Developing Unidirectional Flushing Programs in a Water Distribution System

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Outline

Unidirectional Flushing
Why, When, Where, What, How?

Developing A Program

Hydraulic Models & GIS Data
– Benefits of Integration

Case Study

Questions/Answers
Components of a Distribution System
Unidirectional Flushing Program

Why You Might Need a Flushing Program

Deciding When and Where to Flush

What Data Will You Need?

How Flushing Works (In the Field, In the Office)
Aging/Decaying Pipes

Sediments and deposits (e.g. alum)

Biofilm build-up

Pits (water corrosivity)

RESULTS

- Increased pumping costs
- Increase in pipe roughness
- Reduction in hydraulic capacity
- Reduction in effective diameter
- Increase in chlorine degradation rate
- Increase in taste and odor problems
Why You Might Need a Flushing Program

In General

To Remove impurities
- accumulated
- associated w/ new and repaired mains
- associated w/ complaints
- hazardous to the public health

In Particular

- Reduce
  - high bacterial concentrations
  - chemical contamination
  - turbidity
- Remove
  - tastes and odors
  - discolored water
  - accumulated sediment
- Respond to customer complaints
- Increase chlorine residuals
- Increase/maintain the life of mains
FLUSHING STRATEGIES

Spot Flushing
Reactive. Most common type of flushing. Used when there are local quality complaints

Stagnant Area Flushing
Short term preventive. Used in areas with longer detention times (i.e. Dead-ends, low demand areas)

System-wide Flushing
Long term preventive. Most comprehensive form of flushing. Maintains WQ and useful life of the mains.
FLUSHING METHODS

- Conventional Flushing
- Unidirectional Flushing
- Continuous Blow-Off
Conventional Flushing

Water from all directions
Low flow velocities
Less scouring
Don’t control flushing direction

Can result in dirty water flushed to clean areas!
Unidirectional Flushing

- Water channeled
- Higher flow velocities
- More scouring/better cleaning
- Systematic valve operation

Uses up to 40% less water!
Continuous Blow-off

- Water “bled” at stagnant areas
- Low flow velocities (<1 fps)
- Less scouring/poor cleaning
- Large quantities of H₂O used
**“Traditional” Flushing**

**When**
- Response to water quality complaints (taste/odor, color; red, brown, other)
- Sanding
- Positive coliform (cross-connection)

**How**
- Go to location
- Open hydrant(s) and flush
- Basically move the problem to a new area
- Wait for additional complaints
Unidirectional: Deciding When and Where to Flush

When: Time

- Monthly, quarterly, semiannually, yearly, etc.
- Seasonally, usually spring or fall for large areas
- Before and after main disinfection
- In response to complaints
- In response to regulatory violations (i.e., high bacterial counts or low chlorine residual)
- Coincides with related programs (i.e., fire hydrant testing or valve inspection programs)
Unidirectional: Deciding When and Where to Flush

Where: Location

- Entire distribution system
- Portions of the system (i.e., older areas and/or chronic complaint areas)
- Mains subject to sedimentation
- Dead ends
- Areas identified by water quality monitoring records
What Data Will You Need?

Data Directly Related to Flushing Program

Data Indirectly Related to Flushing Program

Background Information & Requirements
Data Directly Related to Flushing Program

- Complaint records
- Data for each blowoff or hydrant flushed
- Pressures in mains surrounding the flushing area
- Record of color, odor, clarity, or presence of visible objects or organisms
- Measurements of chlorine, turbidity, dissolved oxygen, pH, temperature
- Sample collected at the time of flushing

- Analyses associated w/ monitoring dedicated to the flushing program
- Maintenance records (i.e., valve/main replacements, relining mains, valve inspections, etc.)
- Fire hydrant testing records by water utility or fire dept.
- Record of unusually high flows (i.e., main breaks or fire fighting)
Data Indirectly Related to Flushing Program

• Record condition of mains, valves and fittings removed from the system as indication of corrosion rates

• Record of routine monitoring program of the system for compliance
Background Information Requirements

**Do**
- Have a flushing plan for each area based on system maps
- Flush from source toward periphery
- Flush one small section at a time to maintain 20 psi
- Flush at night (reduces effect on pressures and capacity and lessens customer complaints)
- Keep flushing velocities in the range of 2.5 to 12 fps (lower velocities for discolored water, higher velocities for sediment removal)
- Know your sensitive customers (i.e., hospitals, laundries)

**Do Not**
- flush a large main supplied by a single smaller main
How Flushing Works (In the Field)

- Notify sensitive customers
  - Hospitals
  - Dialysis clinics
  - Food processing
  - Bottling
  - Specialized manufacturing
    - Micro-chip
How Flushing Works (In the Field)

• Isolate section to be flushed from the rest of the system
  ▪ Close valves slowly to prevent water hammer
How Flushing Works (In the Field)

• Open hydrant/blowoff valves slowly until the desired flow is obtained
  ▪ Direct water away from traffic, pedestrians, underground utility vaults and private lands
  ▪ Confirm storm drains or natural water courses can handle the flow
  ▪ Prevent contaminated water from discharging to sensitive areas
  ▪ Dechlorination may be required
  ▪ Flushing water into a tanker truck may be required
How Flushing Works (In the Field)

- Maintain 20 psi minimum around flushing area
- Record data
- When water clears, close hydrant/blowoff valve slowly
- Reopen valves connecting flushed section to the larger system
- Proceed to next section to be flushed
Obtain information on activities affecting the flushing program
Develop systems for organizing, storing, and retrieving data associated with the flushing program (i.e., paper files, spreadsheets, or databases)
Use WQ records to determine when and where to flush
Routinely flush dead ends and other areas associated with complaints
Increase/decrease periods between flushings using time-to-clear data
Flushing on a WQ basis can be determined by using WQ parameters
Develop costs including labor, equipment, water use, and administration and try to assess benefits
How Flushing Works
(Program Administration)

Design Considerations When Extending the Distribution System

- Locate blowoff valves at low points and dead ends to permit removal of sediment
- Locate hydrants, blowoffs and valves, for minimum disruption to customers
- Design system w/ enough capacity to flush for long periods w/o reducing fire-fighting capacity
- Make allowances for the proper disposal of flushing water
How Flushing Works (Program Administration)

- **Program Champion**
  - Hiring and supervising crews
  - Representing program to the larger water supply organization

- **Equipping**
  - (Developing, purchasing, and maintaining equipment)

- **Keeping public informed**
  - (Giving notice to affected areas, especially sensitive customers)

- **Explaining need for the program to the public**
  - (drought or conservation)
Elements of Unidirectional Flushing Program

Plan

Evaluate

Notify Public

Track

Flush
**Staffing**

- **Flush Program Coordinator**
  - Water Quality Field Services Supervisor
  - Hydraulic Modeler/Student Intern

- **Planning**
- **Training**
- **Monitoring**
- **Data Inputs**
- **Data Analysis**
- **Purchases**
Staffing

- Flushing Crew
  - Crew Leader
  - Utility Worker
- Preparation
- Traffic Control
- Set-Up
- Flush
- Dechlor
Staffing

- Routining Crew
  - Crew Leader
  - Utility Worker

- Checks all Valves
- Checks Lay of Land
- Anticipates Problems
Outline

Unidirectional Flushing
Why, When, Where, What, How?

Developing A Program

Hydraulic Models & GIS Data – Benefits of Integration

Case Study

Questions/Answers
Why Use a Hydraulic Model?

Models are Extremely Valuable Tools for Planning, Engineering and Ops

“One Size Doesn’t Fit All” – each hydraulic system has unique characteristics, and there are Different Platforms Available

Today’s Software Is Extremely Sophisticated, and User Friendly, but…

- Needs high quality input data
- Needs Technical Interpretation, Evaluation and Engineering Judgment
Why Use a Hydraulic Model con’d?

The “Modeling Bar is Raising”

- Static models are no longer the norm
- Calibrated/Verified Operational model

Models Migrating to GIS Interface

Distribution System Models are Important Tools Now, But Are Only Going to Become More Important
What Are Benefits Of Hydraulic System Modeling?

- Designs Are Less Conservative and Expensive
- Calculations Performed Faster and More Accurately
- Better Management of Large Complicated Systems
- Ability to Safely Evaluate Multiple Scenarios Quickly
- Allows More Time to Focus on Alternative Development
- Aid to Communication
Creating A Hydraulic Model

Infrastructure: All Physical Facilities in System
- Develop network topology (GIS data sets, CAD drawing, other)
- Populate topology
- Input facility data
- Populate elevations
- QA/QC of developed model

Demands
- Allocation - Uniform distribution, land use polygons, geocoded meter data

Calibration
- Steady-state, extended period or water quality
Evolution of GIS Integration

Exchange Outside of GIS

Attribute and geometry information is exchanged through a non-GIS database file

Exchange Through GIS

Attribute and geometry information is exchanged through a GIS database file (i.e. Shapefile)

Complete GIS Integration

Model uses the GIS database (i.e. Geodatabase) as the modeling database
Developing Sequences: Historical Methodology

- Engineers must add hydrants and valves to the model as additional model elements (5,000 -> 25,000 pipes)
- Hydrant laterals, emitters, and head losses must be accounted for
- Each sequence must be laboriously set up and analyzed with results stored in an external database
- Flushing maps must be created by hand
- Any change causes a ripple effect that may negate previously determined solutions
- No flexibility in the field
- Very time, labor, and $$ intensive effort
Sequences: Integrated GIS Modeling

- Determine flush zones and set criteria
- Add Hydrants & Valves as Feature Classes
Sequences: Integrated GIS Modeling

Spatial Join finds hydrant-pipe and valve-pipe info

Hydrant lead lengths spatially calculated

Hydrant Emitters automatically assigned based on nozzle diameter
Sequences: Integrated GIS Modeling

User defines each sequence of pipes & hydrants

User defines start time and turnovers or total flush time

Automatic selection of isolation valves to close

Run Sequences and Calculate Results!
Unidirectional Flushing UDF – S1
Unidirectional Flushing UDF – S2
Unidirectional Flushing UDF – S3
Unidirectional Flushing UDF – S4
Unidirectional Flushing UDF – S5
Automated Field Book Creation

Zone: ZONE_1
Sequence: 3

Parameters:
- Date of Flush: 02/06
- Start Time: 12:00
- Duration: 11.2 min
- Hyd. to Open: 120
- Valves to Open: 233, 235, 236, 206, 207, 199, 229, 208, 210, 217
- Valves to Close: 234, 237, 242, 245, 246, 204, 205, 203, 300, 198
- Pipes to Flush: P343, P295, P305, P195

Model:
- Static Pressure: 64.3 psi
- Res. Pressure: 42.5 psi
- Discharge Flow: 1,095.9 gpm
- Available Flow: 1,620.1 gpm
- Total Flushing Pipe Len.: 1,620.1 gpm

Field:
- Int. Turbidity NTD
- Final Turbidity NTD
- Disinfectant Res. Name
- Initial Value
- Final Value

WQ Parameters:
- Min Flushing Vol: 547.2 ft³
- Desired Flushing Vol: 1,641.6 ft³
- Min Flushing Time: 3.7 min
- Desired Flushing Time: 11.2 min

Prepared By:
Benefits of GIS Integration

- Simplifies model building and maintenance
- Provides single repository for data storage
- Provides a visual context for modeling infrastructure
- Provides thematic mapping and plotting of model results
- Allows development of specialized spatial modeling applications
  - Unidirectional Flushing
City of Tracy, CA
Case Study

Population
~74,000
Program Elements

1. Review System Maps and Hydraulic Model
2. Develop Optimized Flushing Program
3. Develop Field Crew Mapbooks
4. Pilot Test Worse Case Areas
5. Develop Implementation Program
1. Developed Map of System for UDF Program

Not the Entire System

Worked with O&M Staff to Verify Locations for Hydrants, Valves, and Blow-offs
1. Developed Seasonal Diurnal Curves

Normal Flow Paths and Direction of Water Movement in System Under Typical Seasonal Demands

Puts the “Uni” in Unidirectional flushing

Fall Diurnal
Summer Diurnal
Spring Diurnal

Spring average demand = 63% of annual average
2. Optimized Program

1. Divide System into Sectors

- Sequenced to moving water from clean to dirty areas
- Configured for a minimum velocity of 6 feet per second
- Configured to maintain minimum pressure for basic service and fire flows (30 psi)
- Loops sized for completion by flushing crew in 1 day
2. Divide Sectors into Loops

- Sized for completion by flushing crew in 1 day
- Assures valves don’t stay closed for extended periods
- Alphabetically sequence assures clean water moves into dirty areas (and not vise versa)
3. **Field Mapbooks**

- Detailed Steps
- Step-by-Step Specific for Each Loop
- Color Coded Maps
- Test Sheets (feedback)
4. Pilot Testing

<table>
<thead>
<tr>
<th>Worst Case Loops</th>
<th>Best Case Loops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assess extent of any needed repairs</td>
<td>Road tests Mapbook procedures with field staff</td>
</tr>
</tbody>
</table>

Lesson Learned: Field Reconnaissance (Hydrant, Valves and Blow-offs) and include time to exercise valves
5. **Implementation**

- **Safety**
  - Accident Prevention, Emergency Response, Traffic Control, First Aid

- **Response Plans**
  - Predict and Plan: WQ Complaints, Ruptures, Stuck Valves, etc.

- **Public**
  - Raise Need Awareness, Give Notice, Stick to Schedule
5. **Implementation**

- **Pre-Flush**
  - Mark Hydrants, Clean Valve Boxes, Exercise Valves, Identify Potential Problems
- **Site Visit**
### Before The 2005 Program

#### Location Specific Graphics

#### After InfoWater Output

<table>
<thead>
<tr>
<th>Zone</th>
<th>900/LK</th>
<th>Hydraulics</th>
<th>Hydrant 1</th>
<th>Hydrant 2</th>
<th>Water Quality</th>
<th>Initial Value</th>
<th>Final Value</th>
<th>Initial Value</th>
<th>Final Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Time</td>
<td>0:00</td>
<td>Res. Pressure</td>
<td>17.1 psi</td>
<td>1.08 psi</td>
<td>Turbidity</td>
<td>10.0 psi</td>
<td>1.08 psi</td>
<td>Turbulent</td>
<td>10.0 psi</td>
</tr>
<tr>
<td>Duration</td>
<td>28.2 min.</td>
<td>Discharge Rate</td>
<td>10.0 gpm</td>
<td>10.0 gpm</td>
<td>Disinfected</td>
<td>10.0 gpm</td>
<td>10.0 gpm</td>
<td>Disinfected</td>
<td>10.0 gpm</td>
</tr>
<tr>
<td>Open</td>
<td>Yes</td>
<td>Available Flow</td>
<td>10.0 gpm</td>
<td>10.0 gpm</td>
<td>pH</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Valves</td>
<td>Open</td>
<td>Total Flowing</td>
<td>10.0 gpm</td>
<td>10.0 gpm</td>
<td>TDS</td>
<td>10.0 gpm</td>
<td>10.0 gpm</td>
<td>TDS</td>
<td>10.0 gpm</td>
</tr>
<tr>
<td>Valves</td>
<td>Closed</td>
<td>Min. Flowing Val</td>
<td>10.0 gpm</td>
<td>10.0 gpm</td>
<td>Odor</td>
<td>10.0 gpm</td>
<td>10.0 gpm</td>
<td>Odor</td>
<td>10.0 gpm</td>
</tr>
<tr>
<td>Pipes</td>
<td>In-Flow</td>
<td>Deemed Flushing</td>
<td>9.3 min.</td>
<td>9.3 min.</td>
<td>HPC</td>
<td>10.0 gpm</td>
<td>10.0 gpm</td>
<td>HPC</td>
<td>10.0 gpm</td>
</tr>
</tbody>
</table>

Prepared By: [Signature]

Date: 8/16/2007 8:17:36 AM

Legend:
- Flushing Hydrant
- Closed Valve
- Open Valve
- Flushed Pipe
- Flushing Pipe

Note:
Before The 2005 Program

After InfoWater Output

Location Specific Graphics
## Sequencing Table

**Before The 2005 Program**

**After InfoWater Output**

### Table 1: Sequencing Table

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Initial System from Mathews to 7302</td>
<td>220</td>
<td>110</td>
<td>945</td>
</tr>
<tr>
<td>2.</td>
<td>Park Valley and Bash Groenew Dr from Yacht to Grunewald Dr</td>
<td>340</td>
<td>100</td>
<td>240</td>
</tr>
<tr>
<td>3.</td>
<td>Rush Rhees Avenue, Sedgefield Avenue to Grunewald Dr</td>
<td>280</td>
<td>110</td>
<td>170</td>
</tr>
<tr>
<td>4.</td>
<td>Rush Rhees Avenue, Sedgefield Avenue to Grunewald Dr</td>
<td>280</td>
<td>110</td>
<td>170</td>
</tr>
<tr>
<td>5.</td>
<td>Rush Rhees Avenue, Sedgefield Avenue to Grunewald Dr</td>
<td>280</td>
<td>110</td>
<td>170</td>
</tr>
</tbody>
</table>

### Table 2: Model Results

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
<th>Value [gpm]</th>
<th>Parameter</th>
<th>Value [gpm]</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Open Valve</td>
<td>220</td>
<td>Static Pressure</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Open Valve</td>
<td>220</td>
<td>Static Pressure</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Open Valve</td>
<td>220</td>
<td>Static Pressure</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>Open Valve</td>
<td>220</td>
<td>Static Pressure</td>
<td>85</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The tables and diagrams are placeholders and do not reflect the actual content of the document.
**Conclusion**

**CIP Savings**

8” Diameter, 340 feet long pipe

<table>
<thead>
<tr>
<th>Demand</th>
<th>C-Factor</th>
<th>HL</th>
<th>Velocity</th>
<th>Pres. U/S</th>
<th>Pres. D/S</th>
<th>Pres. Drop</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 gpm</td>
<td>40</td>
<td>0.00</td>
<td>0.03</td>
<td>54.28</td>
<td>54.28</td>
<td>0.00</td>
<td>No Fire Flow</td>
</tr>
</tbody>
</table>

- Flush instead of constructing new facilities (or delay them)
- Reduce pumping costs (long-term) due to less head to pump against
- Use pilot testing to determine $/pipe-mile for UDF, and obtain metrics for postponing/eliminating CIP facilities
Conclusion (Con’t)

Hydraulics

- Helps control corrosion
- Removes sediments without damaging pipes
- Restores system flows and pressure
- Restores hydraulic capacity of mains
- Prolongs system life

Water Quality

- Restores disinfectant residual
- Reduces disinfectant demand and DBP concentrations
- Curbs bacteria regrowth
- Dislodges biofilm
- Eliminates taste and odor problems
- Improves water quality
- Diminishes potential for waterborne disease outbreaks
- Assists in meeting regulatory compliance

Unparalleled calibration data!