Data Analytics and Water Treatment Process Optimization

Christopher Miller, PhD, P.E.

CEO and President

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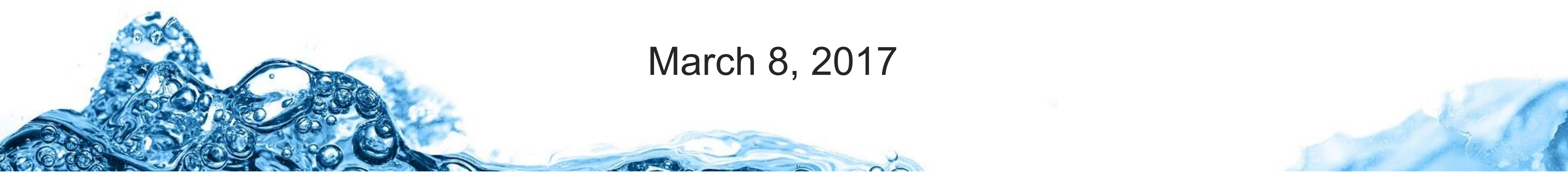
The Operator Training Committee of Ohio

55th Annual Water Workshop

March 8, 2017



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Long-Term Comparison of Disinfection By-Product Formation Potential in a Full Scale Treatment Plant Utilizing a Multi-Coagulant Drinking Water Treatment Scheme

Andrew T. Skeriotis [1,*], Nancy P. Sanchez [1,†], Marla Kennedy [1], David W. Johnstone [2] and Christopher M. Miller [1]

1 Department of Civil Engineering, University of Akron, 210 Auburn Science and Engineering Center, Akron, OH 44325, USA; nanmorcote@gmail.com (N.P.S.); kennedy.marla.j@gmail.com (M.K.); cmmiller@uakron.edu (C.M.M.)
2 Department of Civil Engineering, Ohio Northern University, 107 Biggs Engineering Building, Ada, OH 45810, USA; davidwjohnstone@gmail.com
* Correspondence: andrewskeriotis@gmail.com; Tel.: +1-330-475-2238
† Current address: Department of Civil and Environmental Engineering, Rice University, Houston, TX 77005, USA.

Skeriotis et al., 2016.

- 3 year study at the Akron water plant ("real" data)
- Measured DOC, THM, and HAA of raw and treated samples
- Compared alum vs. ACH performance

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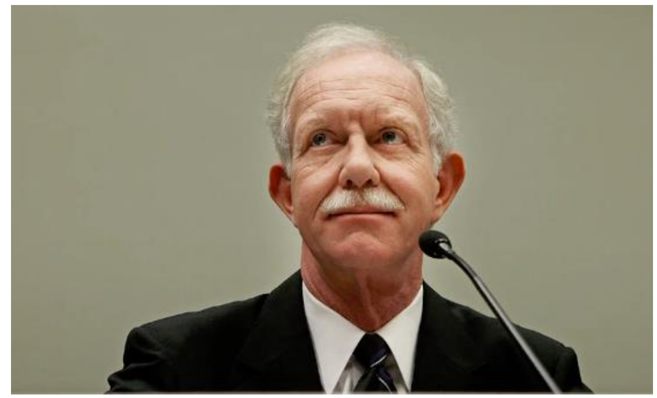
SOURCE: Chris McGrath/Getty Images News/Getty Images



"Autopilot didn't put pilots out of a job; instead it foreshadowed an increasing collaboration between human and machine on complex tasks."

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Lake Erie's toxic blob may be putting drinking water at risk

BY KAREN GRAHAM OCT 20, 2016 IN ENVIRONMENT LISTEN | PRINT

Cleveland - In what sounds like a Halloween horror story, a toxic blob of cancer-causing chemicals in the sediment of Lake Erie might be spreading dangerously close to a water intake pipe that supplies drinking water to Cleveland.

News Briefs: Residents Launching Their Own Utility to Deal With Bad Water

Online Exclusives | March 1, 2017 | Recommend 0

Comment Share

In this week's water and wastewater news, a group of 500 citizens in New Mexico is looking at starting its own utility to solve water problems; and water testing near Atlanta uncovers nearly 50 schools with lead contamination.

Residents near Bloomfield, New Mexico, are forming their own utility after dealing with bad water for the past nine months. The state hasn't been able to get the local water company to fix the problem.

Around 500 people have decided to form a domestic water users association to inherit the defunct water system.

Detroit Free Press
PART OF THE USA TODAY NETWORK

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Inspector General: EPA too slow to act on Flint lead

Paul Egan, Detroit Free Press 8:02 p.m. EDT October 20, 2016

Many challenges including:

- Increasing treatment complexity and compliance risk
- Budget-financial pressures
- Heightened public expectations

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AWWA G100-11 Water Treatment Plant Operation and Management

Publisher: American Water Works Association
Publication date: 2011
AWWA catalog no: 47100
Media Type: Softbound
Number of pages: 32

The purpose of this standard is to describe critical requirements for the operation and management of water treatment plants, including maintaining water quality, system management programs, and operation and maintenance of facilities.

2016 Draft

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The purpose of this standard is to describe critical requirements for the operation and management of water treatment plants, including maintaining water quality, system management programs, and operation and maintenance of facilities.

Sec. 4.4 Water Quality Management

4.4.1 *Performance goals.* ~~In order to protect public health and enhance customer satisfaction, high-quality water must be continuously produced regardless of source water changes or treatment plant component malfunctions.~~ The goals of each treatment plant should include the reliable provision of high quality drinking water on a regular basis. While source water changes or treatment plant component malfunctions may impact the ability to continuously provide high quality water, goals should include plans for meeting challenges and returning to high quality water production.

Drinking water treatment plants shall deliver the quantity of water sufficient to satisfy normal water demands and the quality of water to meet applicable regulatory requirements. While not required, ~~as well as~~ satisfying the aesthetic demands of customers should be considered as an important part of managing public perception and acceptance.

The plant shall adopt a multiple-barrier philosophy that, with regard to particulate removal and disinfection, ~~relies on~~leverages the ~~optimized~~ performance of each major unit process to achieve optimized overall plant performance. The procedures of the Partnership for Safe Water (International Water Treatment Alliance) described in *Self-Assessment Guide for Surface Water Treatment Plant Optimization* satisfy many of the requirements of this standard. Surface water plants that are

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Analytics
business
data
analysis
decision
science
based
mathematics
Statistics
statistical
definition
use
field
patterns
practical
may
predicting
process
improving
choose
people
qualitative
aspects
optimal
management
Operations
modeling
fraud
using
understand
marketing
computation
include
strategy
involving
erroneous
arrives
credit
might
considered
historical
fields
Probability
applications
mining
making
performance
make
past
i.e
risk
area
study
closely
eye
includes
enterprise
managers
entity
realistic
extensive
limit
simple
order
Common
decisions
rules
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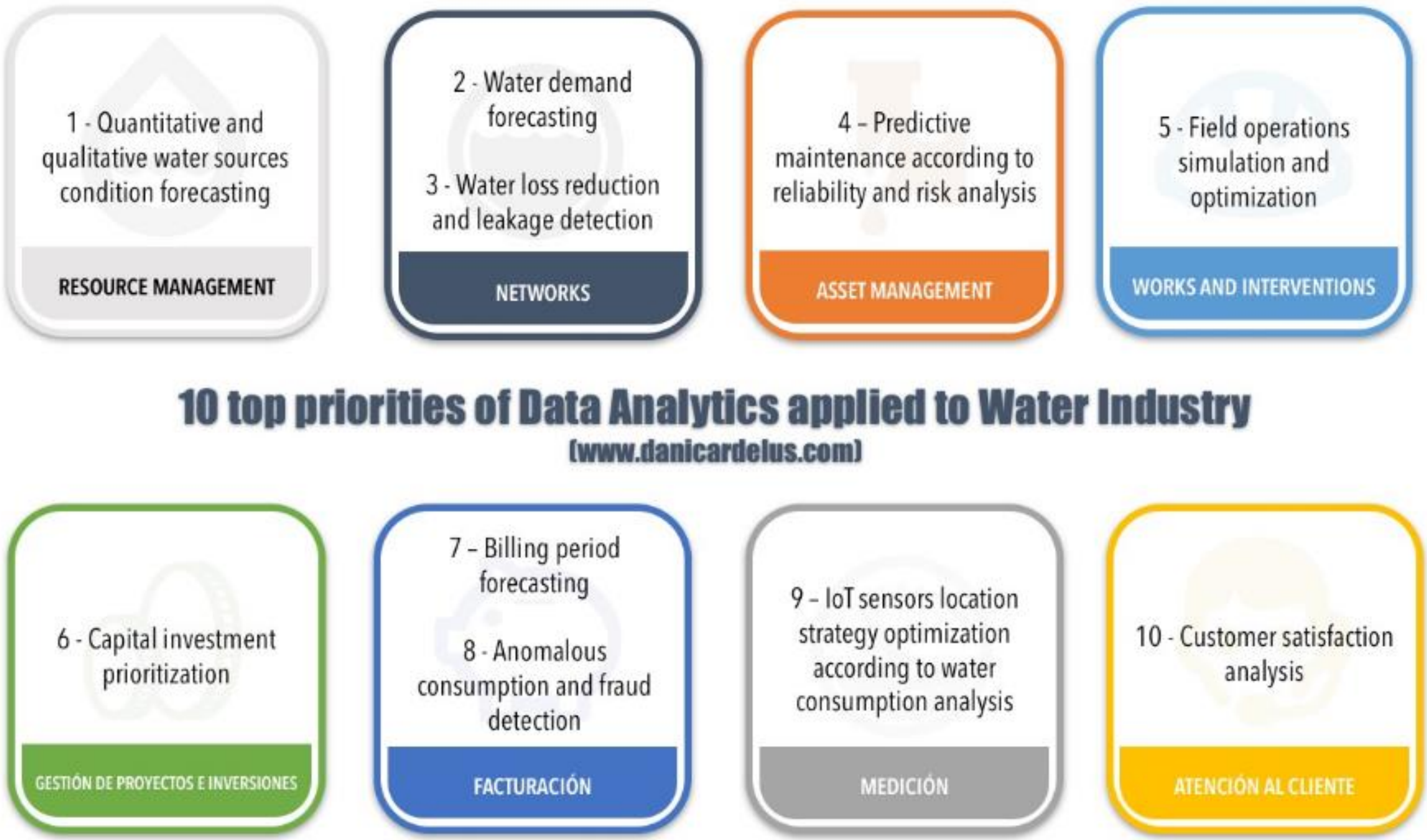
1 - Quantitative and qualitative water sources condition forecasting
RESOURCE MANAGEMENT
2 - Water demand forecasting
3 - Water loss reduction and leakage detection
NETWORKS
4 – Predictive maintenance according to reliability and risk analysis
ASSET MANAGEMENT
5 - Field operations simulation and optimization
WORKS AND INTERVENTIONS
10 top priorities of Data Analytics applied to Water Industry
(www.danicardelus.com)
6 - Capital investment prioritization
GESTIÓN DE PROYECTOS E INVERSIONES
7 – Billing period forecasting
8 - Anomalous consumption and fraud detection
FACTURACIÓN
9 – IoT sensors location strategy optimization according to water consumption analysis
MEDICIÓN
10 - Customer satisfaction analysis
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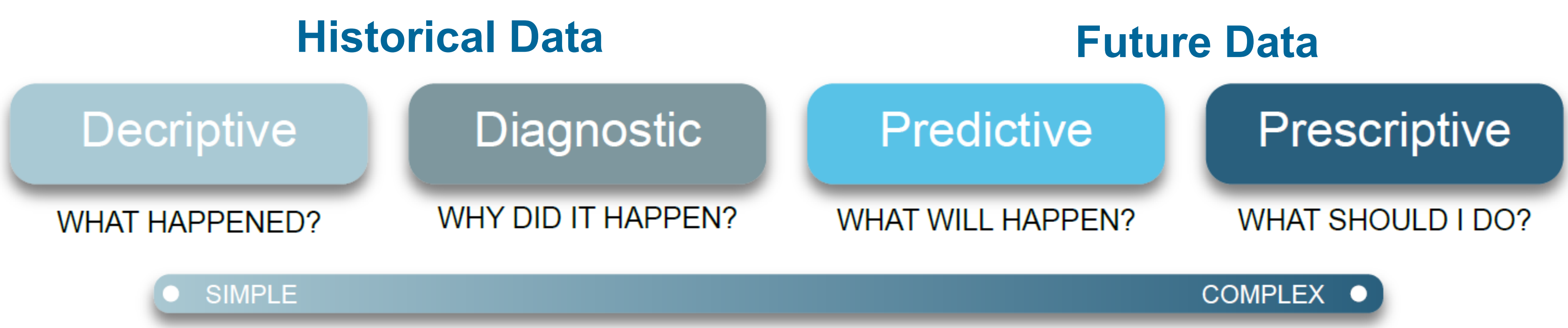
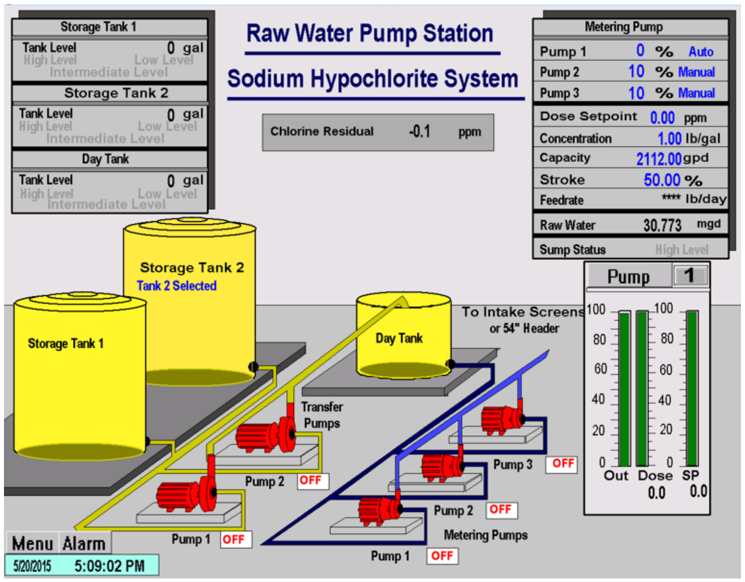
Data Analytics



How do we apply Data Analytics to Water Treatment Process Optimization?


Storage Tank 1
Tank Level 0 gal
High Level Low Level
Intermediate Level
Storage Tank 2
Tank Level 0 gal
High Level Low Level
Intermediate Level
Day Tank
Tank Level 0 gal
High Level Low Level
Intermediate Level
Raw Water Pump Station
Sodium Hypochlorite System
Chlorine Residual -0.1 ppm
Metering Pump
Pump 1 0 % Auto
Pump 2 10 % Manual
Pump 3 10 % Manual
Dose Setpoint 0.00 ppm
Concentration 1.00 lb/gal
Capacity 2112.00 gpd
Stroke 50.00 %
Feedrate **** lb/day
Raw Water 30.773 mgd
Sump Status High Level
Pump 1
Out Dose SP
0.0 0.0
Storage Tank 2
Tank 2 Selected
Storage Tank 1
Day Tank
To Intake Screens
or 54" Header
Transfer Pumps
Pump 1 OFF
Pump 2 OFF
Pump 3 OFF
Metering Pumps
Menu Alarm
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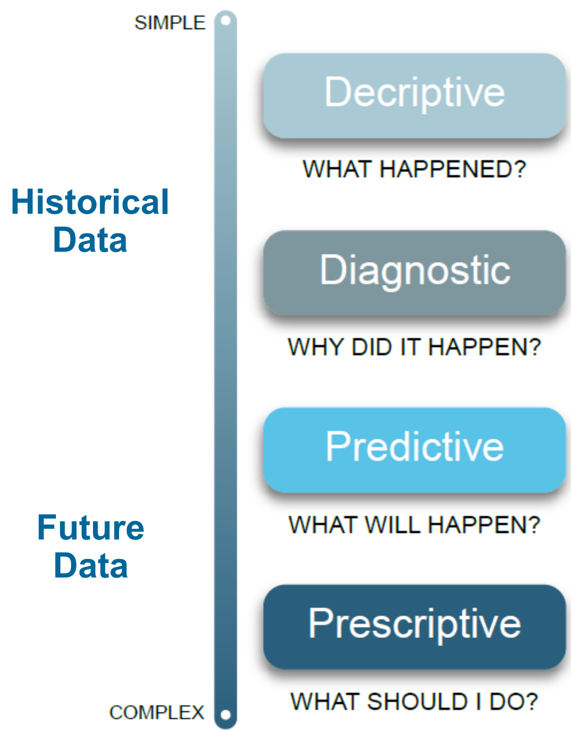
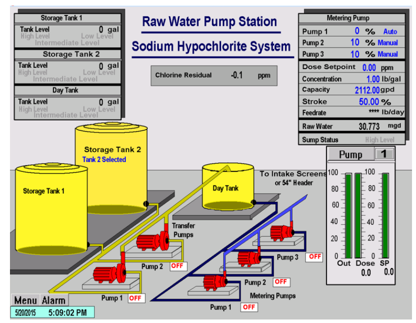
Data Analytics



SCADA



Can be customized for Predictive and Prescriptive Data Analytics

$$$$$$

Excel

AllMax Software

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Data Analytics

SIMPLE

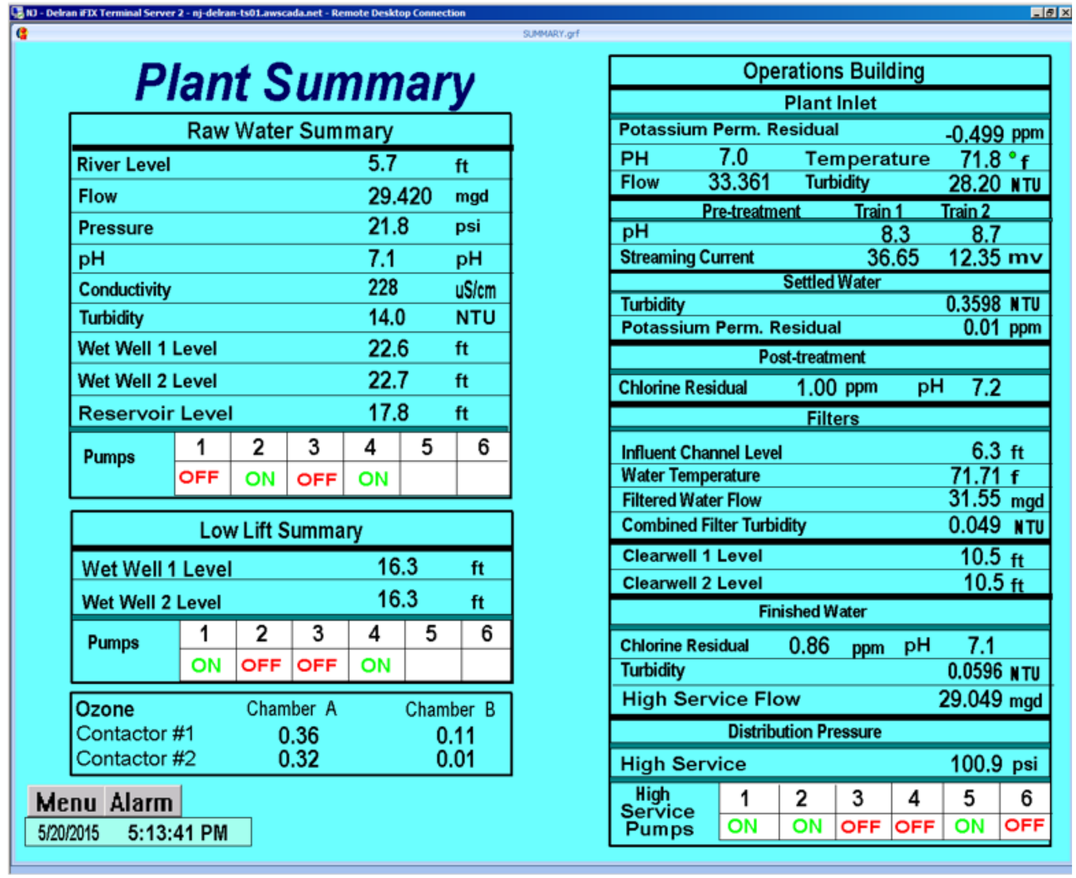
Historical Data

- **Decriptive** — WHAT HAPPENED?
- **Diagnostic** — WHY DID IT HAPPEN?

Future Data

- **Predictive** — WHAT WILL HAPPEN?
- **Prescriptive** — WHAT SHOULD I DO?

COMPLEX



NEW JERSEY AMERICAN WATER

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Data Analytics

SIMPLE

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- Decriptive — WHAT HAPPENED?
- Diagnostic — WHY DID IT HAPPEN?

Future Data

- Predictive — WHAT WILL HAPPEN?
- Prescriptive — WHAT SHOULD I DO?

COMPLEX

NJ - Delran iFIX Terminal Server 2 - nj-delran-ts01.awscada.net - Remote Desktop Connection

FTRVIEW.grf

Filter Overview

	Mode	Filter Control	Headloss (ft)	Runtime (hrs)	Effluent Turbidity (NTU)	Effluent Valve (% open)	Effluent Flow (Mgd)	Effluent Flow Sp. (Mgd)	Effluent Control
Filter 1	Normal	Automatic	4.7	25.4	0.05	42	3.953	3.953	Level
Filter 2	Normal	Automatic	1.8	9.9	0.04	44	3.976	3.976	Level
Filter 3	Normal	Automatic	0.5	1.8	0.05	40	4.055	4.055	Level
Filter 4	Normal	Automatic	4.2	29.2	0.04	37	3.947	3.947	Level
Filter 5	Normal	Automatic	6.3	39.5	0.04	49	3.988	3.988	Level
Filter 6	Normal	Automatic	6.5	45.1	0.03	50	3.946	3.946	Level
Filter 7	Normal	Automatic	8.4	33.6	0.03	59	3.980	3.980	Level
Filter 8	Normal	Automatic	3.5	15.4	0.04	33	3.990	3.990	Level

System Data	
Total Filter Effluent	31.82 mgd
Influent Channel Level	6.30 ft
Influent Channel Setpoint	6.30 ft
Combined Filter Turbidity	0.049 NTU

Enter 1 to inhibit turbidity alarm
Enter 0 to clear inhibit of turbidity alarm

Clearwell Turbidity 0

Filter 1	0	Filter 5	0
Filter 2	0	Filter 6	0
Filter 3	0	Filter 7	0
Filter 4	0	Filter 8	0

Menu Alarm

5/20/2015 5:23:42 PM

NEW JERSEY AMERICAN WATER

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Data Analytics

SIMPLE

Historical Data

Decriptive
WHAT HAPPENED?

Diagnostic
WHY DID IT HAPPEN?

Future Data

Predictive
WHAT WILL HAPPEN?

Prescriptive
WHAT SHOULD I DO?

COMPLEX

Home | DOC Monitor | DBP Monitor | HAB Monitor | Cynatoxin Calculator

Data Entry

Update Charts

Total Chlorine Dose
3.2 mg/l
Update

Date: 03/03/17

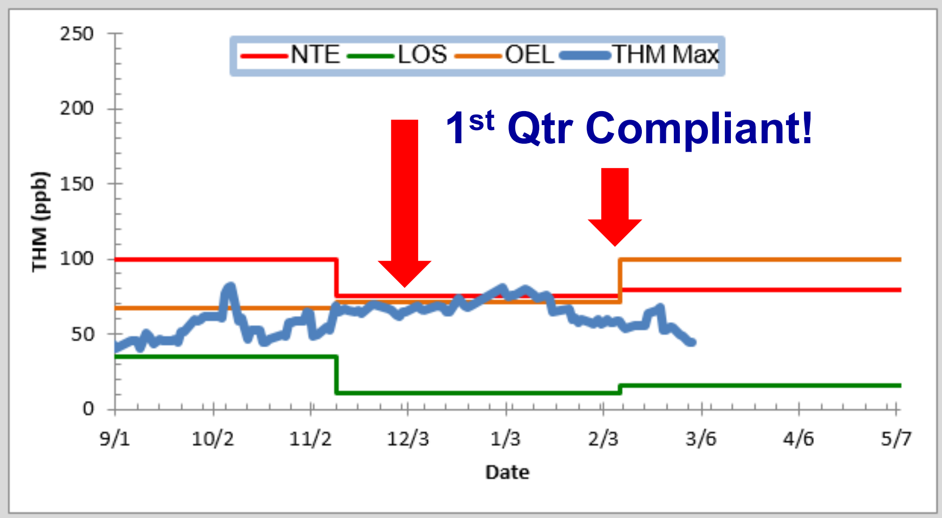
Sample Location	THM max	HAA max
TP01	128	64
TP02	45	22

Summary Table

As of: 2/8/2017	THM (ppb)				HAA (ppb)			
Site	LRAA	NTE	OEL	LOS	LRAA	NTE	OEL	LOS
DS201	77	79	99	15	30	155	83	107
DS202	50	168	124	104	36	132	91	84
DS203	48	173	125	186	32	143	93	95
DS204	52	159	116	95	34	136	91	88

LRAA = Locational Running Annual Average
OEL = Operational Evaluation Level
NTE = Not to Exceed Value (Compliance Value)
LOS = Level of Service Target

THM Max Chart



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Data Analytics

SIMPLE

Historical Data

Decriptive

WHAT HAPPENED?

Diagnostic

WHY DID IT HAPPEN?

Future Data

Predictive

WHAT WILL HAPPEN?

Prescriptive

WHAT SHOULD I DO?

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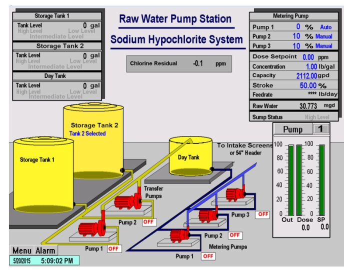
Water Treatment Process Optimization



Excel

AIMAX Software

Common Approach

Water Quality Monitoring → Simulation → Optimization → Decisions

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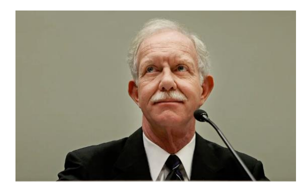

- **Chemical Dose Recommendations**
- **Performance Tracking**

Dosing Recommendations

The treatment objective value estimates and corresponding dosing recommendations include an acceptable range-tolerance around the treatment objectives.

Current Conditions

Cost Savings (%)	Settled UV-254 (1/cm)	Settled Turbidity (NTU)	Ozone (ppm)	KMnO4 (ppm)	Lime (ppm)	FeCl3 (ppm)	Cat.Floc (ppm)	SuperFloc (ppm)
0.0	0.060	0.85	2.97	0.54	26	93	0.19	0.66

Lower Cost/Similar Quality Solutions

Cost Savings (%)	Settled UV-254 (1/cm)	Settled Turbidity (NTU)	Ozone (ppm)	KMnO4 (ppm)	Lime (ppm)	FeCl3 (ppm)	Cat.Floc (ppm)	SuperFloc (ppm)
23.4	0.039	0.92	2.38	0.43	24	65	0.23	0.46
25.3	0.054	0.94	2.38	0.43	21	65	0.23	0.46
22.4	0.032	0.91	2.38	0.43	26	65	0.23	0.46

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SOURCE: Chris McGrath/Getty Images News/Getty Images

"Autopilot didn't put pilots out of a job; instead it foreshadowed an increasing collaboration between human and machine on complex tasks."

Laurent Haug

Decision Blue® A.I.

Thank You!

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Water Treatment Objectives Overview

Core Treatment Objectives:

1. Minimize settled and/or filter turbidity
2. Comply with the TOC removal targets based on water quality and disinfection byproduct limits
3. Provide “high” quality water at low cost

How does a water plant simultaneously meet all three objectives under “normal” conditions? Other challenging scenarios (“Large” rain event)?

Multi-objective Optimization!

Raw Water TOC (mg/L)	Source Water Alkalinity (mg/L as CaCO3)		
	0-60	60 - 120	120+
TOC ≤ 2	No Action	No Action	No Action
2 < TOC ≤ 4	35%	23%	15%
4 < TOC ≤ 8	45%	35%	25%
TOC > 8	50%	40%	30%

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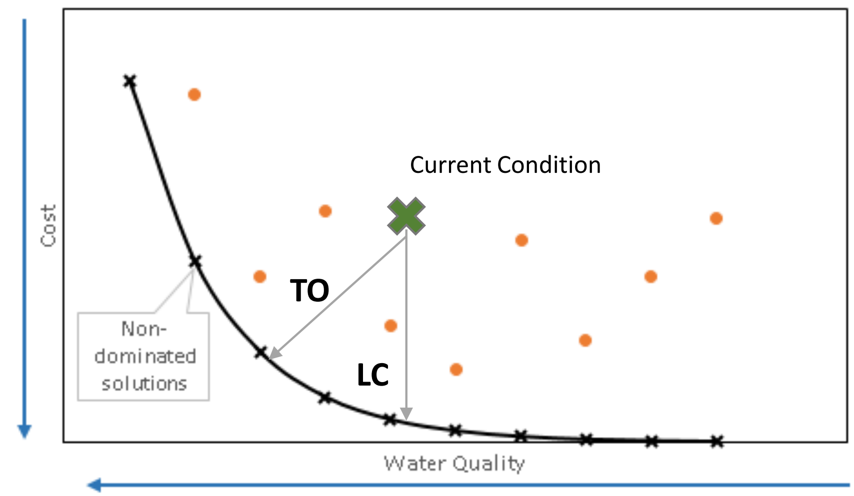
Multi-Objective Optimization Basics

- The goal is to find chemical dose combinations that minimize cost and minimize water quality measures (e.g. settled turbidity)
- The Current Condition (CC) is not the optimum condition
- DB-AI provides optimum solutions for two other conditions:
  - (a) Lower Cost – Similar Water Quality (LC)
  - (b) Treatment Objective – Lowest Cost (TO)
- Solutions are chemical dose recommendations



And as the source water quality changes, the current condition and optimum solutions will also change

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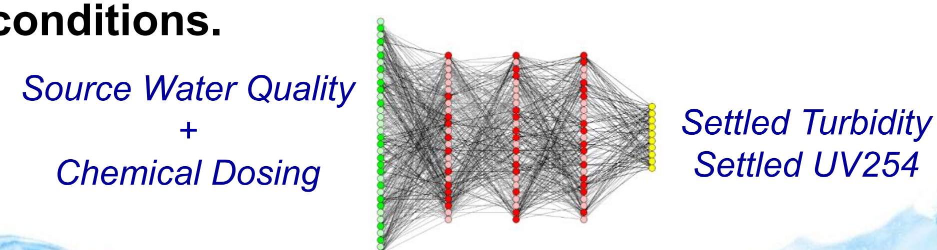
Decision Blue A.I. (DB-AI) Introduction

- **Decision Support with Modeling and Multi-Objective Optimization (i.e. Artificial Intelligence) as Foundation**
- **Benefits**
  1. Incorporates Water Plant Experience and Expertise in the Decision Making Process
  2. Chemical Cost Savings
  3. Operational Cost Savings (e.g. improved filter performance and reduced sludge production, reduced labor costs associated with jar or other testing)
  4. Enhanced Water Quality: > 10% reduction in average filter effluent turbidity and > 30% DBP reduction
- **Customized for the current water plant chemical use, water quality data sources, and treatment objectives without any additional equipment requirements.**
- **Operators and supervisors can receive valuable chemical dose recommendations for changing water quality and treatment conditions.**



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Treatment Optimization Proficiency

1. **Scenario Based Multi-objective Optimization**
   - How can chemical application be optimized under various treatment scenarios?
     1. High Turbidity
     2. Taste and Odor Event
     3. High DOC or DBP Concerns
     4. Chemical spill or specific chemical of concern (e.g. atrazine)
2. **Daily Multi-Objective Optimization**
   - Optimal chemical doses for “routine” operations made on a daily basis
3. **Real-Time Multi-Objective Optimization**
   - Dose recommendations can be made in real-time with automated data collection (SCADA) and daily lab results

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