NewFields
Perspective. Vision. Solutions.

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SUN02–Real Time Modeling Workshop

Data Collection & Integration (9:45-10:45)

Presented by: Paul West, P.E.

Sunday, June 9, 2013

Brief Bio of My Real-time Modeling Experience

- 2003 – Built WDS real-time model (RTM) using commercial platform (35 MGD system)
- 2008 – Real time WDS energy optimization pumping system implementation project with CH2M HILL & Derceto (80 MGD system)
- 2011 to Present – Developing / using new portable on-line multiple parameter monitoring systems that support RTM

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Most Important Message of the Day!

- You can build a Water Distribution System (WDS) Real-time Network Model (RTM) in a matter of months, not years!
- A **New Modeling Paradigm** is needed.
- Rapid advances in technology in recent years have removed most of the barriers
- Doesn't matter where the RTM sits! Control room, consultant's office, etc.
- Can be implemented during routine model update project, but you have to include in the RFP!

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Data Collection & Integration (Agenda Timeline)

- 9:45-10:15 (Presentation Part 1)
- 10:15-10:25 (Exercise #1 / Q&A)
- 10:25-10:40 (Presentation Part 2)
- 10:40-10:50 (Exercise #2 / Q&A)
- 10:50-11:00 (Hands On Equipment)

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RTM Data Collection and Integration - Agenda Topics

- RTM Definitions & Distinctions
- RTM Data Dilemmas and Requirements
- SCADA/Telemetry Equipment and Next Generation On-line Sensors
- SCADA Security
- Traditional Physics Based Network Models vs. Data Driven Empirical WQ Models

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Definitions & Distinctions: Real-Time Modeling (RTM)

- RT Calibration vs. RT Modeling
- RTM vs. Near RTM (15 min., daily, or weekly interval?)
- Auto Timer Run vs. Manual Run RTM
- "Facility" vs."All Pipe" Calibrated RTM
  - Multi-pressure zone vs. large or no pressure zones
- Control Room vs. Remote RTM
- "Physics-based pipe-node network" vs. "empirical" real-time models (RTM)

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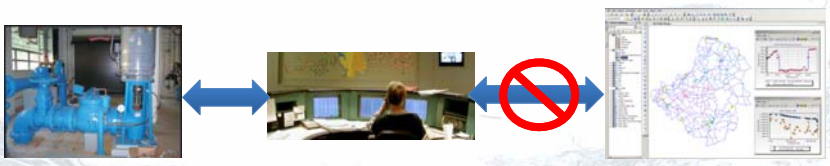
The RTM "Data Dilemmas"

- Standard industry practice for model calibration requires 3 primary data inputs:
  1. SCADA data downloads *(text or Excel file)*
  2. Customer Demands *(billing database)*
  3. Field Tests *(pump curve tests, hydraulic grade line test, fire hydrant flow test, C-factor tests, district flow measurement tests, fluoride tracer studies, water quality grab samples by Lab personnel)*
- Requires a **new paradigm** as we move into the RTM space

The RTM "Data Dilemma"

#1 – The SCADA "Data Dilemma"

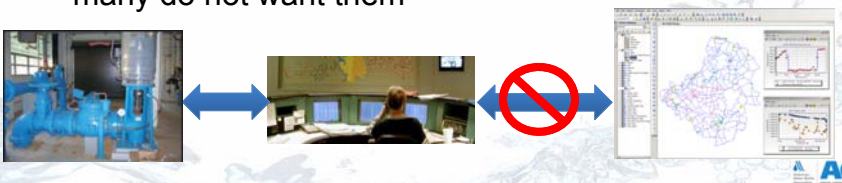
- Out of 50,000+ water systems in the U.S., best estimates are that < 0.1% are currently using RTMs (approximately 15)
- RTM software available for 10+ years
- Why the slow up-take when the advantages are so obvious and enormous?



The RTM "Data Dilemma"

#1 – The SCADA "Data Dilemma"

- SCADA = Control of Assets = High Risk ≠ Access
- Even though backdoors for SCADA vendors existed, modelers were denied access or didn't know to ask
- "Modeling community" is operating under a false paradigm (RTMs can only exist in the Control Room)
- While some control room operators may want a RTM, many do not want them



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The RTM "Data Dilemma"

#1 – The SCADA "Data Dilemma"

- Wide discipline gaps, organizational silos, and different agendas (Control room operator vs. water resources/modeling engineer vs. SCADA engineer)
- Recently, the desire & expectation to have real-time business intelligence is pushing us to change!

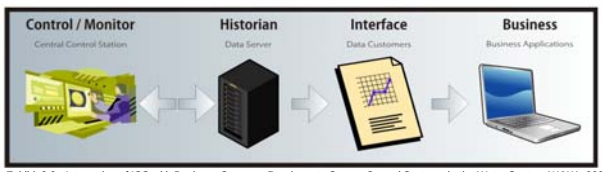

Exhibit 3.2 - Integration of ICS with Business Systems, Roadmap to Secure Control Systems in the Water Sector, AWWA, 2008

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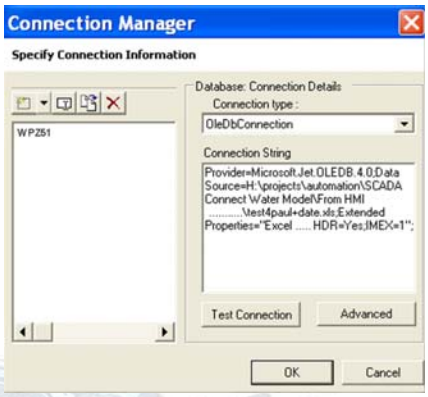
Connecting SCADA Database File to Hydraulic Model

- *Example database connection string to CSV file, SQL server, etc. in commercial modeling platform*



Mature Technology (10+ years)

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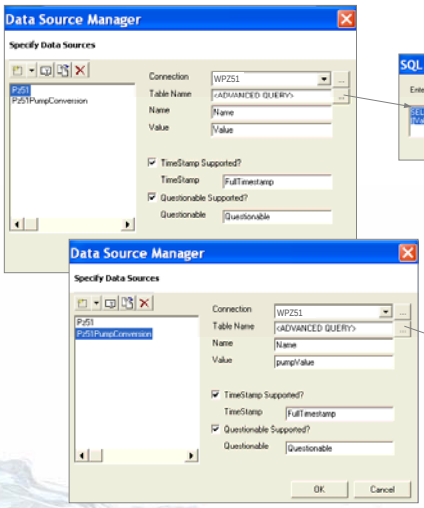
Performing Database Queries to Format Data for Model



Tools already in Commercial Modeling Platforms

- *Date/time merging and data validation query*
- *Pump speed numerical modification*

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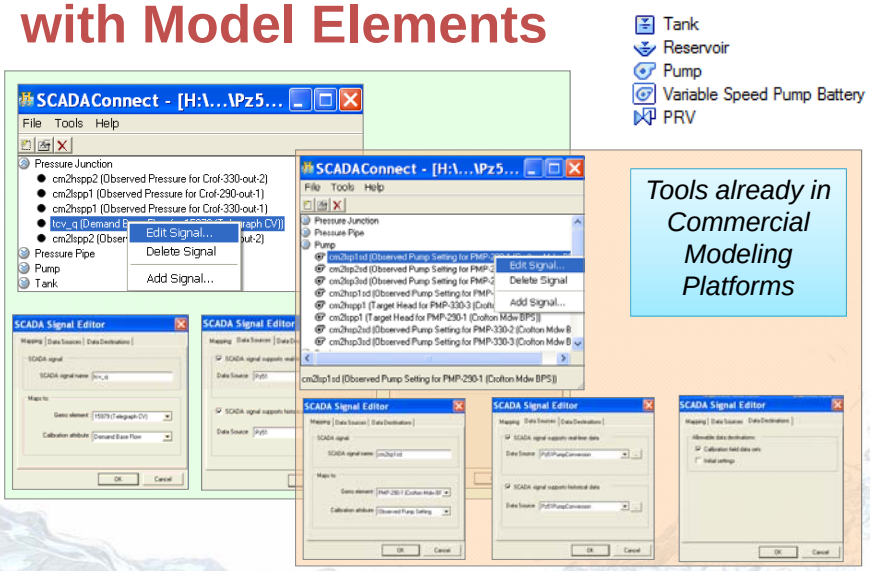
Mapping SCADA Signal (Tags) with Model Elements



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The RTM "Data Dilemma"

#2 – Customer Demand "Data Dilemma"

- A big source of poor calibration of U.S. water distribution models (hydraulic & WQ) – many systems don't have good way to obtain real-time diurnal demand patterns
- Customer billing databases - typically only source of spatial demand data in a U.S. water system (3 months old!)
- In the U.K. single-fed district metered areas (DMAs) – flow meter is connected to SCADA providing high precision spatial / temporal flow data; very rare in the U.S.
- Temporary DMA testing w/ insertion flow meters – been around 100+ yrs, but it can be difficult and expensive!

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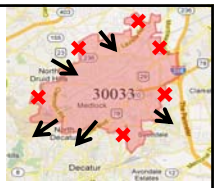
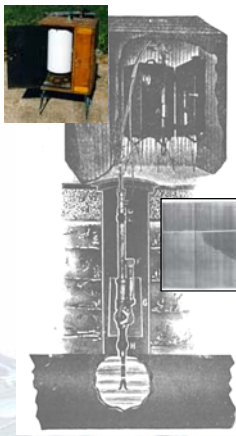
The RTM "Data Dilemma"

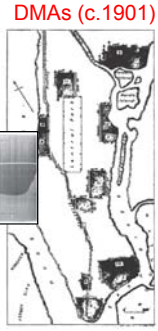


100+ Years of Insertion Flow Metering

Pitometer Street Box



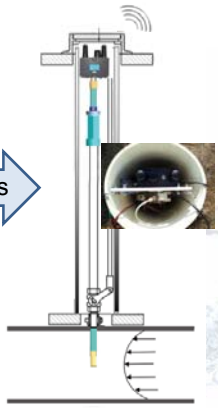
Manhattan DMAs (c.1901)



100 years

New Smart On-line Insertion Flow Meters

(pressure, transient detection, flow, auto air purge solenoid, alarms, real-time web application)



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The RTM "Data Dilemma"

#2 – Customer Demands "Data Dilemma"

- Advancements in Customer Meter Reading → *Manual Reads → Wireless Wand → Drive-by Short Range Wireless → to a Fixed Network Wireless Customer Meters (900 MHz or lower frequency licensed system), also known as Advanced Metering Infrastructure (AMI)*
- Ability to obtain daily demand pattern for each meter will drastically improve network modeling calibration!
- What technology will solve the Demand Data Dilemma in the U.S. first? On-line DMA or customer Advanced Metering Infrastructure (AMR/I)?
- Combination as they emerge over next 5-10 yrs?

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The RTM "Data Dilemma"

#3 – Field Testing (Where You Don't Have SCADA Data)

- Pump tests, hydraulic grade line (HGL) tests (passive and active), master meter flow and DMA tests, pressure monitoring tests, fire flow tests, C-factor tests, fluoride tracer studies, water quality grab samples from Lab Personnel
- For the past 20 years data loggers have been our primary tool for obtaining hydraulic data in hard to reach places
- Even worse, for water quality models we typically use grab sample Cl2 data (none of the WQ data is time synchronized!)

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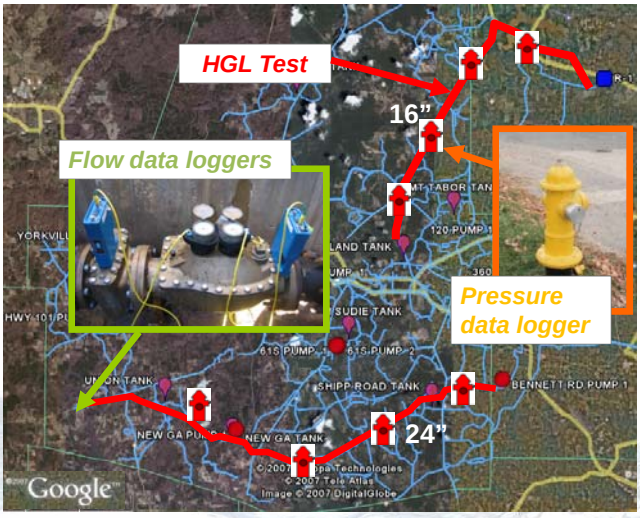
Examples of Traditional Hydraulic Field Tests using Data Loggers

Trunk / Distribution Mains (>12")



Grid Mains (<12")

Fire Flow Tests

Data Loggers in Grid Formation Near FF Test

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#3 – Field Tests (Typical Problems Encountered Using Traditional Data Loggers)

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The RTM "Data Dilemma"

Conclusions:

- Historically, model calibration has been frustrating for some due to the difficulties obtaining good SCADA, customer billing, and field test data
- Recent paradigm shift – new technology is changing how models can be developed, used, and maintained all in real-time
- Exercise 1 will highlight a project where each of the three (3) Data Dilemmas was tackled using innovative approach and technology

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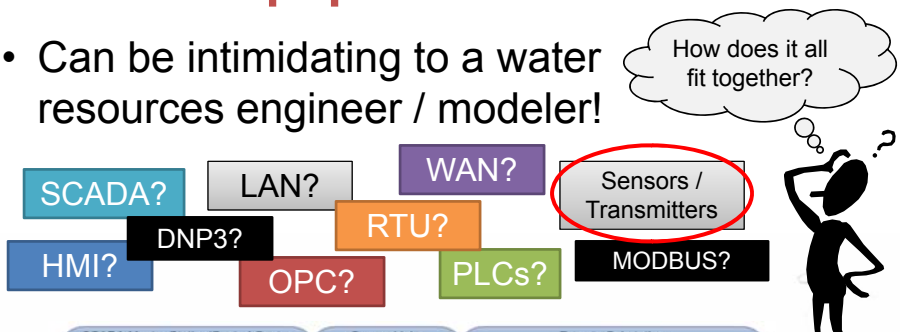
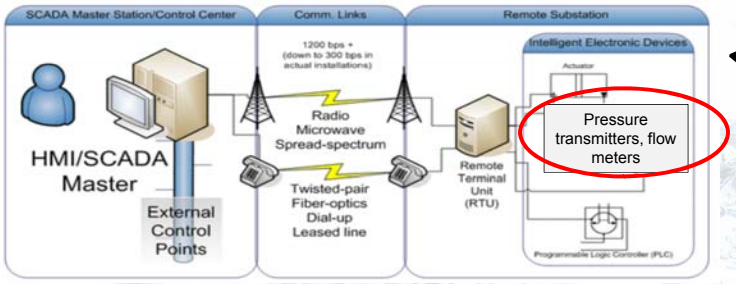
SCADA Equipment & Sensors

- Can be intimidating to a water resources engineer / modeler!





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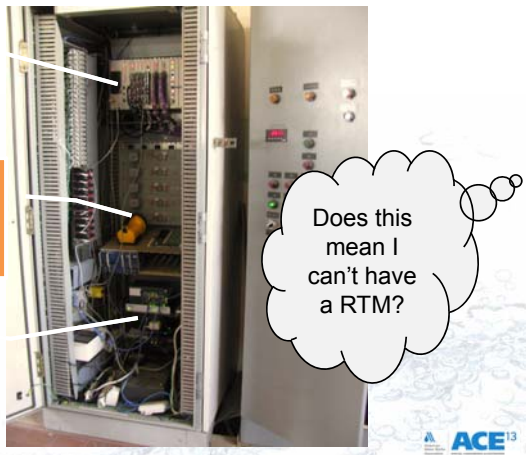
SCADA Equipment & Sensors

- To a water resources engineer ICS/SCADA can look like a Refrigerator Full of Wires!

Freezer
Current PLC with a little freezer burn

Chinese Food from a Month Ago
Old telemetry system left in place during SCADA upgrade15 years ago!

Something's Growing in the Lettuce Bin
Router/ Communications



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SCADA Equipment & Sensors

- SCADA details are really not that important to a modeler, but it's important to:
  - Get both IT & SCADA Departments involved early on in your modeling project
  - Understand how to leverage what you have (existing SCADA) for RTM
  - Get involved in the decision making process on SCADA upgrades and new monitoring points
  - Ask lots of questions; genuinely try to help
  - Take ownership in instrument accuracy (flow meters especially); while they may be accurate enough for Operations, they may not be accurate enough for modeling

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SCADA Equipment & Sensors

"Our flow meters are calibrated twice a year, everything should be pretty accurate."

DP Pressure Transmitter
Anything look fishy to you?

Pump Station
Venturi Flow Meter Vault

What's the Correct Flow Rate?
Can you guess the error?
10%, 30%, 100%?

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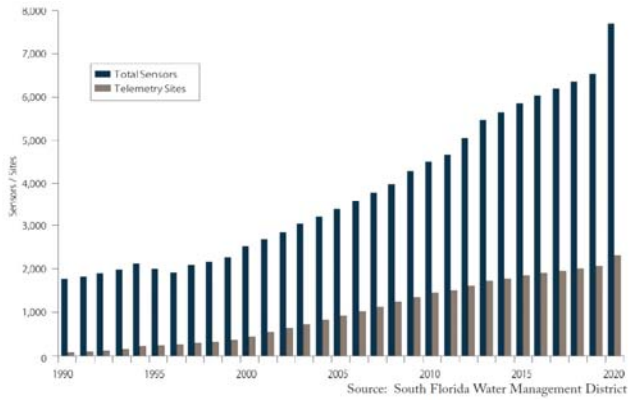
SCADA Equipment & Sensors

- A **New Modeling Paradigm** - Traditional Sensor / SCADA technology may not be adequate to meet future RTM needs for many U.S. water systems



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SCADA Equipment & Sensors

- What you didn't know to ask about traditional SCADA / sensor technology:
  1. Why is SCADA typically only located at facilities (i.e. pump stations and tanks), a small fraction of the entire WDS network?
  2. Why are traditional remote monitoring stations (hydraulic and water quality) so expensive!
     - Installing a remote pressure monitoring station + SCADA integration ($10k)
     - Installing SCADA at existing pressure reducing valve (PRV) station that lacks power ($25k)
     - Installing a remote multi-parameter water quality monitoring station + SCADA integration ($50k+)

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SCADA Equipment & Sensors

- Why traditional Sensor/SCADA technology may not be the ultimate solution for RTM:
  - Traditional SCADA engineered for each particular situation (high $)
  - Typical sensors/SCADA hardware has high power requirements (i.e. requires AC power or installation of mast and large solar panel)
  - Above problem dictates a permanent installation….requires facility hardening to prevent vandalism….engineering design, etc.
  - Integration with existing SCADA HMI
  - This is why single site installation typically takes many months to implement…..high cost $
  - Multi-parameter WQ stations typically have high O&M.

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SCADA Equipment & Sensors

- Next generation of SCADA requires:
  - Low power (can operate on batteries for year+)
  - Portable (can move around the system quickly and easily connect to hydrants or blow-offs, etc.)
  - Cellular, satellite, Super-WiFi ready
  - Integrated with on-line web application (install & data is instantly available in minutes)
  - Easy to use and low O&M
  - **What if you could customize your own SCADA system for WDS modeling?**

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SCADA Equipment & Sensors

- Review 3 Types of Next Generation Online Sensor Technology:
  - Simple pressure and transient "monitoring"
  - Multi-parameter "monitoring" (pressure, transient detection, multiple water quality parameters…Cl2, pH, turbidity, conductivity, etc.)
  - Multi-parameter "monitors and controllers/optimizers"

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Examples of Portable On-line Sensors
(#1 - Pressure & Water Hammer Only)

- Aquas SWIM-1, Telog HPR-32
- Important questions to ask?
  - Can device be upgraded for water quality monitoring?
  - Both web app & traditional SCADA integration?
  - Re-purpose device for other SCADA applications?
  - Database schema supports RT model link & model calibration applications?
  - Battery life and options? # of uploads per day? Instant SMS and upload during alarm or transient event? Transient capture functions?

Aquas SWIM-1

Telog HPR-32

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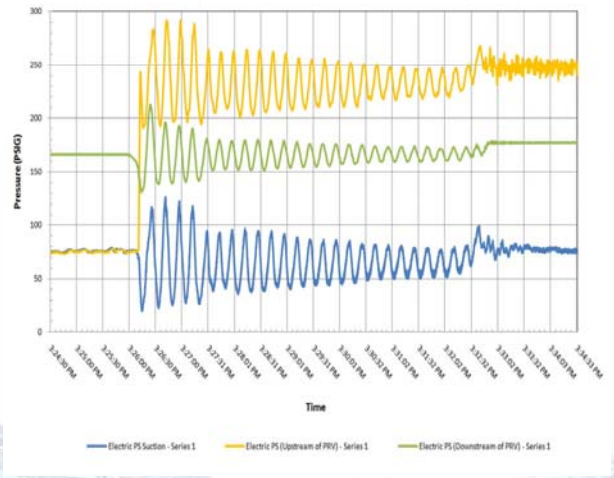
Portable On-line Sensors
(Actual Pressure Transient Data!)



Aquas SWIM-1

Why wasn't this noticed during the pump station preliminary design phase?

Transient monitoring / modeling can provide enormous value vs. a ruptured pipeline

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Examples of Portable On-line Sensors
(#2 - Multi-Parameter Water Quality)

- Aquas SWIM-2, W&T Hydraclam
- Additional questions to ask?
  - Same points as previous slide…
  - Almost all water quality analyzers require AC power or solar panels (not practical!)
  - Require a SCADA professional to set up?
  - Does it use CDMA cellular network (GPRS not adequate coverage in U.S.)
  - Can you make remote config changes?
  - Long deployment w/ no maintenance (6 months)? Self cleaning sensors?

Aquas SWIM-2

W&T HydraClam

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The Need for Portable On-line Sensors (Multi-Parameter Water Quality)

- Utility having to dump contents of remote storage tank on multiple occasions due to low chloramine residual problems! Nitrification anyone?

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Examples of Portable On-line Sensors (#3 - Multi-Parameter WQ Controllers/Optimizers)

- Kupferle i9700 w/ Aquas PRO RTU – Intelligent sensing / flushing system
  - Monitors pressure, transients, and flushes pipeline based on chlorine residual set-points (i.e. <0.2 ppm) or other parameters
  - Minimizes water waste while providing important data for modeling and system optimization

Kupferle i9700 w/ Aquas PRO RTU

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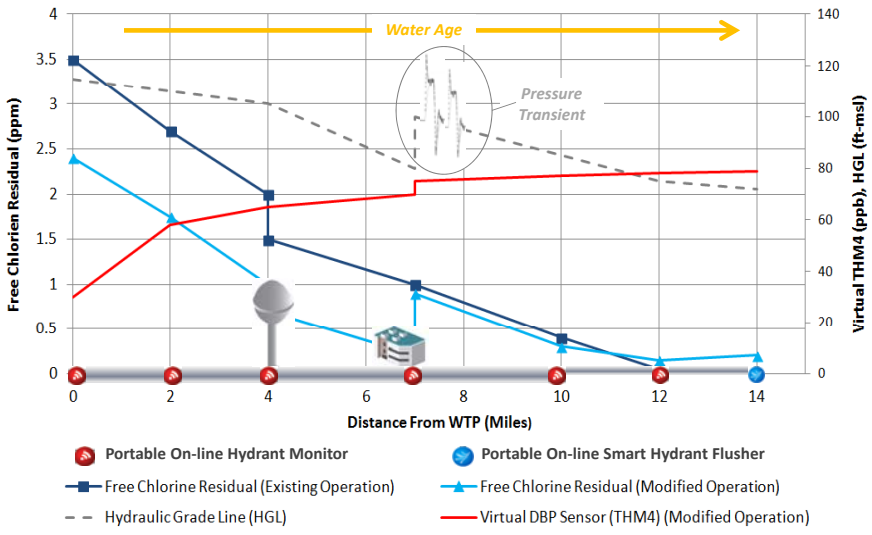
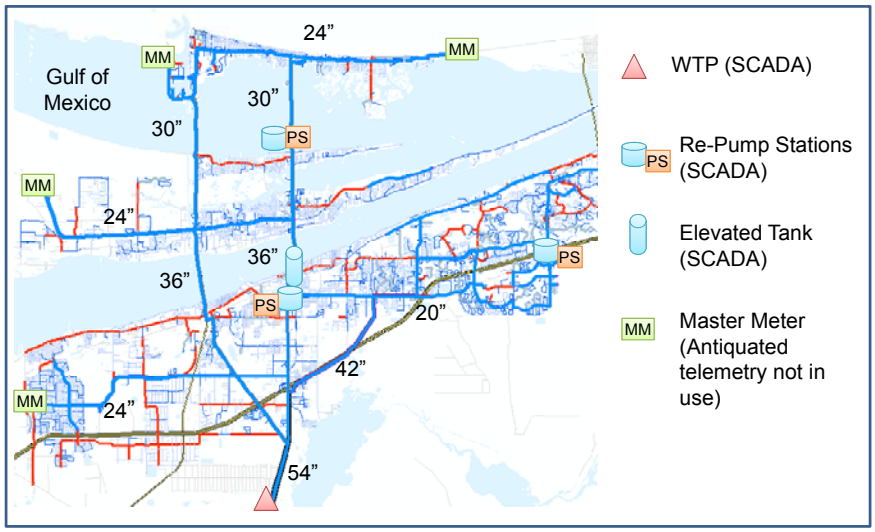
Real-time Hydraulic & Water Quality Data Profile *(WTP → Remote End of WDS)*



Example Project Where the 3 Data Dilemmas Addressed in Real Time *(Will Lead to Exercise 1)*

- Large Water System near Gulf of Mexico, WTP = 30 MGD (ADD), 3 Re-Pump Stations, 1 Elevated Tank (all have SCADA but are manually operated), no pressure zones
- 4 master meter sites to neighboring utilities (not on SCADA system), & potential high Q from a large industrial customer
- Water utility has never built a WDS model and wants Master Plan / CIP completed in 9 months!
- Utility wants a high-accuracy model calibration (we recommend pump tests, HGL tests, fire flow tests, DMA tests)

Example Project Where the 3 Data Dilemmas Addressed in Real Time



Example Project – The 3 Data Dilemmas Addressed in Real Time

- Schedule dictates model calibration must be completed in 4 months from NTP (and we are contending with Christmas Holidays! ☺)
- To complicate matters, an inter-coastal transmission main (36”) would be taken out of service for 2 weeks during the 4 month period.
- Key consulting staff are located in different States.
- We have an $80k SCADA/field testing budget. Can’t afford for staff to reside at water utility for 3 months.
- So how did we go about this???

Example Project – the 3 Data Dilemmas Addressed in Real Time

- Developed on-line system to allow field tests & model calibration to occur simultaneously (stack activities); stakeholders collaborate on-line
- Additional obstacle - SCADA administrator would not allow network connection to push data from SCADA Historian to external server
- Initial site visits revealed pump stations, master meters, and tank signals could be intercepted using Telemetry Overlay Module *(low cost cellular RTU that sits in electrical loop that can replicate facility operational data to a remove server)*

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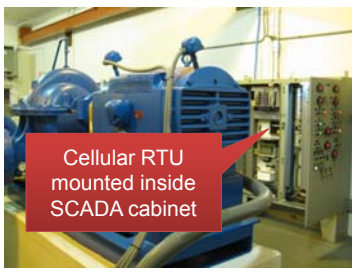
Example Project – Where the 3 Data Dilemmas Addressed in Real Time

- We created a Telemetry Overlay Network in 1 month from NTP *(8 facilities, 10 portable monitors)*

Fixed RTUs at master meter sites



Fixed RTUs at pump stations integrated with existing SCADA *(telemetry overlay network – has no ability to control pumps)*

Mobile RTUs *(HGL, FF tests, DMA insertion FMs)*

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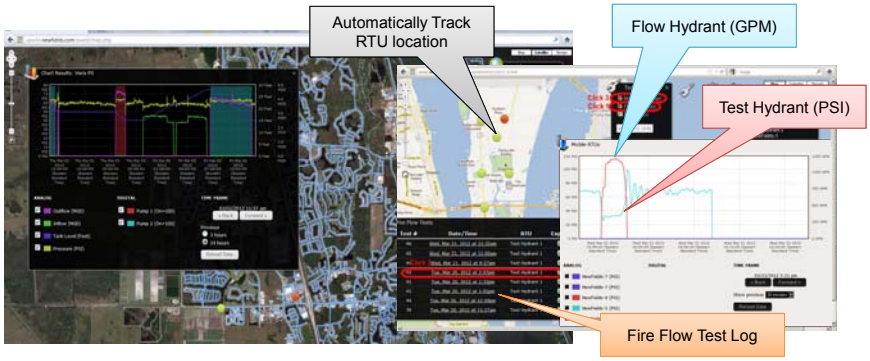
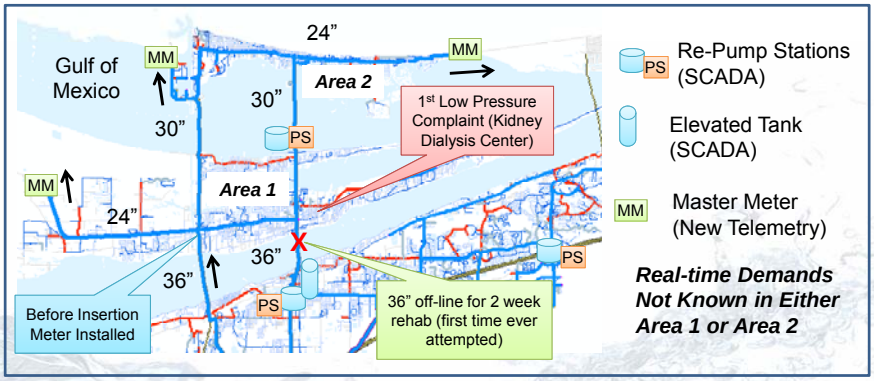
Example Project – The 3 Data Dilemmas Addressed in Real Time

- On-line Web Application *(In real-time monitored all facility operations, HGL tests, fire flow tests, and remotely coordinated with operators and field staff)*



Exercise 1 – What's Causing Low Pressure During 36" Pipeline Rehab?

- Exercise will demonstrate the value of real-time data and on-line collaboration with stakeholders



SCADA Security – Today's Topics

- "Security thru obscurity" doesn't apply any more
- Industry trend toward Business Intelligence
- Connecting SCADA to corporate LAN or backdoors for maintenance - Security questions to ponder
- Water System Realities - 911, Stuxnet, Trend Micro Honey Pot Test Case
- SCADA vs. IT departments
- Several generic approaches NF proposes to moving data to a RTM
- AWWA resources

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SCADA Security – Questions to Ponder

- What would be the consequence of SCADA cyber-attack? What the worst that could happen?
  Overdose chlorine feed at remote booster station? Turn off pumps? Change controls?
- How long could you operate manually and how would Operations change if SCADA working was not working?
- How sure are you that the SCADA systems is secure?
- When was the last time we performed cyber security vulnerability assessments?

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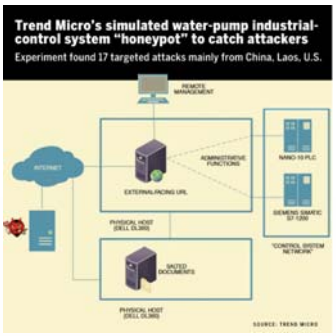
SCADA Security – Honey Pot

- **Honey pot (trap)**
- In Nov 2012, Trend Micro created a fairly open, fictitious "internet facing" U.S. water pump station SCADA system



- Within months, 17 serious targeted attempts were made to disrupt pump station operation from all over the world *(shut down pumps or changed controls)*

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SCADA Security – Stuxnet

- Very advanced virus/worm designed to alter Siemens PLC at Iranian Nuclear Enrichment Facility
- Sophisticated manipulation of PLC code to run centrifuges at different speeds yet report to control room alternate yet normal operating conditions; ultimately destroyed centrifuges
- Fear in water supply community – Could a similar type of sleeping virus/worm infect PLCs found in most pump and chemical feed stations?

*en.wikipedia.org/wiki/**Stuxnet***

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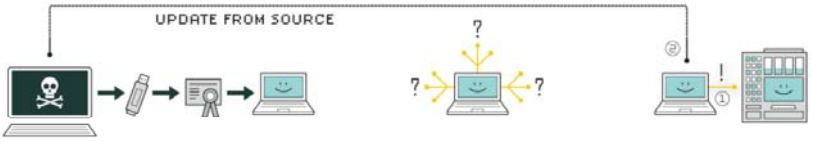
SCADA Security – Stuxnet



1. infection
Stuxnet enters a system via a USB stick and proceeds to infect all machines running Microsoft Windows. By brandishing a digital certificate that seems to show that it comes from a reliable company, the worm is able to evade automated-detection systems.

2. search
Stuxnet then checks whether a given machine is part of the targeted industrial control system made by Siemens. Such systems are deployed in Iran to run high-speed centrifuges that help to enrich nuclear fuel.

3. update
If the system isn't a target, Stuxnet does nothing; if it is, the worm attempts to access the Internet and download a more recent version of itself.

4. compromise
The worm then compromises the target system's logic controllers, exploiting "zero day" vulnerabilities-software weaknesses that haven't been identified by security experts.

5. control
In the beginning, Stuxnet spies on the operations of the targeted system. Then it uses the information it has gathered to take control of the centrifuges, making them spin themselves to failure.

6. deceive and destroy
Meanwhile, it provides false feedback to outside controllers, ensuring that they won't know what's going wrong until it's too late to do anything about it.

IEE - Institute of Electrical and Electronics Engineers

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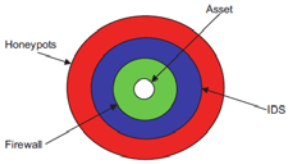
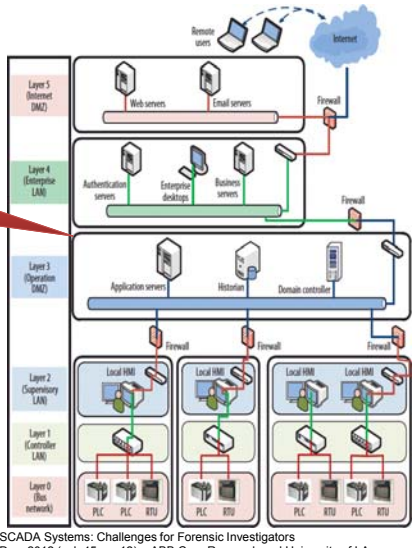
SCADA Security – Defense in Depth

- Multiple layers to reach asset (policies technologies, and techniques)
- Active monitoring – Intruder Detection Systems (IDS), HPs, etc.

Air Gap is Still Best Defense

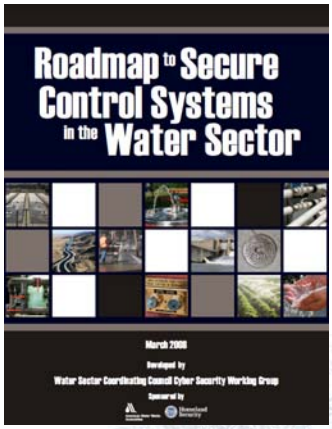




SCADA Systems: Challenges for Forensic Investigators
Dec. 2012 (vol. 45 no. 12) – ABB Corp Research and University of LA

SCADA Security

- Water Sector Coordinating Council (WSCC) and Cyber Security Working Group (CSWG) jointly sponsored by the AWWA and the U.S. DHS National Cyber Security Division.
- Focuses on the goals and strategic milestones for improving the security of ICS in the water and wastewater infrastructures over the next decade

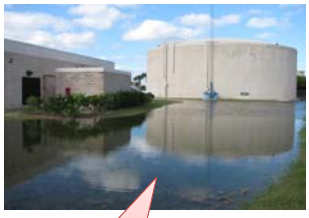


Next Generation Empirical "Data Driven" RTMs

- A provocative question – are "physics-based" pipe-node network models the only tools powerful enough to simulate water quality in the WDS?
- Empirical "data driven" artificial neural network (ANN) models have been used in practical applications for over a decade
- Accurately predict daily water quality out in the WDS from WTP→Customer (THMs, HAAs)

Next Generation Empirical "Data Driven" RT Water Quality Models

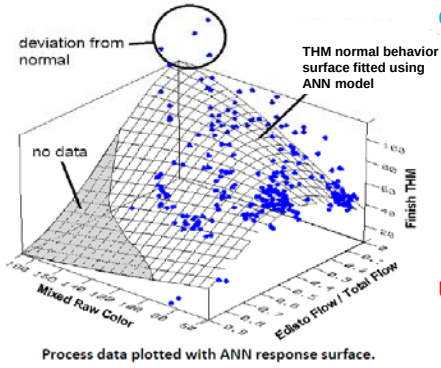
- A common pitfall of traditional water quality "network" modeling (same applies for RTM)
  - Forcing a highly precise network model computation based on inaccurate hydraulics to predict WQ
  - As an industry, we have calibrated WQ models based on non-synchronized (i.e. weeks and months apart) grab sample data provided by the water utility (i.e. chlorine residual)
  - Obtaining good RT WQ data is difficult out in the WDS!
- We may have similar problem transitioning to "real-time" space without a new paradigm



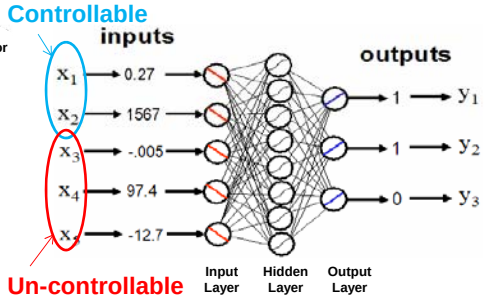
Shouldn't this water be in the storage tank?

Next Generation Empirical "Data Driven" RT Water Quality Models

- Artificial Neural Networks (ANN) models
  - Form of Machine Learning
  - Non-linear, multivariate curve fitting
- Sub and Super Models
  - System model = "supermodel" composed of multiple "sub-models"



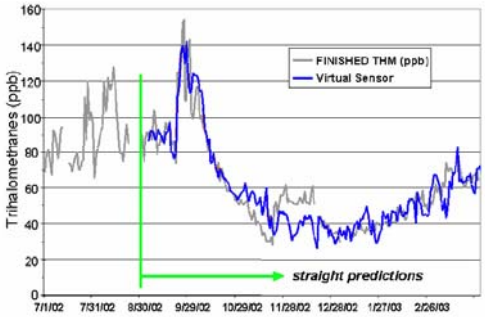
Process data plotted with ANN response surface.

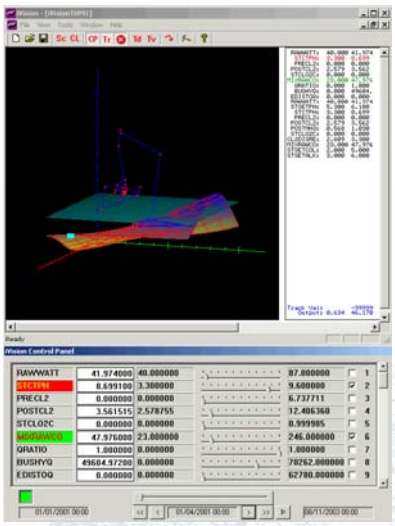


Courtesy of Advanced Data Mining International (ADMI)

Next Generation Empirical "Data Driven" RT Water Quality Models

- THM Predictions in WDS network using real-time ANN Model

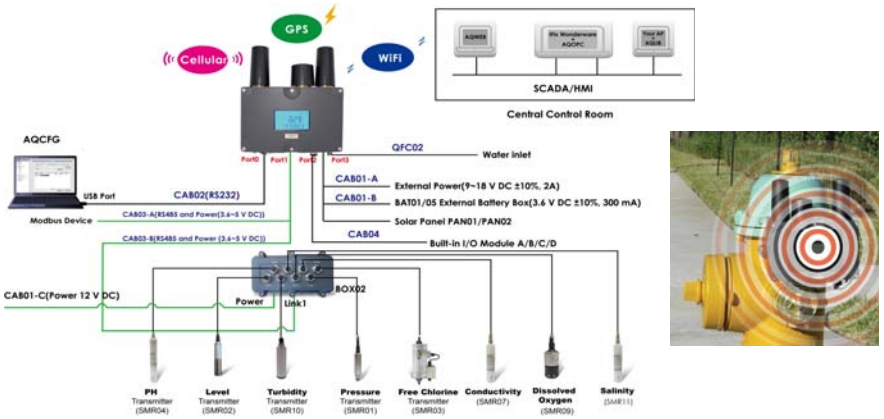




Courtesy of Advanced Data Mining International (ADMI)

Exercise 2 – Demonstration of Next Generation On-line WDS Sensors

- Software/hardware configuration & live link test with remote server and on-line web application



The End

Thank You!

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