell you if flows will increase or decrease
- City has a calibrated collection systems model but no way to currently utilize that tool in a real-time fashion



Collection system model output, manually generated.

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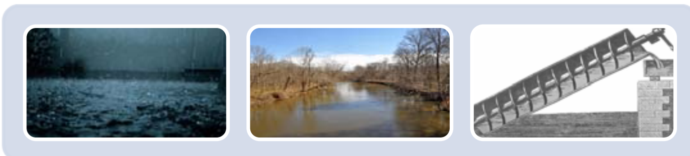
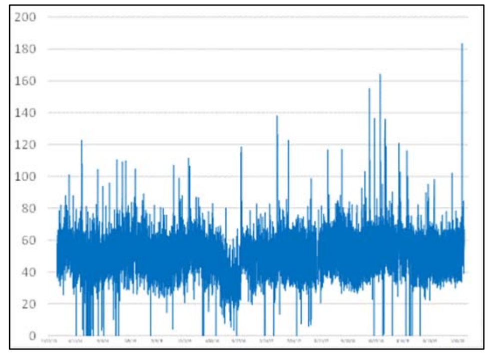
Machine Learning Approach was Developed to Predict Flow up to 72-hours in Advance



Rainfall | Streamflow | Influent Flow to NRRRF



Used python machine learning algorithms to train a model to 6+ years of influent flow data as a function of explanatory variables.

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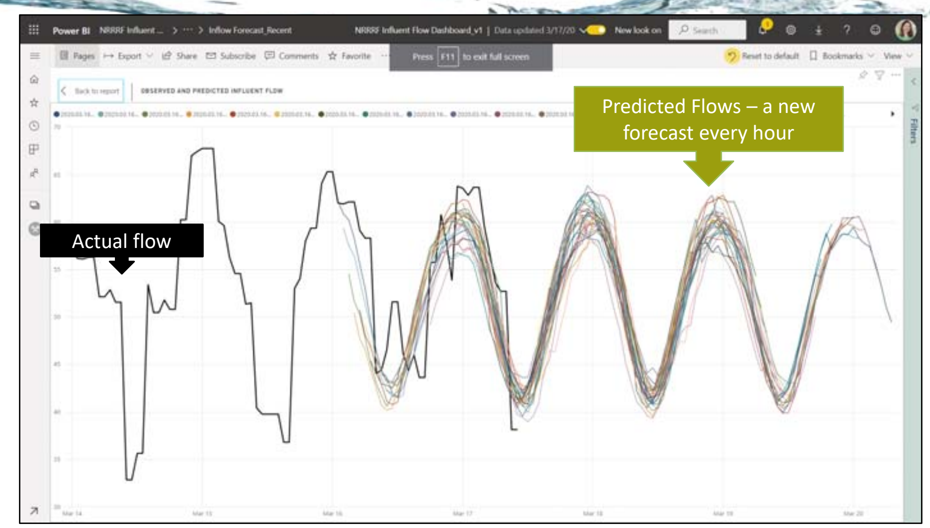
Status: Model was Deployed in Azure, and Dashboard has been in Test Mode for 6 Months.



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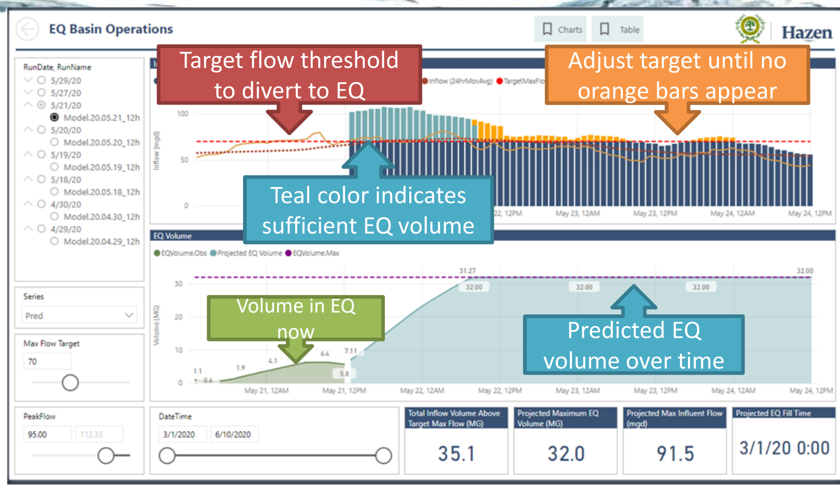
Model will be Finalized this Summer



During wet weather, plant staff can use to tool to determine the flow threshold above which to use equalization to minimize flow to the facility.

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Implementing Cloud-Based Process Management at a Small Water Utility

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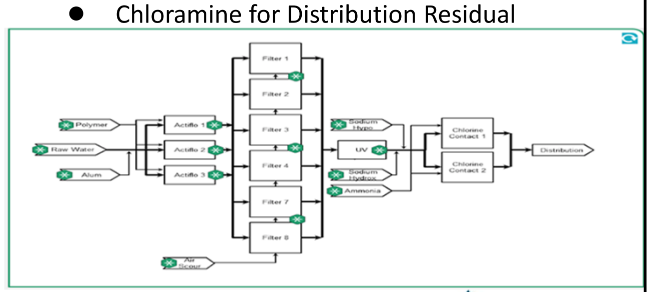
Roxborough Water and Sanitation District
System Overview

- Denver, CO suburb serving 11,000
- First CO facility to receive credits for UV as primary disinfectant with DBP reduction from 80 ppb to 17 ppb
- ACTIFLO
- Filters
- UV Disinfection
- Chloramine for Distribution Residual



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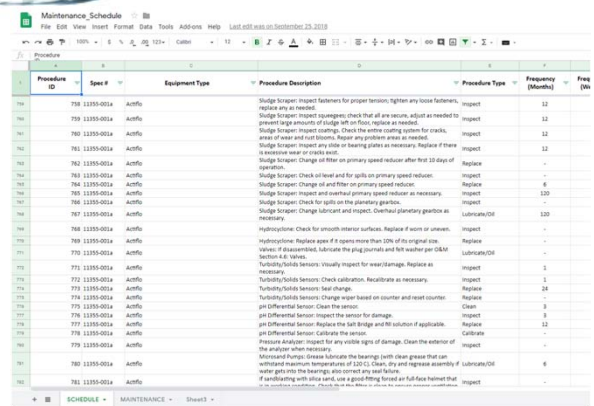
Roxborough Water and Sanitation District
The Problem…

- Explored Several Asset Management Systems
- GOALS
  - Better View of Compliance Parameters
  - Better View of Chemical Consumption
  - Better Tools for Performance Optimization
  - Better View of Equipment Status and Tracking/Scheduling Maintenance
  - Support for young, inexperienced operations staff



The Old: Cumbersome Spreadsheet Manipulation for Managing Maintenance Tanks

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Roxborough Water and Sanitation District
Decisions…

- Most Platforms Focus Only on One Area
- Reasons for selecting AQUAVISTA
  - Touches on all Goals - Total System Management Tool
  - Consolidated Data from Multiple Plant Processes
    - Not Just Veolia Technologies
    - Data from Any Source
  - Access to Veolia Process Experts

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Data Display

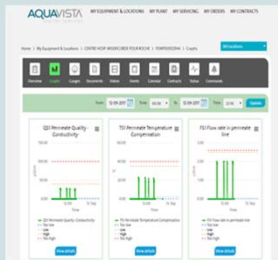
An Advanced Remote Monitoring and Reporting Tool

Instant insights into trends (with selection of data visualization tools)

Management of multiple sites online through an interactive view with status indicators

Key Performance Indicators

Portal



REMOTE MONITORING

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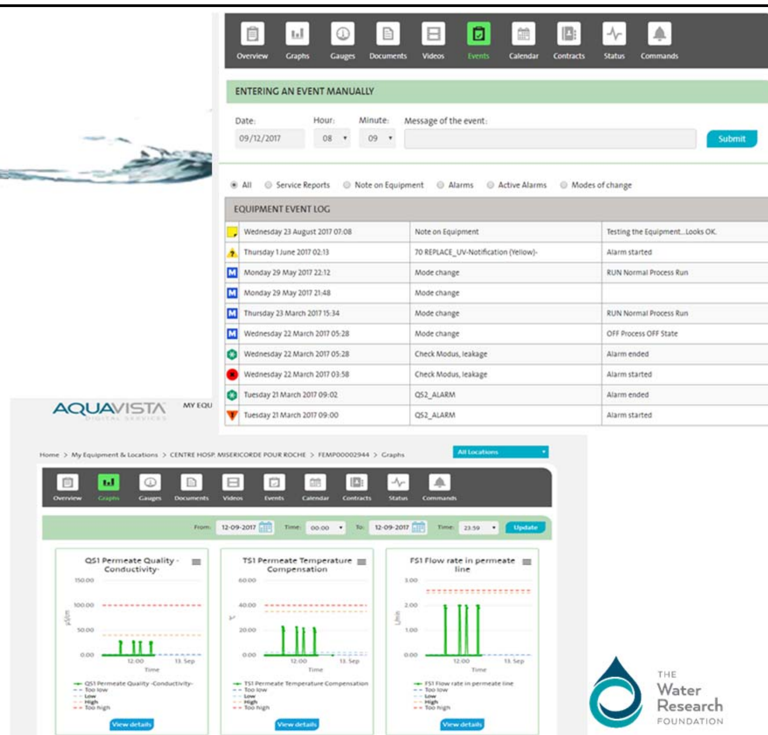
Outcomes

- **Full overview** of equipment from remote locations and **online access to documentation**
- **Convenience** of monitoring **anywhere, anytime, at any device** through a **secure** cloud-based system and a single & intuitive portal
- **Improved asset performance**, higher plant efficiency and stability, improved preventive and predictive maintenance, decrease downtime through **customized KPIs and Maintenance Module**
- **Lower capital and operational costs**, reduced maintenance, chemical use and energy consumption with **Kruger support through ASSIST** offering.



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Barbara J Biggs
General Manager
303.979.7286
www.roxwater.org
barbara@roxwater.org
6222 N Roxborough Park Rd
Littleton CO 80125
Roxborough Water & Sanitation District

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The Role of Digital Twins in our Water Sector

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Gigi Karmous-Edwards

June 18, 2020

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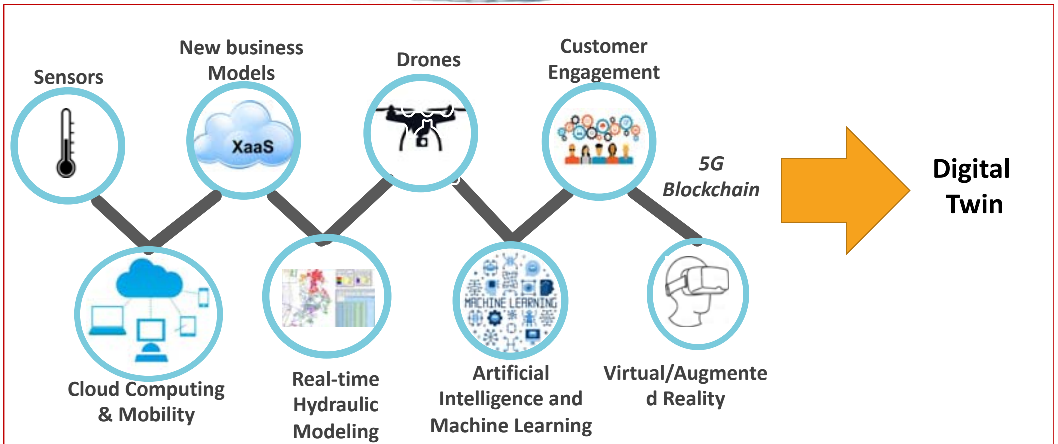
Why Digital Twins Now?
An array of disruptive technologies …Connecting the dots



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Defining Digital Twins

- Digital Twin is a virtual/digital representation of both the elements and the dynamics of a system.
- A digital twin will influence and optimize the design, build and operation of the system throughout its life cycle (concept-design-build-operate-customer experience) and help optimize operation through informed insights.
- The core of a Digital Twin is a model that translates the behavior of the system; real-time data or predicted data is to drive simulations and ultimately the calibration. Once calibrated, it becomes a powerful holistic tool for the physical system.

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Digital Twin Life Cycle

Design Phase

Construction Phase

Operations / O&M

Customer Experience (Avatar)

Digital integration of future planned assets with model allowing for an integrated 3D visualization and decisions for optimized design

Digital integration of assets during construction, recording changes and design conflicts, for synchronized data models

Virtual model of a physical asset or process allowing to run simulations w/real-time data pairing for powerful holistic operational tool

Digital Selves or Doubles allowing full data combination of water utility customers with operational impacts

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BENEFITS OF DIGITAL TWINS IN EACH PHASE

3D visualization

- ✓ Share 3D with All Stakeholders
- ✓ Reduce Conflicts based on planned location
- ✓ Provide visual aid for Executives and Investors

Design Optimization/Cross Sector

- ✓ Multi-objective simulations for optimal design
- ✓ Cross-Sector Design Optimizations
- ✓ Experimentation in digital form prior to construction
- ✓ Agile to changes during design with minimal costs

Collaboration and Transparency

- ✓ All work is conducted transparently across NEOM Sectors and departments
- ✓ Help build strong partnerships for Neom with technology companies, and experts

Construction Optimization

- ✓ Avoid construction conflicts
- ✓ View the dynamic status of the physical system via an integrated and holistic view
- ✓ Reducing the data silos and departmental silos

Holistic Operational Oversite

- ✓ Provide one comprehensive view
- ✓ Warns if anomalies occur early to avoid failure
- ✓ Reduce maintenance costs and unplanned outages by early alerts
- ✓ resource optimization
- ✓ improved asset management
- ✓ deliver cost savings
- ✓ improve productivity and safety
- ✓ Maximizes ROI of investments of assets and tools and extending lifecycle of systems

Predictive Analysis

- ✓ Provide predictive analysis to avoid future failures
- ✓ Proactive operation instead of reactive
- ✓ A near-real-time holistic connection between the physical world and the digital world
- ✓ Ability to run what-if analysis at any time

limitless number of virtual sensors

Customer Experience View and Interactions

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Real-time Hydraulic modeling with Real-time Data Feeds

Physical Water Utility

Data pairing

Digital Twin
-A software model of both the physical connected components and dynamicity of a system via data pairing

- SCADA, CMMS, Lab, data
- GIS data
- Weather Data
- RT/batch sensor data
- Meter data – game changer
- Historical data
- Input parameter assumptions

- Continuous Hydraulic Model Simulation augmented with machine learning for the gaps
- Replace mathematical assumptions with real-time data
- Run what-if scenarios, predictive analysis, and real-time alerts

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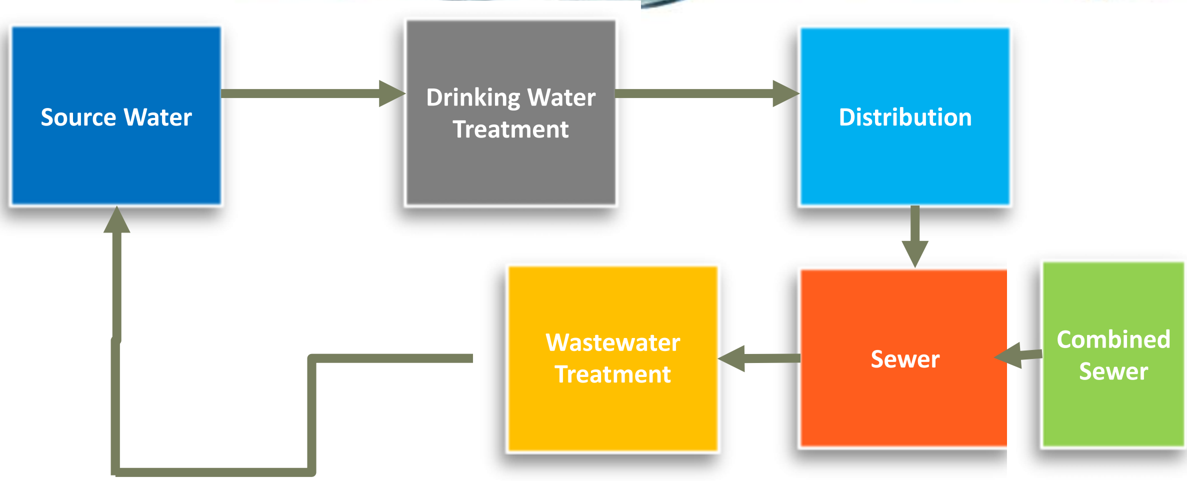
Future Digital Twin Water cycle

Drinking Water + Sewer + Storm + Source Water



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The promise of Digital Twin

- What if water utility staff and executives had access to a complete, up-to-date, holistic view of a water system and actionable, informative dashboards and insights at all times (24/7) at their fingertips?
- What if the operational staff is alerted when an anomaly occurs within the utility and can take action to prevent failures before they occur, drastically reducing costs of asset maintenance?
- What if utilities can tightly monitor and manage water quality or ideal pressure throughout the entire system with fewer sensors than traditionally thought?

We believe that a powerful software tool that provide accurate estimations and awareness of a community's supply would help societies better manage our precious resource and help resolve the global water crisis.

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INTRO TO SWAN H2O DIGITAL TWIN WORKGROUP

The SWAN Digital Twin H2O Work Group Co-Chairs

- **Gigi Karmous-Edwards**, President (Karmous-Edwards Consulting)
- **Colby Manwaring**, CEO (Innovyze)
- **Andreu Fargas-Marques**, Maintenance Department Chief (Consorci d'Aigües de Tarragona)

The goal of the Digital Twin Work Group is to develop a common strategy for adopting Digital Twin technology by bringing together global water leaders from utilities, solution providers, engineering firms, government, and academia.

Three Subgroups

(1) **Holistic Architecture;**
- **Michael Karl**, National Smart Utility Technology Manager (Brown and Caldwell)
- **Chengzi Chew**, Business Development Manager – Emerging Technology (DHI)

(2) **Outcomes and Applications**;
- **Colby Manwaring**, CEO (Innovyze)
- **Gigi Karmous-Edwards**, President (Karmous-Edwards Consulting)

(3) **Digital Twin Lifecycle** *(New)* **;**
- **Wagner Carvalho**, Senior Project Manager (AEGEA)
- **Jim Cooper**, Global Solution Leader - Intelligent Water (Arcadis)

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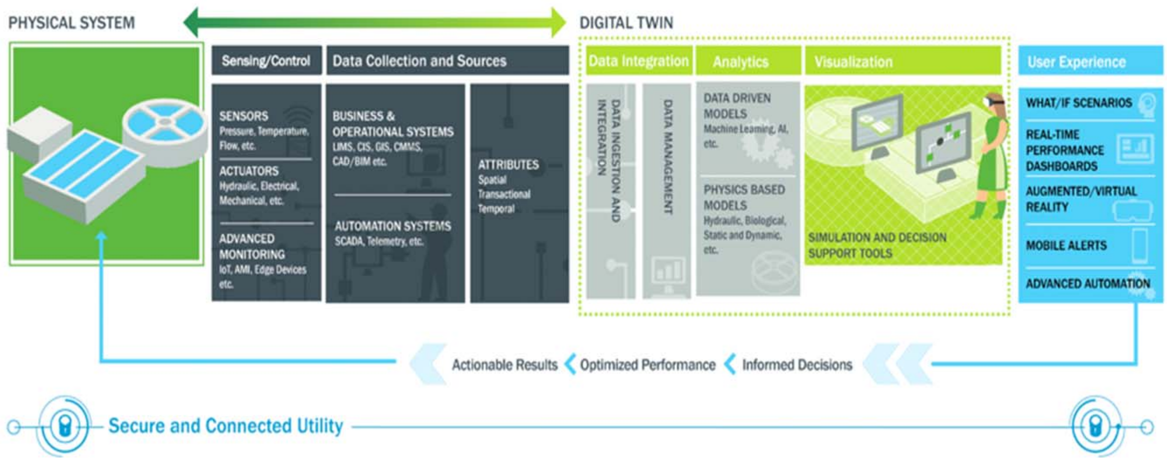
SWAN Digital Twin Architecture



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Gigi Karmous-Edwards
gigi@gigikarmous.com

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Intelligent Water System as a Service

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Meena Sankaran
CEO, KETOS

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What is the Problem Utilities Are Trying to Solve?

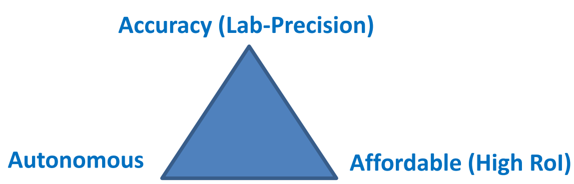
25%
OF TOTAL OPEX FOR INDUSTRIAL, AG, & CITIES IS USED FOR WATER TESTING, TREATMENT

$1T
REQUIRED TO UPGRADE AGING US WATER SYSTEMS

14%
WATER SUPPLY IN US IS LOST TO UNDETECTED LEAKS

7 DAYS
AVERAGE WAIT TIME FOR WATER TESTING IN LABS

Water-intensive industries are 5+ years behind the energy sector in embracing data analytics, automation, and AI.



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What is the Problem Utilities Are Trying to Solve?

Offsite Lab Tests

7 day wait time
Expensive

Handheld Instruments

Labor intensive
One-time readings
No data storage

Online Instrumentation

Single vs. multi-parameter
Manual calibration

- ❑ Conventional water resource monitoring is **antiquated**, and **tools** currently used to monitor water are very **expensive, segmented** and **labor intensive**.
- ❑ **Cohesive data collection**, data mining and actionable insights are missing vs. **sporadic data collection**
- ❑ Lack of foresighted and holistic approaches to problem-solving results in solutions being **vendor-centric** vs. **architecture-centric** for the end user.
- ❑ Time for technology ramp-up, labor, guess estimations on materials, costs and operational inefficiencies cumulatively slowing down overall **digital transformation.**

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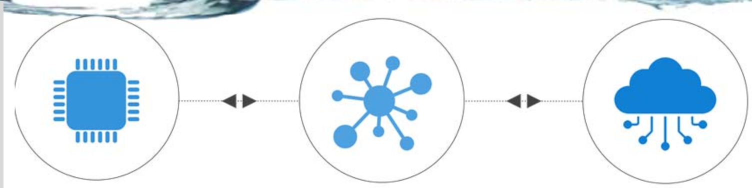
What Solutions Have Been Implemented?

- ✓ Helping customers evolve as innovation evolves – Not fixed devices with limited shelf-life
- ✓ Enabling customers to excel with their own data
- ✓ Asking the question of What am I solving for in 1yr ? 2yrs? 5yrs and 10 yrs?
- ✓ How is the data improving my efficiency? My operational performance? My Business ?



UNMANNED SENSOR HARDWARE

Intelligent Hardware

COMMUNICATIONS INFRASTRUCTURE

Bidirectional, Smart Networked Communication (IoT)

ENTERPRISE GRADE PLATFORM

Data Science (ML/AI) & Business Insights for Water with Actionable Operational Analytics

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What Solutions Have Been Implemented?

Vertically

Integrated

Solutions

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What lessons have been learned?

- Vertically Integrated Solutions
- Centralized data insights and actions
- Software enabled Hardware that delivers actionable intelligence
- Offering unlimited testing regardless of frequency or parameters at a flat price
- Accessibility and time to receive data
- Affordability through OpEx without CapEx investments and sustainable service models

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Meena Sankaran
CEO, KETOS
meena@ketos.co

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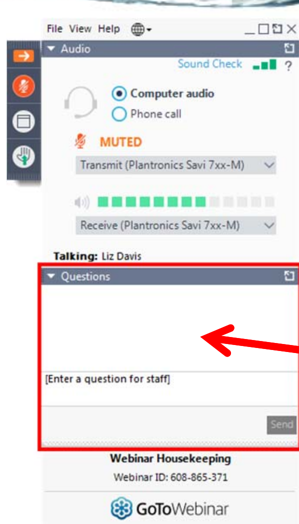
Questions and Answers



Submit your questions using the Questions pane.

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