

Leveraging AI/ML : Essential Element in Managing the Water Cycle

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Agenda

- › **Global drivers** and the case for new approaches and tools
- › **Harnessing AI/ML** to Navigate the Complexity of the Water Cycle
- › Digital Twins: From Big to **Actionable** Data
- › **Concluding** Thoughts



Global drivers and the case for new approaches and tools



Challenging today.
Reinventing tomorrow.

What is driving wastewater infrastructure projects?

Addressing today's issues...

- › Aging infrastructure
- › Service area changes
- › Climate stress
- › Increased regulations
- › Space limitations
- › Improved O&M efficiencies
- › Water equity and community impacts

Rikers Island WRRF, NYC



Ejby Mølle WRRF, Denmark



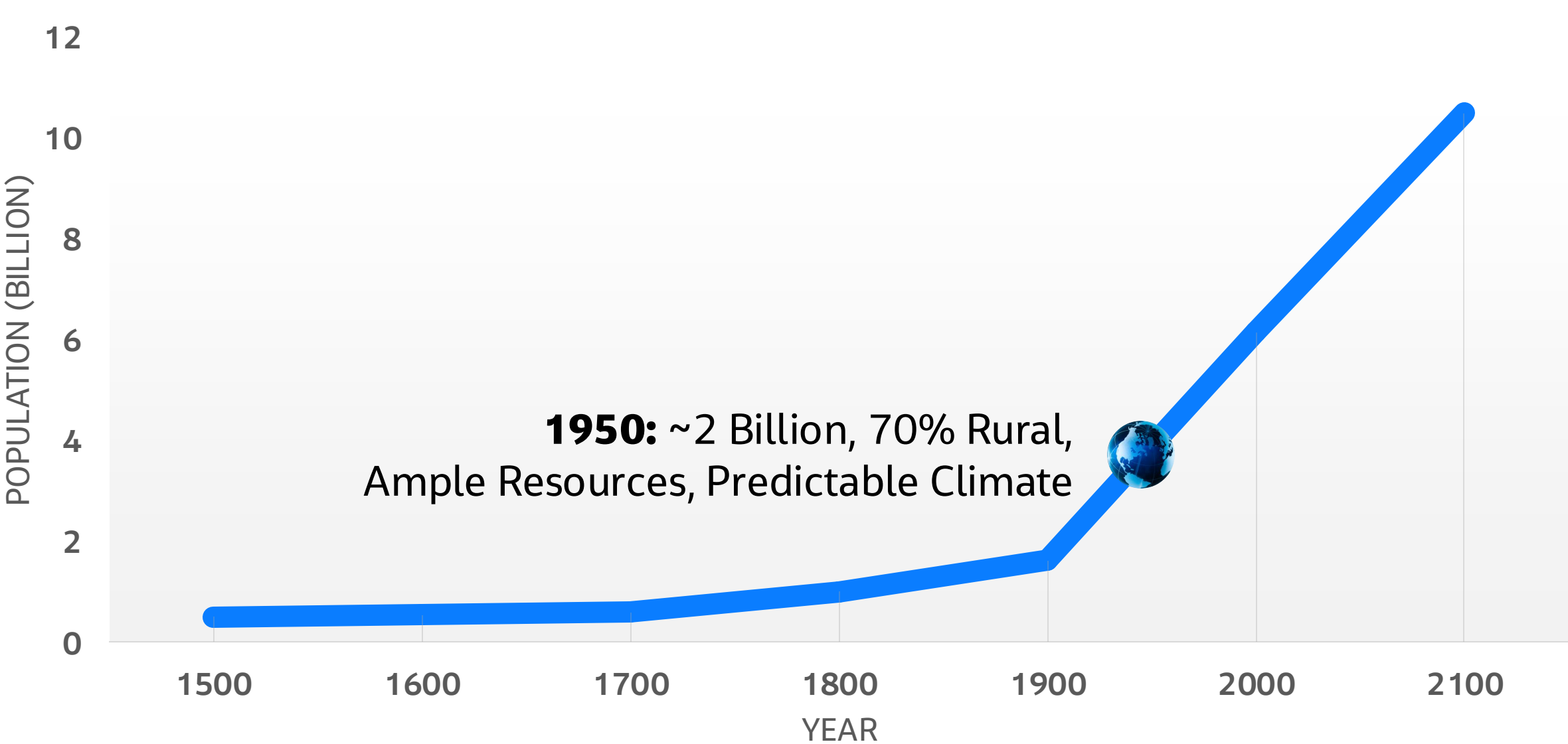
Blue River WWTP, Kansas City



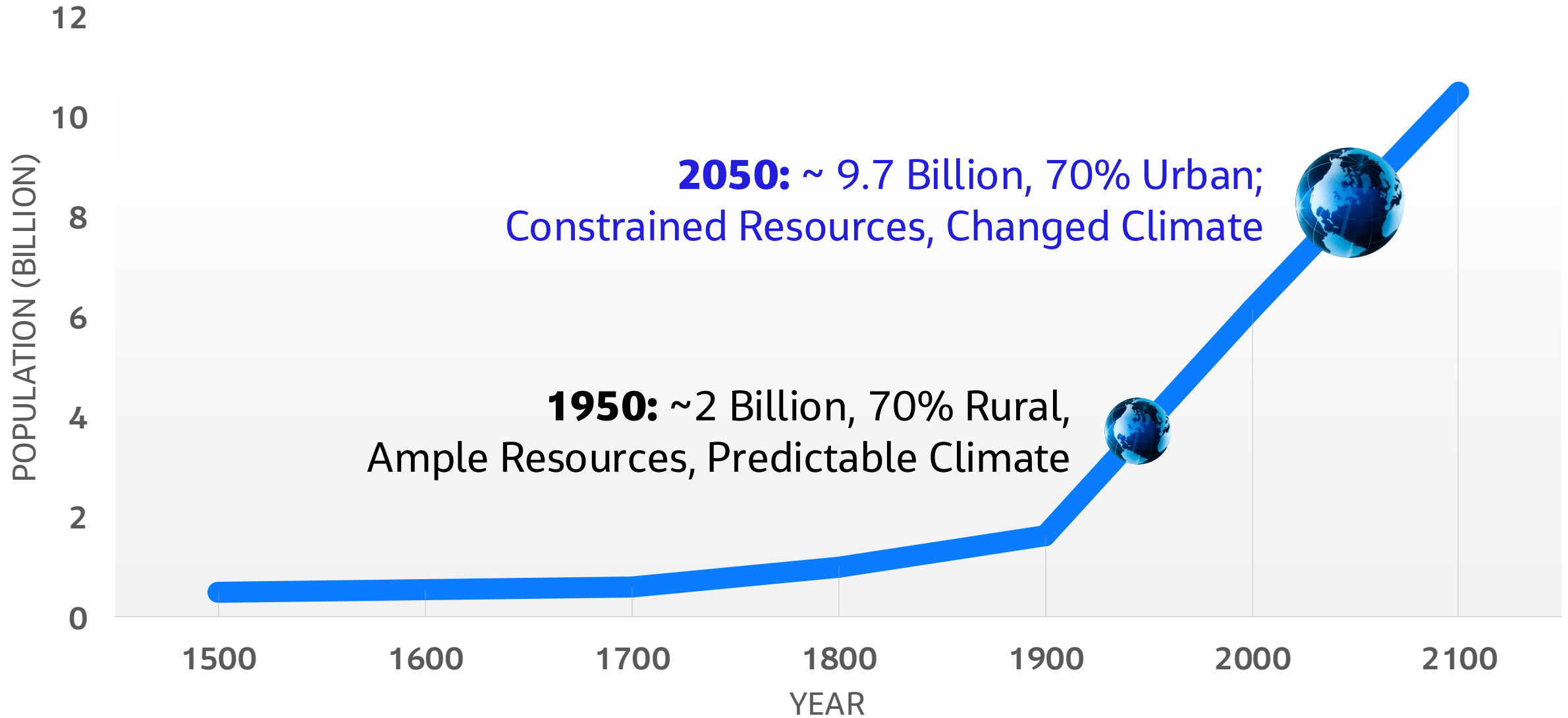
Tuas Nexus, Singapore

While positioning for the future...

Will current approaches meet future needs?



Will current approaches meet future needs?



Harnessing AI/ML to Navigate the Complexity of the Water Cycle



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An interconnected **OneWater** approach is essential for the retooling of water infrastructure to meet new challenges



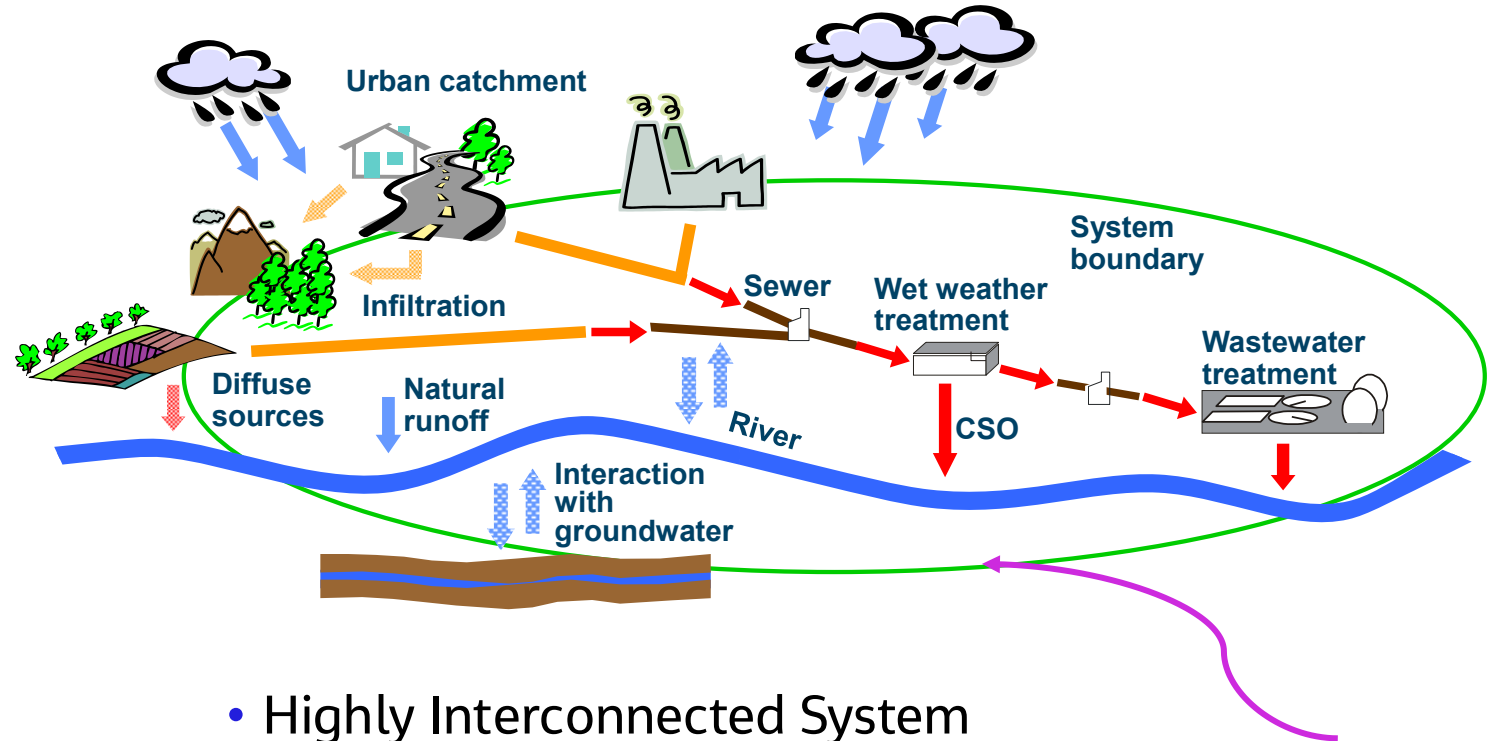
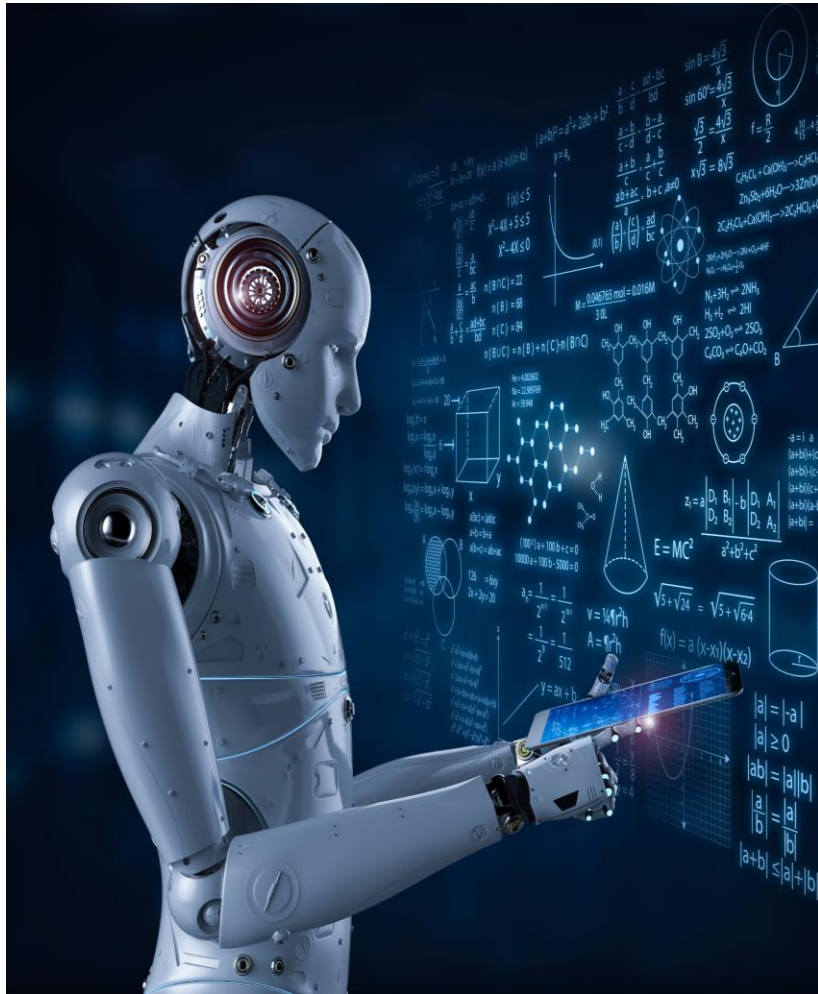
- › **All Water Has Value**
- › **Water Challenges Are Interconnected**
- › **Water Solutions Must Be Sustainable, Inclusive, and Equitable**

Holistic Consideration of the Water Cycle Requires Evaluations of Thousands of Variations and Alternatives

- › Addresses interconnectivity of water cycle
- › Requires advanced simulation/evaluation platforms
- › Enhances system understanding
- › Stimulates innovation
- › Reduces risk
- › Increases system performance
- › Results in robust and defensible solutions



AI/ML is the key to manage the complexity of the water cycle



- Highly Interconnected System
- Massive Data Streams
- Nonlinear Relationships
- Real-Time Decision Support
- Scalability & Automation

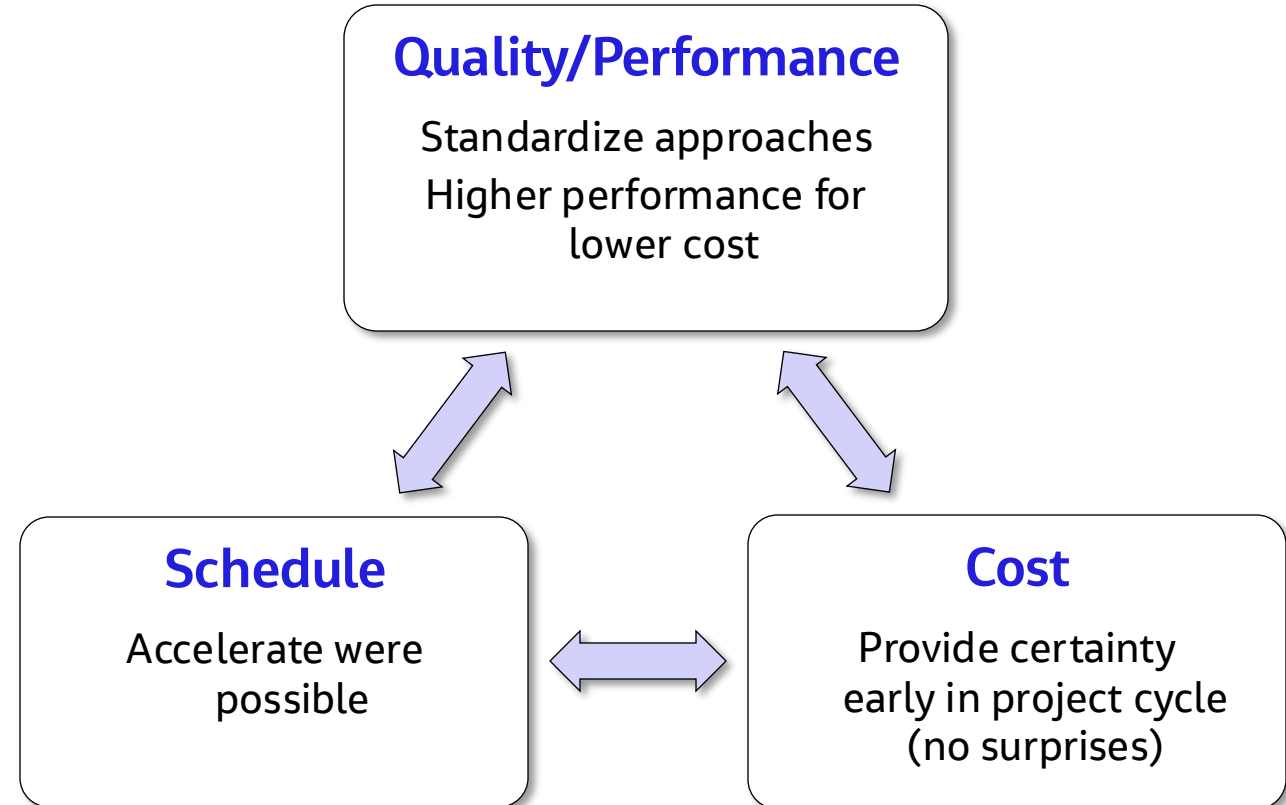
Digital Twins: From Big to Actionable Data



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Too Much of a Good Thing? Water Utilities and Big Data

- › Almost all utilities have **more data** than they can effectively use
- › They need **actionable** data to:
 - Speed up decision making
 - Do more with less
 - Open new opportunities



What is Mechanistic Modelling, Machine Learning, and a Digital Twin?



Mechanistic Modelling

Any physics based mathematical model that describes a system. i.e., chemistry, biochemistry, mass balances, hydraulics.



Machine Learning

A subset of AI - software that can be used to efficiently find relationships in data and use that pattern to recommend a result.

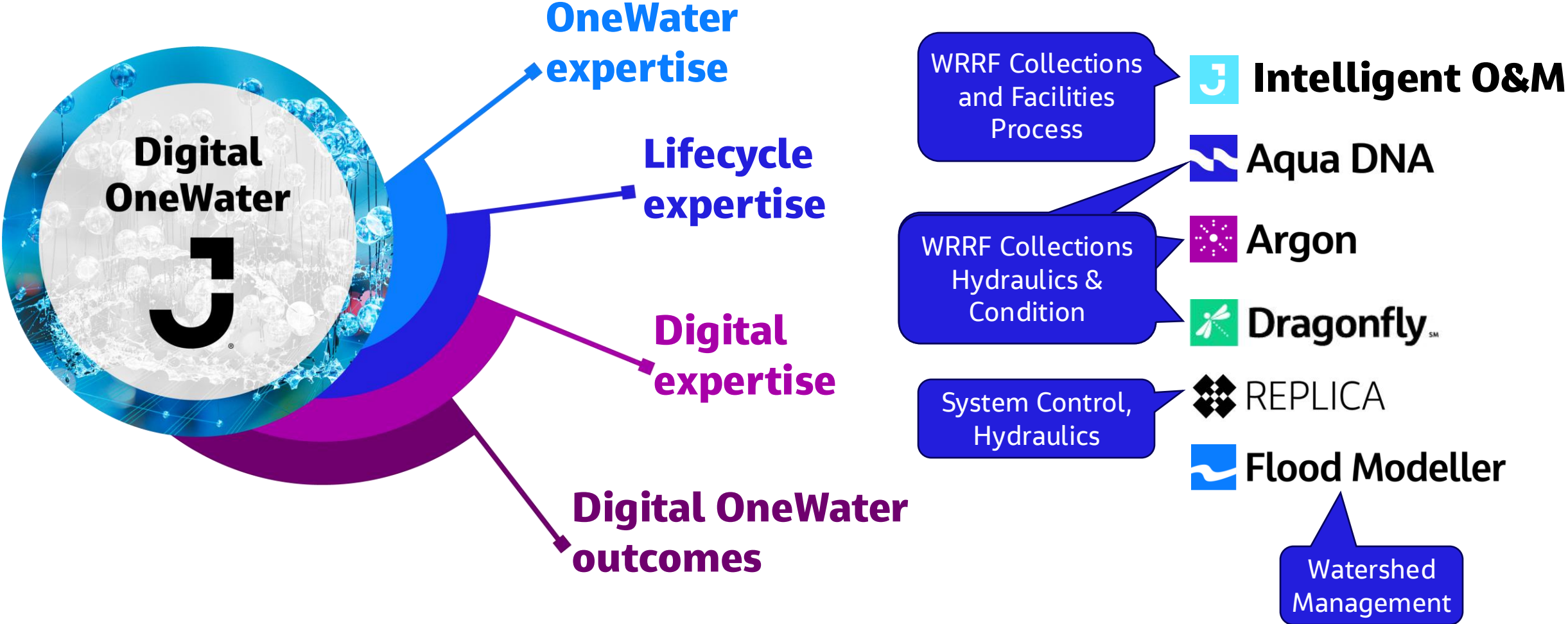
Machine learning auto-calibrates models, thus keeping them current



Digital Twin

A digital representation of a physical system coupled with automated real-time data, that can be used for synthetic data generation, scenario analysis, performance prediction and operational optimization

Bringing Data-Enabled Jacobs Solutions across the Project Lifecycle



What is Jacobs' Hybrid Optimizer?

A live *digital twin* that combines the best of mechanistic modelling with machine learning to reveal comprehensive *insight*, generate *value*, and *support staff*



Provides clear ROI

The hybrid optimizer delivers efficiency, supports proactivity, turns ROI in *less than five years* and gives Jacobs insights into our client's current and future situation.



Hybrid AI model

We combined Jacobs' *deep modelling experience* with *machine learning* to open the machine learning black-box for better optimization, forecasting and predictions than others.



Next Level Digital Twin Innovation

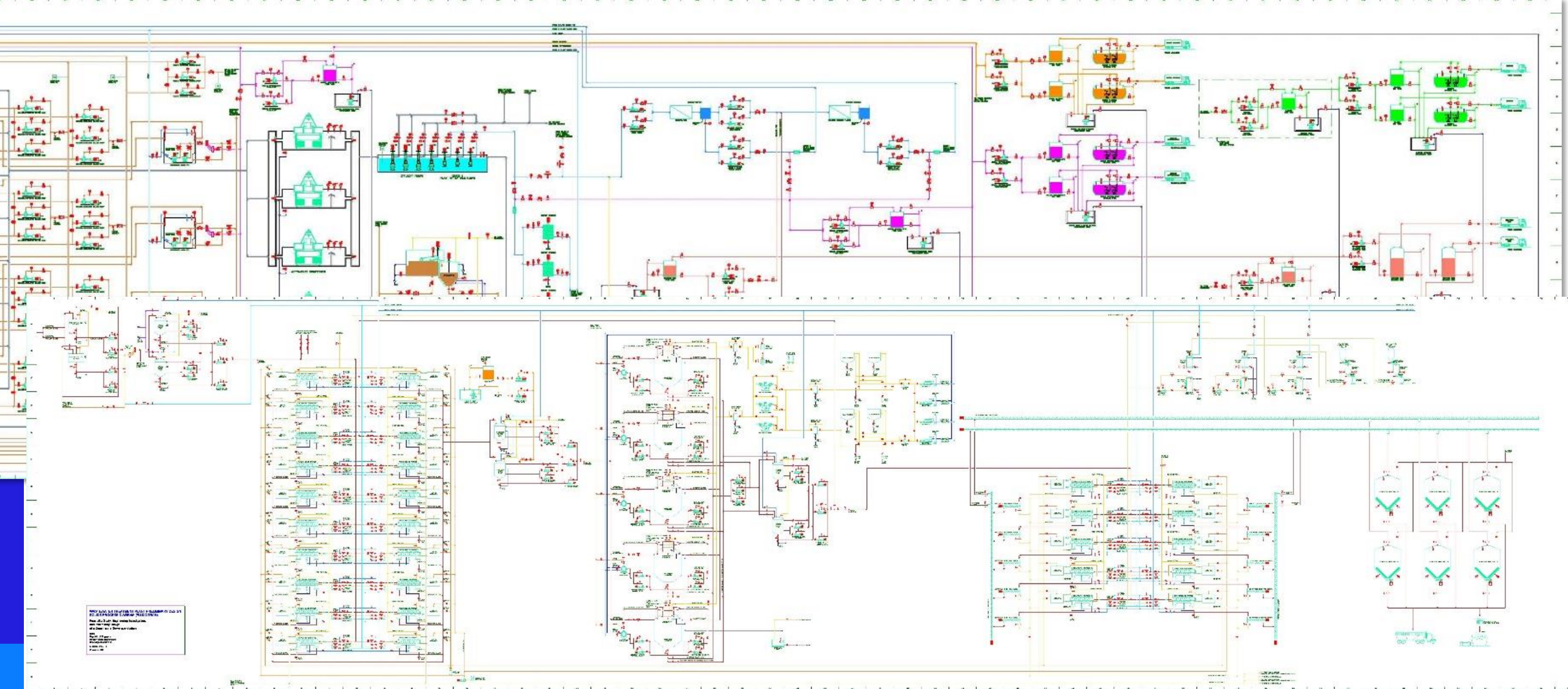
The hybrid optimizer uses live plant data to provide *comprehensive insights* into existing operations and *forecasts future* scenarios, essentially telling the plant what is coming down the pipe.

Case Study: Changi Water Reclamation Plant (CWRP) Singapore

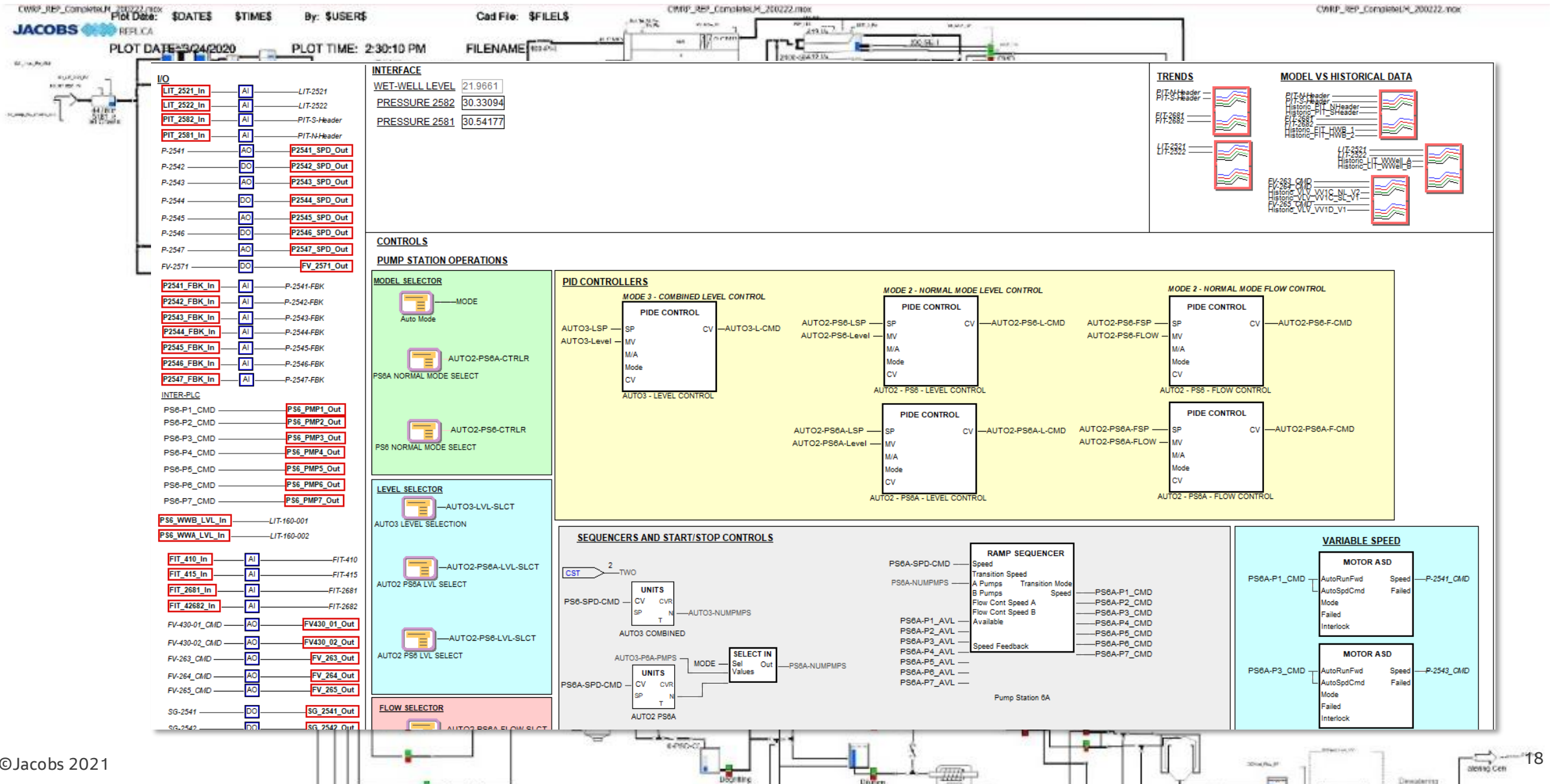


- › Operated by Singapore Public Utilities Board (PUB)
- › Currently treating an average of approximately 920,000 m³/d (243 MGD) of used water
- › Fed by a deep-tunnel sewer system
- › Currently four bioreactor trains. Each train includes primary treatment and a parallel MBR and 5-pass step-feed bioreactor
- › Most effluent is used for indirect potable reuse
- › Solids include thickening, mesophilic anaerobic digestion, dewatering and drying

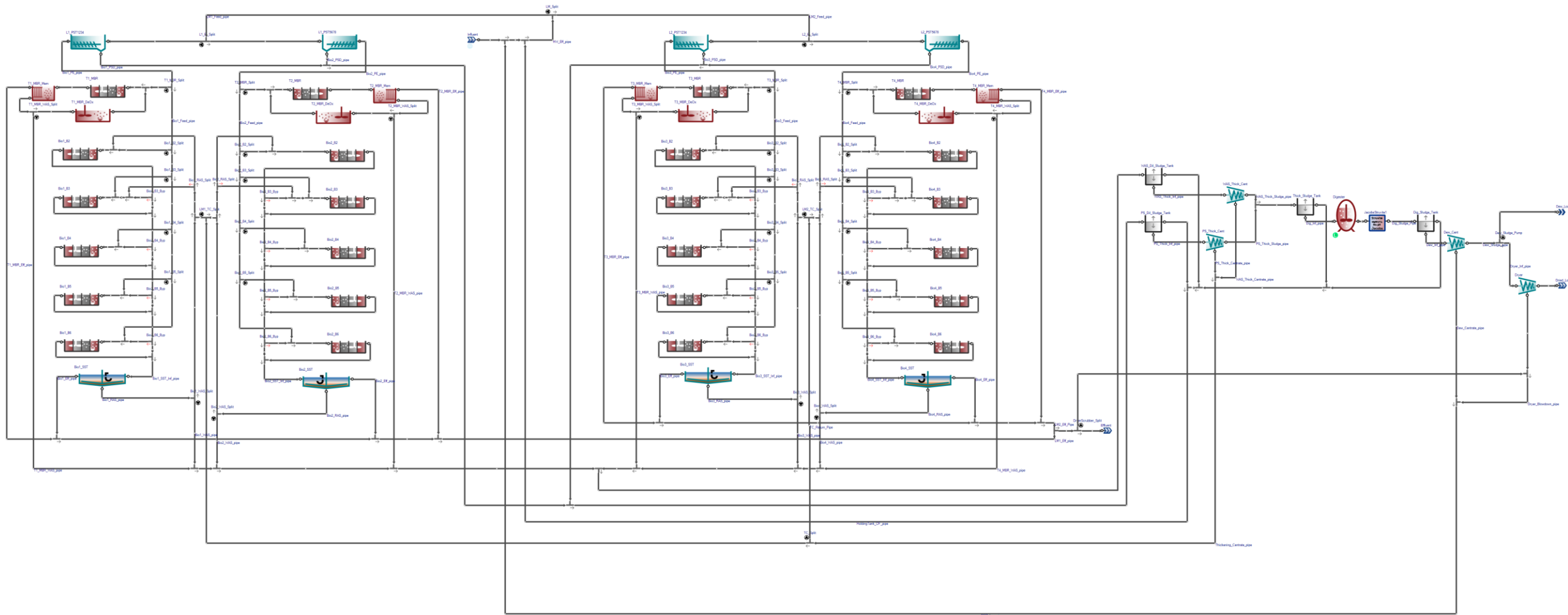
Partial PFDs (one of 4 liquids modules + Solids)



CWRP Replica™ Hydraulics and Control Model

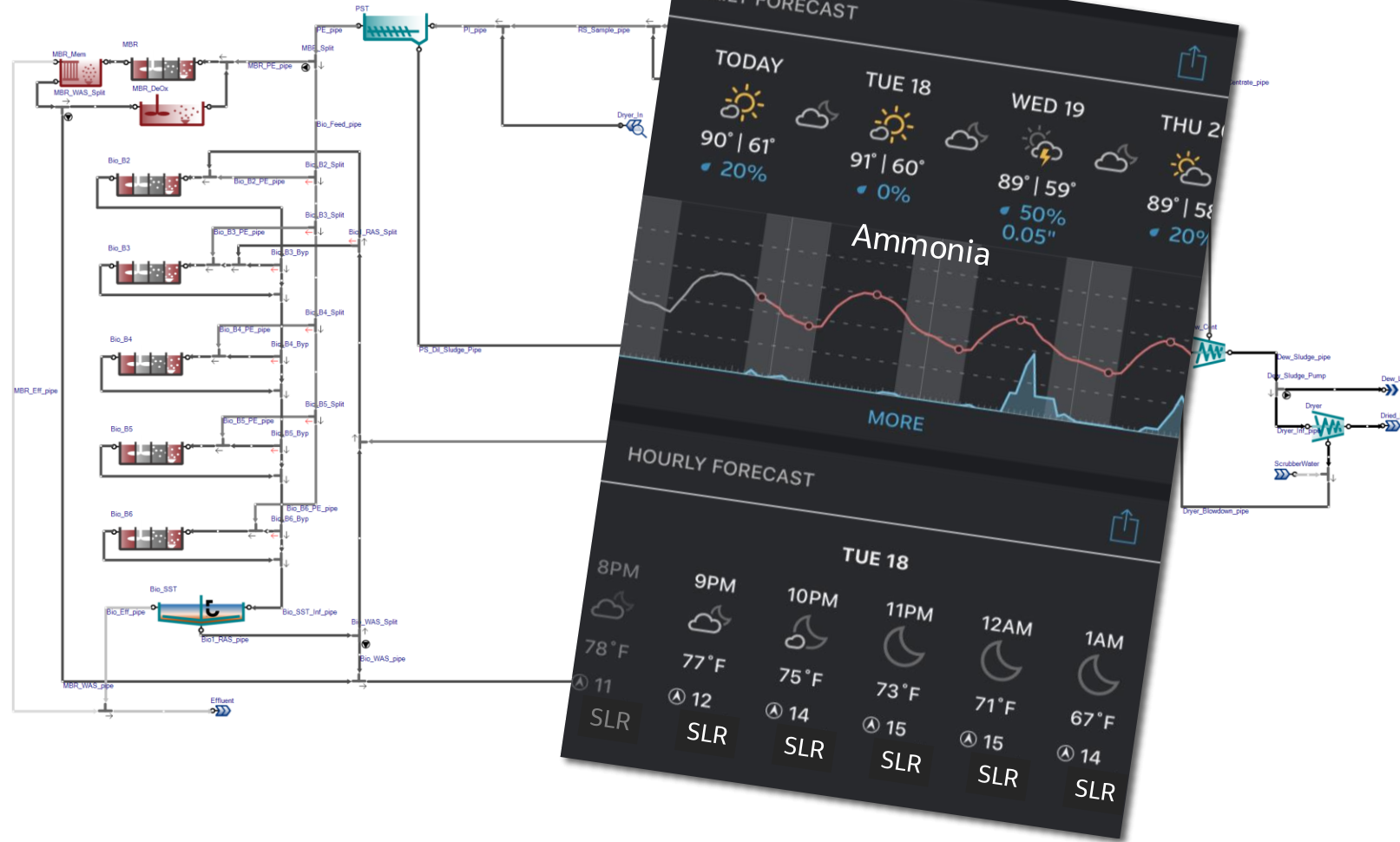


CWRP Sumo Process Model (169 biological reactors)



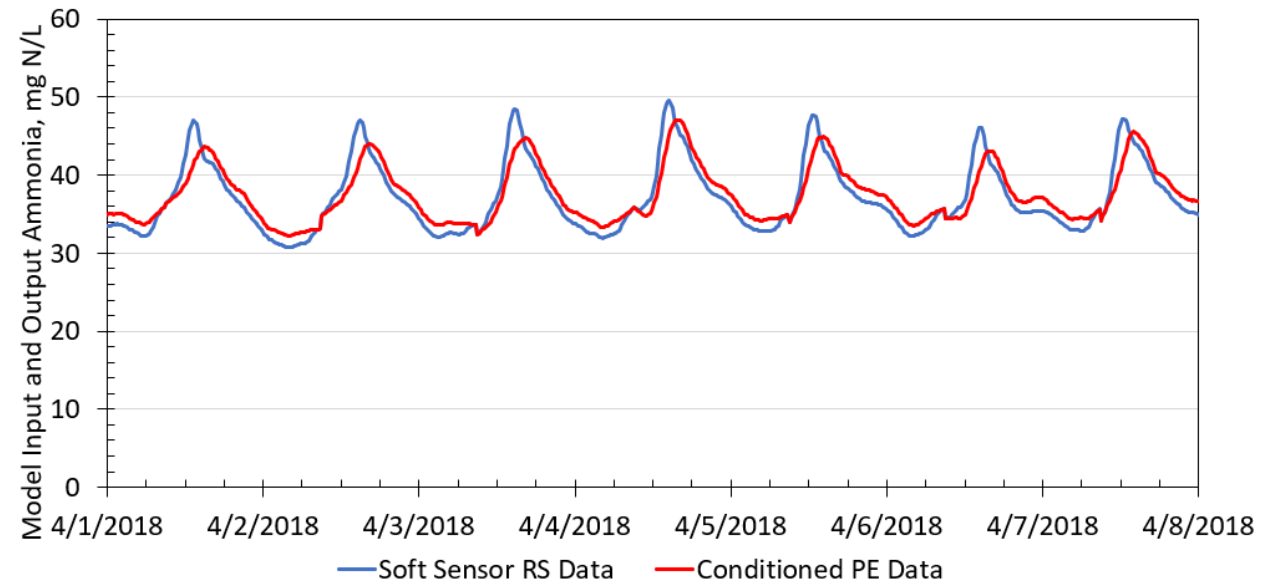
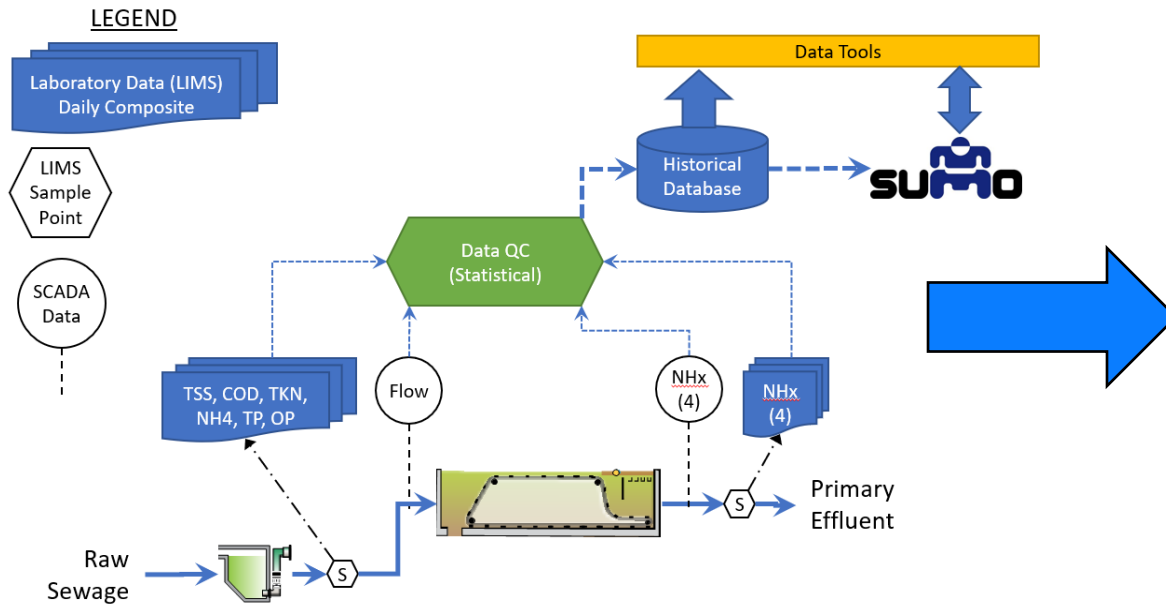
Predictive Analytics: Wastewater “Weather” Forecasting

- › Monte Carlo tools to predict likelihood of events
 - 1, 3, and 5 days into the future
 - likelihood of clarifier overloading
 - high nitrates, etc.
- › Uses simplified model for speed
 - “Only” 40 bioreactors
- › Provides results in “Weather App” type format
 - familiar method of viewing probabilistic information!



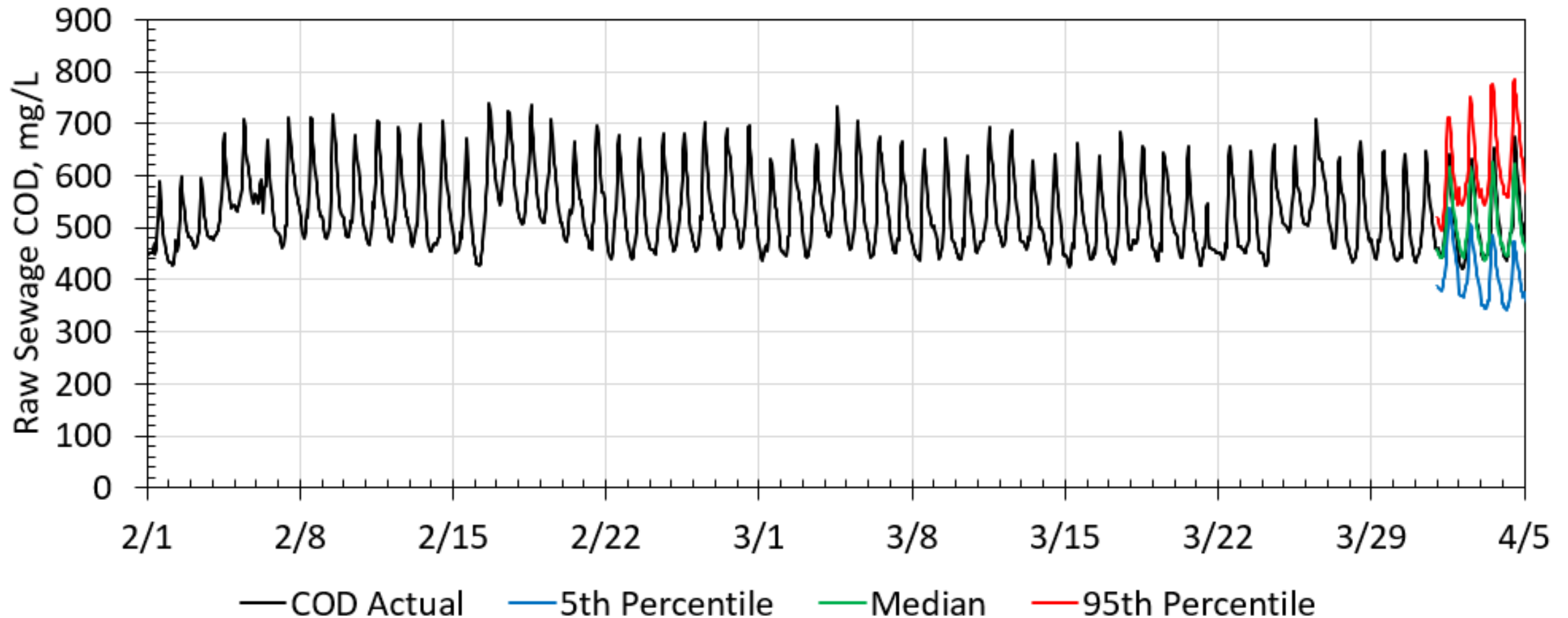
Soft Sensors for Influent Quality

- › A “soft-sensor” uses the model to estimate what a sensor might have read, without needing the sensor
 - Reduces capital and maintenance costs
- › CWRP Raw Sewage Characteristics (ammonia example)
 - Uses primary effluent ammonia measurements (on-line and laboratory)



Looking Forward: Moving from Reactive to Proactive Operations

- › Laboratory results are combined with predicted influent ammonia concentrations to develop 5-day dynamic predictions of COD concentrations

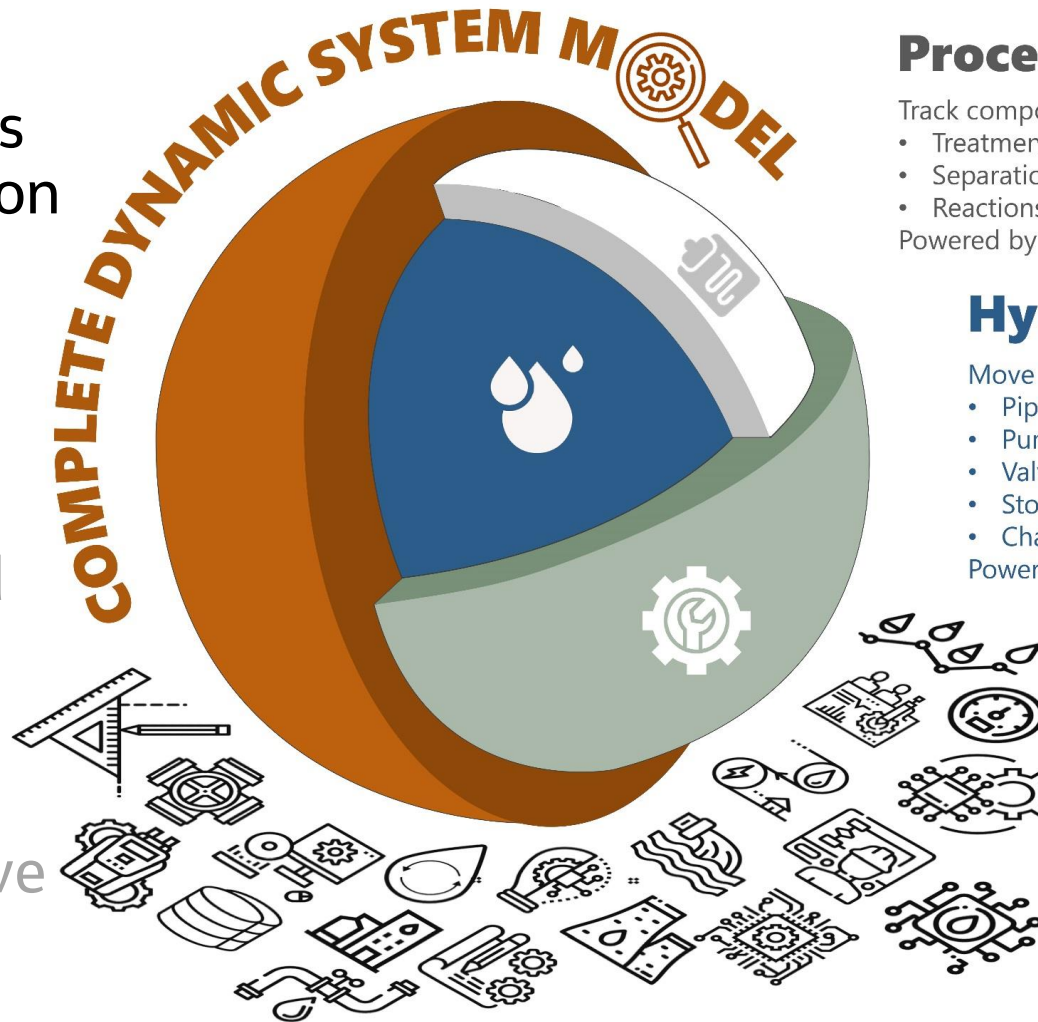


Digital Twin Summary

Changi WRP Digital Twin replicates all significant aspects of a facility on a digital platform, hydraulics, I&C, process

Benefits:

- › **Increasing Productivity** with:
Real-time operation insights and process trouble-shooting.
- › **Enhancing Resilience of Operations** by:
Moving from Reactive to Proactive
- › **Optimize critical operation scenarios**



Process

Track components (Wastewater Quality)

- Treatment processes
- Separation
- Reactions

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Hydraulics

Move fluids through system

- Pipes
- Pumps
- Valves
- Storage
- Channels

Powered by REPLICA™

Instrumentation & Controls

Drives system operation

- Measuring devices
- Transmitters
- Control Algorithms
- Controls Tuning

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Delivering the Benefits of Digital Solutions to Front Line Staff

No tool is useful unless **people want to use it and trust it**

- › This means different things to different stakeholders
- › To be successful it must provide benefits to the majority of users
- › User interface customized to meet the specific needs of the operators
- › The first priority must be to make life better for the primary users, which is most often the operators



Concluding Thoughts



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Why AI/ML Is Essential in Urban Water Management

- › **Urban Complexity:** Cities face unique challenges—aging infrastructure, population growth, pollution, and climate variability—all requiring the holistic management of the water cycle.
- › **Integrated Systems Thinking:** AI helps manage interdependencies between stormwater, wastewater, drinking water, and green infrastructure.
- › **Real-Time Monitoring & Control:** AI/ML enables smart water systems that dynamically adjust to usage patterns, detect leaks, optimize operations and improves performance.
- › **Predictive Analytics:** Machine learning models forecast urban flooding, drought risk, and infrastructure stress, supporting proactive planning.

Why Engineering Schools Should Teach AI/ML Principles

- › **Workforce Demand:** Industry and government increasingly seek engineers who can apply AI to infrastructure, climate adaptation, and resource optimization challenges.
- › **Future-Ready Skills:** AI/ML literacy equips engineers to design resilient, data-driven water systems.
- › **Interdisciplinary Innovation:** Understanding AI fosters collaboration across civil, environmental, and computer engineering domains.
- › **Ethical & Sustainable Design:** Educating students in AI/ML encourages responsible use of technology for equitable water access and sustainability.



Thank you!

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