Hydraulic Modeling – Predicting and Resolving Water Quality Issues

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Presentation Summary

- Hydraulic Water Modeling Overview
- Water Quality Modeling
  - What is it, How is it accomplished, Why it is beneficial
- Case Studies
Water System Models – Almost Every Community Needs One!

- Current System Conditions
- Design Information and Results
- Planning Tools
- “What ifs”? 

What is a Water Model?

- Computerized representation of a real water distribution system
- Pipes, nodes (pipe junctions/demand points), valves, reservoirs, storage tanks, pumps, etc.
Water System Models Used to Support Many Decisions

- Simulate various hydraulic scenarios and conditions
  - Steady state (snapshot in time)
  - Extended Period Simulation (EPS)
  - Fire Flow
  - Water Quality (Age)
  - Transients (Surge)

Courtesy of: Strand Associates, Inc. ©, Kentucky American Water Company Northern Division Connection Project, 2013
Accurate Model Development Requires Utility Input

- All Pipes Valve (APV) vs. Skeletonized Model
- Calibration
- Demand
- Accurate Source Information
- Accurate Control Schemes

Model Development Can Be Very Simple

- **APV** – All Pipes and Valves (often excludes service lines)
- **Skeletonized** – Eliminates some smaller diameter mains
### Additional Detail has Benefits

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>APV</th>
<th>Skeletonized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development Cost</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Higher</td>
<td>Moderate</td>
</tr>
<tr>
<td>Processing</td>
<td>Slower</td>
<td>Faster</td>
</tr>
<tr>
<td>Licensing</td>
<td>More Expensive</td>
<td>May be less depending on link breakpoints</td>
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<tr>
<td>Analyses (Fire Flow, Water Quality, EPS, and Steady State)</td>
<td>Best</td>
<td>May be limited depending on degree of skeletonization</td>
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Accurate System Mapping Efficiently Develops a System Model

- Manual process – Plans sets/Drawings
- Automated process – Building tools in modeling software via GIS
  - Mains
  - Nodes
  - Elevations
  - Pumps
  - Tanks, etc.
Good Calibration Yields Confident Results

- Adjusting data until observed (SCADA) values are similar to modeled values
- Fire flow tests
- Pump tests
- C-factor tests

Courtesy of: Strand Associates, Inc. ®, Hardin County Water District No. 1 IDSE Water Modeling, 2008
Distributing the System Demand has Options

- Location of Demand
  - Actual Consumption
  - Estimated Consumption
  - Large Users
  - Global/Blanket
Daily Water Demand Curve Unique to Each System

- Diurnal Demand
  - Standard AWWA
  - Created from tank / flow data

AWWA M32


Controls Play Big Role in Model Development

- Logical Controls – Based on System Hydraulics
- Simple Controls – Based on Time
- SCADA

Courtesy of: Strand Associates, Inc. ®, Central City River Water Pumping Station and Water Treatment Plant Expansion, 2012
Water Quality Modeling Goes Beyond System Hydraulics

- Utilizes the water model to simulate movement of water and constituents through a distribution system
- Models the growth/decay of constituents
  - Water Age
  - Chlorine(-amine) Residuals
  - Phosphates
  - DBPs
  - Source Blending
  - Temperature
How is Water Quality Modeling Accomplished?

- Based on conservation of mass and reaction kinetics, the following apply\(^1\):
  - Advective transport in pipes
  - Mixing in Storage Facilities
  - Bulk Reactions
  - Mixing at Pipe Junctions

\(^1\)(Rossman et al. 1993)
Contaminants May Travel by Advective Transport or React Over Time

- Constituents travel at same velocity as carrier fluid
- Constituent reactions occur during travel at a specified growth or decay rate (K Value)

\[ [A] = [A]_0 e^{-kt} \]
Storage Facility Mixing Impacts Water Quality

- Completely Mixed
  - Ex: Tank with a mixing system installed

- Two Compartment Mixing
  - Ex: Large tanks with stratification issues

Source: EPANET 2 Users Manual, USEPA, 2000
Mixing in Storage Facilities

- **FIFO (First in First Out)**
  - Ex: Elevated tank with inlet near top and outlet near bottom

- **LIFO (Last in First Out)**
  - Ex: Tall, narrow standpipe, inlet and outlet near bottom of tank

Source: EPANET 2 Users Manual, USEPA, 2000
Constituent Reactions Occur Inside Water Mains

- Bulk Reactions and Wall Reactions
- Variable Reaction Rates
  - Linear – Water Age
  - Growth – DBPs
  - Decay – Chlorine Residual

Source: EPANET 2 Users Manual, USEPA, 2000
Wall Reactions Are a Major Source of Contaminants

- Dissolved substances are transported to the pipe wall and react with corrosion products or biofilm, or particulate matter on the wall.
Pipe Walls and Tanks Produce Most Reactions

Source: Infowater Users Guide, p 4-38
Water Quality Model Calibration Increases Confidence

- Verification of Water Quality Results
- Constituent Residuals/Concentrations
  - Compare Model Results to Actual Sample Data
- Water Age
  - Tracer Study
Good System Models Return Many Financial Benefits

- Issue Resolution Cost = $0 to $?????
- Identify unintended consequences
- Prevent future issues
- Quickly review numerous alternatives
Reliable Models Provide Regulatory and Planning Benefits

- Previous WQ Regulation focus on water leaving WTP
- Higher focus on WQ delivered to customers (Flint Michigan)
- High speed, low cost analysis and checks based on real-world data

Models Improve Success of Common WQ Resolution Strategies

- Flushing Strategies
- Zone Boundary “Bleed Water” strategies
- Operational Changes
- Tank Mixing
- Appropriate Water Main Sizing
- Eliminate Dead Ends
- Modeling Case Studies
Models Help Generate Beneficial Flushing Strategies

- Automatic vs. Manual
- Locations
  - Dead end mains
  - Areas of limited accessibility
- Quantity and Frequency
Models Identify Best Uni-Directional Flushing Strategies

- Systematic closing of valves to flush a main in a single direction
- Conserves water and scours/cleans mains
Models Demonstrate Benefit of Zone Boundary Bleed

- Small Diameter Bleed Bypass at Zone Boundaries
- Small, Steady flow from high to low pressure zone
- Low Cost
- Moves water at dead ends
- Reduces water age
Operational Changes are Quickly Modeled to Evaluate Benefits

- Increase tank operating range
- Example:
  - If tank maintained with 8 feet of overflow, increase to 10-12 feet
- Use model to determine WQ benefits and check system pressures
Model Runs Evaluate Tank Mixing Options

- Eliminates ‘dead zones’ and stratification
- Static vs. Dynamic

Static

Dynamic

With Permission of: Red Valve Company, Inc. - Tideflex Technologies Division, 2016

With Permission of: PAX Water Technologies, 2016
Modeling Water Main Size Changes Avoids Water Age Problems and Saves Money

• Larger Mains are Not Always Better!
• Larger Diameter = More System Volume
• More System Volume = Higher Water Age
• Use combination of Hydraulic and WQ Modeling to Determine Size
Model Demonstrates Benefits of Eliminating Dead End Mains

- Depending on demand, can cause water quality problems
- Common location for Uncirculated Water
Case Studies – DBP Test Location Evaluation Improves Confidence

Courtesy of: Strand Associates, Inc.®, Joliet Water Model Update, 2010
Case Studies – System Looping Reduces Water Age

Existing System

Additional Looping to Eliminate Dead End Mains

Case Studies – Modeled Looping Demonstrates Improvements to Water Age

Existing System

Additional Looping to Eliminate Dead End Mains

Courtesy of: Strand Associates, Inc.®, Harrison County Water Association Water Distribution Disinfection Byproducts Analysis, 2014
Case Studies – Modeling Also Predicts Unintended Consequences

Existing System

Additional Looping to Eliminate Dead End Mains Caused Overall Increase in Water Age

Case Studies – Modeling Tank Operation Shows Benefits of Changes

Existing Operation

Tank Mixing and Increased Tank Drawdown Depth

Courtesy of: Strand Associates, Inc. ©, Harrison County Water Association Water Distribution Disinfection Byproducts Analysis, 2014
Case Studies – Modeled Water Age Yields Efficient Flushing Program

Water Age Simulation Identifies Problem Areas

Automated Early Morning Flushing – Maintains Pressure and Reduced Water Age by ~100 hours

Courtesy of: Strand Associates, Inc. ®, Harrison County Water Association Water Distribution Disinfection Byproducts Analysis, 2014
Case Studies – Model of Storage Tanks Demonstrates Benefit of Operational Changes

- System with 8 ground storage tanks
- Each filled and drained 1/3 each day, labor intensive operation
- Used model to develop a Rotating Tank Cycle with 3 Groups
- Showed a simpler operation without compromising service to customers
Use of Existing Resources Benefits Utility Owners

- Modeling Software Staff
- AWWA, EPA, etc. Reference Guides
- Consulting Engineer
Today’s Water System Model Predicts and Helps to Resolve Water Quality Issues

Questions?

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Thank you!