Development and Implementation of a Unidirectional Flushing Program

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Distribution Seminar

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Outline

• Concept of Unidirectional Flushing (UDF)
• UDF Program in Sault Ste. Marie
• Hydraulic Modelling for UDF
• Field Testing (UDF) Procedure
• Field Testing (UDF) Results
• Summary
• Acknowledgements
Concept of Unidirectional Flushing
Issues with Aging Decaying Pipes

Aging Pipes

- Sediments
- Deposits
- Biofilm build-up
- Pits (water corrosivity)

Results

- Taste and odor
- High turbidities
- Chlorine degradation
- Increase pipe roughness
- Increase O&M Costs
- Reduction in hydraulic capacity
What is Unidirectional Flushing (UDF)

• The systematic closing of valves and opening of hydrants to obtain adequate pipe scour velocities to flush debris, dirty/discolored water from the distribution system

Source: Photos from Florida Water Resources Journal, December 2009
Unidirectional Flushing

- Method of systematically flushing watermains using single flow path sequences assisted by calibrated hydraulic model
Conventional Flushing vs. Unidirectional Flushing

**Conventional Flushing**

With Conventional Flushing, flow comes from all directions reducing cleaning velocity through the pipe.

**Unidirectional Flushing**

This method of flushing consists of isolating a particular pipe section or loop and exercising the hydrants in a sequential manner. Flushing would generally progress from the treatment plant or source to the periphery of the system, from large-diameter to smaller-diameter pipes, and always from cleaned sections to dirty ones.

Source: Photos from Hurco Technologies, Inc.
Why UDF; Advantages

Unidirectional Flushing

Can result in dirty water
Flushed to clean areas!

Uses up to 40% less water!

Advantages of a UDF Plan over Conventional Flushing:

- Improved flushing and scouring velocities
- Removes biofilm and sediment
- Flushes with clean water
- Overall cleaner distribution system

Source: Photos from Paul F. Boulos, *WaterWorld Magazine*, 23(9), September 2007
General Approach of Unidirectional Flushing

Start with Well 2 as the source for Sequence Group 1.

Legend:
- UDF Sequence Groups
  - Sequence Group 1
  - Sequence Group 2
  - Sequence Group 3
  - Sequence Group 4
- Elevated Tank

Legend:
- Valve Closed (Current Sequence)
- Valve Open
- Valve Closed (Previous Sequence)
- Current Flushing Sequence
- Hydrant
- Completed Flushing Sequence
- Wells
- Water Line Not Flushed
UDF Program in Sault Ste. Marie
Water Quality Issues in the City of Sault Ste. Marie

• Existing Water Quality Issues in the City of Sault Ste. Marie
  – In 2011 PUC modified the City’s water treatment process
  – Old method used Chloramine; new method used Chlorine
  – Water from the different treatment sources with a wide pH variation when mixed with chlorine resulted in issues including tastes and odours in some areas of the City.
  – While the change to Free Chlorine continued to produce safe drinking water, some customers continue to experience objectionable taste or odour and discoloured water (i.e. red or brown water).

• Addressing the Problem
  – Long term: Water Quality Improvement Strategy
    • Remove Lorna Wells (Believed to be the main source of WQ issues)
    • Implement recommended advanced treatment methods to harmonize pH levels
    • Improve corrosion control across the distribution system
    • Assess potential to increase capacity at WTP and existing wells
  – Short/Long Term: **Unidirectional Flushing**
City of Sault Ste. Marie Water Distribution System

- Location: Ontario, Canada
- Population: 75,141
- Treatment: 1 WTP + 4 Wells Sites (6 production wells)
- Length of Watermains: 470 km of pipes 2” and bigger
- Pressure Zones: 2
- Booster Stations: 1
- Reservoirs: 2
- Hydrants: 2,450
Goals for UDF Program

• Goal 1 – Improve Water Quality
  – Due to Aging Infrastructure, and
  – Change in Disinfectant

• Goal 2 – Reduce Customer Complaints

• Goal 3 – Improve Hydrants and Valves Conditions
1. Divide PZ1 in Sub Areas
   - Fifteen (15) Sub Areas

2. Start from Source of Water
   - WTP or a Production Well

3. From Larger to Smaller Mains
   - Avoid “Contaminating” Clean Water

Area also being flushed by PUC
Examples of Sequences - Close/Keep Closed/Open Valves Concept
Legend

- Red Circle: Close for Sequence
- Purple Circle: Keep Closed (From Prev. Seq.)
- Blue Circle: Re-Open for this Sequence
- Blue Line: All Other Pipes
- Yellow Line: Currently Flushing
- Green Line: Previously Flushed

Open Valves

Flush Hydrant

Close Valves

Keep Closed
Selection of Software to Undertake UDF Program

• Innovyze: **InfoWater**  **UDF**  
  – Add-on Software at an additional cost

• Bentley: **WaterGEMS**  
  – It has a built-in UDF Function

• Innovyze: **InfoWorks WS**  
  – It has a built-in UDF Function

• Hurco Technologies:  
  – **Infrastructure Management System**; not modeling software

• Innovyze: **InfoWater**  
  – Used without the UDF add-on
UDF Criteria and Considerations

• Minimum Scouring Velocity: 5 ft/s
• Flush from larger mains to smaller mains (create high velocities)
• Maximum flushing sequence length: 1,600 feet (500 m)
• Target volume flushed: 3 times the volume of the pipe
• Must maintain minimum pressure of 20 PSI (entire system)
• Typical flushing times: targeted: 5 to 10 minutes; actual 7 to 60 minutes
• Each flushing area has a target of 40 to 100 sequences
• Flush from cleaner mains to dirtier mains (clean source)
• Maintain service to all customers during flushing

• Water Turbidity "Goal" 1.0 – 2.0 NTU

Flushing lasted until this criteria was achieved
Hydraulic Model Setup

Water Model

- Calibrated Model; Identify Valves, Hydrants
- Identify Clean Water Sources
- Delineate Flushing Zones
InfoWater Model Setup

Modeling Scenario for UDF
Map Flushing Sequences in Area 15
There was co-ordination between hydraulic modeling and field crews to provide and use UDF Maps and Logs based on actual demands in the year.

<table>
<thead>
<tr>
<th>Model ID</th>
<th>Month</th>
<th>Area</th>
<th>Dmd (m3/d)</th>
<th>Dmd (L/s)</th>
<th>Factor</th>
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<tr>
<td>UDF_2013_01</td>
<td>January</td>
<td></td>
<td>32,300</td>
<td>374</td>
<td>1.50</td>
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<tr>
<td>UDF_2013_02</td>
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<td>36,000</td>
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<td>UDF_2013_07</td>
<td>July</td>
<td>10</td>
<td>36,500</td>
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<td>1.54</td>
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<td>UDF_2013_10</td>
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<td>13 and 14</td>
<td>31,700</td>
<td>367</td>
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<td>UDF_2013_11</td>
<td>November</td>
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<td>30,900</td>
<td>358</td>
<td>1.44</td>
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<tr>
<td>UDF_2013_12</td>
<td>December</td>
<td></td>
<td>31,800</td>
<td>368</td>
<td>1.48</td>
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</table>
Add Flow at Flushing Hydrant

Recommended Flow for 150 mm pipe diameter: **27 L/s**

Flow to be added to the model: **18.15 L/s = (27 L/s / 1.48742)**

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Flow Rate Required to Flush Water with 5 ft/sec Velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>in</td>
</tr>
<tr>
<td>100</td>
<td>4</td>
</tr>
<tr>
<td>150</td>
<td>6</td>
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<td>200</td>
<td>8</td>
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<td>250</td>
<td>10</td>
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<tr>
<td>300</td>
<td>12</td>
</tr>
<tr>
<td>400</td>
<td>16</td>
</tr>
<tr>
<td>50</td>
<td>2</td>
</tr>
</tbody>
</table>
Check Pressures and Velocities

Inactivated pipes
Available Flow at Flushing Hydrant
### Master Table

<table>
<thead>
<tr>
<th>Area / Sequence</th>
<th>Hydrant(s)</th>
<th>Max Flow (L/s)</th>
<th>Recommended Flow (L/s)</th>
<th>Comments</th>
<th>Valve ID</th>
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<td>A03_S04</td>
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<td>30.7</td>
<td>27</td>
<td>Potential for low pressures.</td>
<td>D12-7</td>
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<td></td>
<td></td>
<td></td>
<td>D12-8</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>D12-48</td>
</tr>
<tr>
<td>A03_S05</td>
<td>D12-17</td>
<td>28.00</td>
<td>27</td>
<td>Potential for low pressures.</td>
<td>D12-46</td>
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<td></td>
<td></td>
<td>D12-8</td>
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<td></td>
<td>D12-48</td>
</tr>
<tr>
<td>A03_S06</td>
<td>C12-4</td>
<td>130.21</td>
<td>108</td>
<td>Pressure: 40+ psi</td>
<td>D12-3</td>
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<tr>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>D12-8</td>
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</table>
Export GIS Information for Creating Maps and Logs

Export from GIS - Valve, Hydrant and Pipes Information

<table>
<thead>
<tr>
<th>SHAPE Length</th>
<th>UDF_D_S</th>
<th>OBJECTID</th>
<th>MOID</th>
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<tbody>
<tr>
<td>11.280576</td>
<td>A15_S81</td>
<td>10231</td>
<td>11946.000000</td>
</tr>
<tr>
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</table>

Vlookup in Excel based on Master Table and exported info from GIS

Production of Maps – Join to Excel tables, import symbology

Production of Logs

City of Sault Ste. Marie - UDF Program
Area/Sequence #A15-S01

<table>
<thead>
<tr>
<th>Watermain</th>
<th>Diameter (in)</th>
<th>Length (feet)</th>
<th>Material</th>
<th>Required Flow Rate (usgpm)</th>
<th>Minimum Flush Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albert St., from Trancred St. to 100 ft. south of Dennis St.</td>
<td>6</td>
<td>352</td>
<td>PVC</td>
<td>780</td>
<td>9</td>
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</table>

Flushing Hydrant / Hose Monster

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C07-24</td>
<td>770</td>
<td>2180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
</tr>
</tbody>
</table>

Date:
## City of Sault Ste. Marie - UDF Program

**Area/Sequence #A15-S01**

### Watermain

<table>
<thead>
<tr>
<th>Material</th>
<th>Diameter (in)</th>
<th>Length (feet)</th>
<th>Required Flow Rate (usgpm)</th>
<th>Minimum Flush Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PVC</td>
<td>8</td>
<td>852</td>
<td>760</td>
<td>9</td>
</tr>
</tbody>
</table>

### Flushing Hydrant / Hose Monster

<table>
<thead>
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<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>C07-24</td>
<td>770</td>
<td>2180</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Begin</td>
<td>Min Time</td>
<td>End</td>
</tr>
</tbody>
</table>

**Total Flush Time: 9**

### Initial Quality Observations

- [ ] Clear
- [ ] Particles
- [ ] Yellow/brown
- [ ] Red/Black

**Comments**

**INSTRUCTIONS:**

**CAUTION!** Begin with one 2.5” outlet, then proceed to 2x2.5” or 4.5”. Maintain flow rate reasonably close to recommended flow to prevent dirty water from entering partially closed network.

**Standards:**
- Residual Pressure: minimum 20 psi - monitor from hydrants / hose bibs
- Flush Velocity: target 5 feet per second for 3 pipe volumes
- Turbidity: Target 1 NTU. Maximum 5 NTU.
Required Flow Rate

• The flushing times needed for each segment should be estimated. This is an automated formula in the electronic spreadsheet. The flushing time should remove approximately three times the volume of water in the pipe. The actual flushing time needed will be determined by the water quality observed in the field (e.g., Turbidity measurements).

<table>
<thead>
<tr>
<th>Pipe Diameter</th>
<th>Volume per 100m of Pipe*</th>
<th>Min. Required Flow Rate to Achieve Velocity of 5 ft/sec</th>
<th>Pipe Diameter</th>
<th>Volume per 100ft of Pipe*</th>
<th>Min. Required Flow Rate to Achieve Velocity of 5 ft/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>L</td>
<td>L/s</td>
<td>in</td>
<td>gal</td>
<td>GPM</td>
</tr>
<tr>
<td>100</td>
<td>785</td>
<td>12</td>
<td>4</td>
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<td>261</td>
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<td>4,909</td>
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<td>408</td>
<td>1,186</td>
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<td>7,069</td>
<td>108</td>
<td>12</td>
<td>588</td>
<td>1,708</td>
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<tr>
<td>400</td>
<td>12,566</td>
<td>192</td>
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<td>50</td>
<td>196</td>
<td>3</td>
<td>2</td>
<td>16</td>
<td>47</td>
</tr>
</tbody>
</table>

* Volume assumes three times pipe volume removed
Modelling Challenges

• Long dead ends.

• Changing order of predesign sequences where minimum pressures are not met.

• Minimum required flow for reaching scour velocity is higher than available flow at hydrant.

• Revising sequences based on inoperable valves/hydrants found in the field.

• Revising sequences based on new improvements done to the system: new valves, hydrants and pipes.

• Multiple sources of supply.
Field Testing (UDF) Procedure
Pre Flushing Work

Prior to UDF

Ensure Valves are operational (closed or opened)

Install pressure gauges in residual hydrants

Install de-chlorination and flow equipment
Typical Site Set-up

The general procedures to be completed during a flushing sequence are as follows:

1. All hydrants and valves should be inspected prior to UDF work to ensure they are operational.

2. Each sequence should be planned in detail beforehand to determine specific hydrant and valve operations. Hydraulic model used to generate field logs and maps ensuring minimum pressure in the system and desired scour velocities are achieved.

3. Norms such as 
   
   **AWWA Manual M17: Installation, Field Testing, and Maintenance of Fire Hydrants (AWWA, 2010)** as well as 
   
   **NFPA 291: Recommended Practice for Fire Flow Testing and Marking of Hydrants (NFPA, 2013)** should be considered and reviewed before Field Testing (UDF) Procedure.

4. After reviewing UDF maps and logs, identify valves to be closed/open as well as hydrants to be flushed.
Typical Site Set-up

5. Specific flow and residual pressure hydrants must be selected for each sequence that are accessible, in good working order and can be safely flowed without damage or disruption. Proper traffic control measures should be applied.

6. Set the Hose Monster in an appropriate location for flowing water. Attach hydrant gate valve on the hydrant, then attach the hose and Hose Monster equipment. Attached Dechlor Demon equipment for water dechlorination.

7. With the hydrant gate valve closed, slowly open the hydrant fully. Control water flow with hydrant gate valve.

8. During the UDF program, regular hydrant flushing activities within the same zone should be curtailed, if possible.

9. Measure flow-rate from Hose Monster® to determine flushing velocity. Use flow charts. Ensure minimum flushing time and turbidity targets are achieved.

10. When flushing operation is complete, slowly close hydrant gate valve, then hydrant. Verify that hydrant is fully closed and drained. Remove equipment and replace caps. Move to next location and repeat procedure.
Setup for a Typical UDF Sequence

- Elements involved in a UDF program include watermain to be flushed, flow direction, flow hydrant, residual hydrant, and valves.

Source: Photos from Hurco Technologies, Inc.
Setup for a Typical UDF Sequence

- Graphics of flow hydrant and potential residual hydrants in the vicinity.
- Some hydrants were used in some tests to monitor system pressure to ensure it was higher than 20 psi.

Source: Photos from Hurco Technologies, Inc.
Communication Plan

• PUC Communication Plan included the following:
  – Periodic newspaper Notices to advise residents of the upcoming flushing program.
  – Periodic banner ads in the newspapers to remind residents of the flushing program and provide further information on the PUC website.
  – The PUC website was continually updated with information regarding progress of the flushing and flushing areas.
  – In advance of the flushing operations in a specific area, Notices would be hand delivered to all of the property owners in the area and included a number of frequently asked questions as well as a map of the area that would be flushed and the estimated timeline for the flushing.
  – PUC fabricated signs indicating flushing is ongoing in the area. The signs are installed daily on the road(s) leading into the area being flushed.
Customer Notice and PUC Website Updates

IMPORTANT NOTICE

WATERMAIN CLEANING & FLUSHING IN YOUR AREA

PUC crews will be flushing the water mains on your street:

Between: Tuesday, July 2nd And: Friday, July 5th
Weather Permitting

Please see below for answers to frequently asked questions and other information.

Why is the PUC "flushing" the water mains?
Flushing the water mains improves water quality by removing sediment that slowly builds up at the bottom of the watermain over time. The sediment comes from internal corrosion of the water mains over many years.

What is unidirectional flushing?
This type of flushing increases the speed of the water flowing in the main so as to produce a scouring action that removes loose sediment and deposits. The flushing starts at a clean water source (e.g. the water pumping station) and moves through the distribution pipes. This ensures that clean water is always used to flush the mains.

How will I know when the PUC is cleaning the water mains in my neighbourhood?
The PUC will inform residents before starting the flushing program by posting notices on its website and placing advertisements in local newspapers. You will receive a notice at your door at least one day before flushing starts. Also, during the flushing activities you will see yellow signs on streets where flushing is taking place.

What should I do if my water is discoloured after PUC has flushed the water mains?
Water is sometimes discoloured after water main cleaning, but this should not last long. You should avoid laundering clothing to minimize staining, and using hot water to avoid drawing sediment into your hot water tank.

How much does it cost me for the water I use to flush my taps?
The typical kitchen faucet delivers about 6 to 7 lites per minute when opened up to flush household plumbing. Therefore the typical cost of flushing taps amounts to a little less than 4 cents (including the sewer charge), for every 5 minutes of flushing and for each tap used.

How long does it take to clean the water mains on each street?
It takes about 30 minutes to 60 minutes to flush the water mains on each street.
Typical Equipment used in a UDF Program

• Typical list of field testing equipment:
  – Calibrated pressure gauges (100 psi, 150 psi) (± 0.25%)
  – Hydrant gate valves
  – Two-way radios
  – Hydrant Wrench
  – Fire flow test kit with interchangeable nozzles and pitot gauge
  – Quick disconnect pitot gauges (100 psi, 150 psi)
  – Mechanism for dechlorination (Dechlor Demon & Vita-D-Chlor tablets)
  – Hydrant flow diffuser
  – Hose Monster (Big Boy 2 ½” unit and the 4” unit)
  – Service truck and a flat deck unit (used to transport traffic control equipment, hose and the dechlor equipment, and additional personnel)
  – Hach 2100Q Portable Turbidimeter to record the turbidity

Ensure that the pressure gauges and pitot gauges (or equivalent equipment) are calibrated and in proper working order
## Obtaining Flow Readings in the Field

### Actual Filled UDF Field Log

<table>
<thead>
<tr>
<th>Watermain</th>
<th>Diameter (in)</th>
<th>Length (feet)</th>
<th>Material</th>
<th>Required Flow Rate (USGPM)</th>
<th>Minimum Flush Time (minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Market St. from Market St. to East of Eastern Ave.</td>
<td>8</td>
<td>467</td>
<td>PVC</td>
<td>780</td>
<td>6</td>
</tr>
</tbody>
</table>

**Flushing Hydrant / Hose Monster**

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>C12-33</td>
<td>791</td>
<td>1723</td>
<td>25</td>
<td>10</td>
<td>675</td>
<td>2.25</td>
<td>50</td>
<td>2.75</td>
</tr>
</tbody>
</table>

**Total Flush Time**

- Begin Time: 1:47
- End Time: 3:45

### Pitotless Nozzle™ THD FLOW CHART

- **10-60 PSI**
  - Open Atmosphere
  - End Time Value
  - Pressure Range: 10-60 PSI

- **1-3 PSI**
  - Open Atmosphere
  - End Time Value
  - Pressure Range: 1-3 PSI

Source: Hydro Flow Products, Inc.
Field Testing (UDF) Results
Area 3A UDF Flushing Program

Area Flushed twice
1. August 20-23 2012
2. July 2-4, 2013

Total of 26 Sequences
Required Flushing Times 2012 vs. 2013 (Area 3A)

**Year 2012**
- Avg. Time: 28.8 min.
- Total Time: 720 min.

**Year 2013**
- Avg. Time: 19.5 min.
- Total Time: 449 min.
Recommended and Actual Flushing Times

2012/2013 - UDF Flushing Times Area 3 Results

Flushing Sequence

Time (Minutes)

Recommended Flush Time  
Actual Flush Time 2012  
Actual Flush Time 2013
Turbidity Levels for UDF Program Area 3A

2012/2013 - UDF Turbidity Levels Area 3A Results

- **2012 UDF Program**
  - Avg. Turbidity at Start of Flushing: 103 NTU
  - Avg. Turbidity at End of Flushing: 1.7 NTU

- **2013 UDF Program**
  - Avg. Turbidity at Start of Flushing: 87.6 NTU
  - Avg. Turbidity at End of Flushing: 2.4 NTU

Flushing Sequence:

- Start of Flushing 2012
- Start of Flushing 2013
- End of Flushing 2013
There was a total of 160 recorded water quality related complaints from December 2002 to April 2014 in Area 3A

Customer Complaints are filed in a database and linked to GIS

Typical issues included discolorations, odours, bad tastes and particulates

Not all complaints are recorded in the database (e.g., voicemails after hours)

Additional data required to assess the effectiveness of UDF Program on reducing water quality complaints
Customer Water Quality Complaints – Area 3A

Prior to Flushing – 9
During Flushing – 1
After Flushing - 0

Prior to Flushing – 0
During Flushing – 2
After Flushing - 2

Count of Complaints

Year / Month

2009 2010 2011 2012 2013 2014

0 5 10 15 20 25

Count of Complaints


0 10 20 30 40 50 60 70

Development and Implementation of a UDF Program

May 7, 2014

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Water quality complaints decreased after the City UDF Program in 2012

No. of Water Quality Complaints Before and After 2012 UDF Program

86 Complaints pre UDF
19 Complaints post UDF
General Field Comments

• Photo on the right shows typical water quality immediately after starting UDF – some were more turbid than others.

• An issue encountered when flushing large volumes of water was the lack of good drainage.

• In some cases the flushing velocity may have come up short of the recommended because of drainage issues.

• Customer complaints diminished after UDF Program.

• Frequency of Required UDF in East area is approximately 6 months. This is longer for other areas of the City.

• This period of 6 months is a challenge with the long winter that provides only a 6 month flushing window.

• The stones on the right are probably remnants from a main repair or poor construction activities. Some of the flatter pieces are scale pulled from the pipe walls.

Source: PUC Photo Material
Summary

• A UDF program enhances distribution system water quality. It does a more effective job of removing debris, biofilm and dirty water.

• UDF is more efficient than conventional flushing as higher scour velocities reduce flushing times and total water required. Can also reduce the frequency of required flushing.

• Utilizing the hydraulic model unnecessary low pressures can be minimized/eliminated.

• The existing UDF program in SSM is working. Some areas need to be repeated every 6 months due to source water quality.

• Unidirectional flushing model is a tool to enhance O&M. Identifies missing/broken valves and hydrants, helping to maintain a more reliable system.

• UDF Maps and Logs are valid for a good number of years.
Acknowledgements

Mr. Paul Dalseg, Manager Water Distribution, PUC Services Inc.
Mr. Andrew Hallett, P.Eng, Water Distribution Engineer, PUC Services Inc.
Mr. Rick Talvitie, P.Eng., Office Manager AECOM, Sault Ste. Marie Office
Mrs. Carolina Lopera, E.I.T., AECOM, Markham Office
Thank You

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