Development and Implementation of a Unidirectional Flushing Program

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Introduction

Hydrant flushing is an important component of any water utility’s routine system maintenance. Flushing removes sediments, deposits and biofilm build-up from water system, improves water quality triggering reductions in customer complaints. Incorporating unidirectional hydrant flushing (UDF) techniques allow utilities to improve degree of watermain cleaning, reduce total water consumption per flush and decrease frequency of flushing.

This methodology, as opposed to routine water main flushing, is a process of closing valves and opening hydrants to direct clean water down a single water main, thus increasing scour velocities and removing sediments more efficiently from the inner surface of the pipe.

The City of Sault Ste. Marie, located in Ontario, Canada, has undertaken a comprehensive watermain unidirectional flushing program including over 800 flushing sequences. The main goals of this program were to improve water quality and restore carrying capacity of pipes.

The City’s calibrated hydraulic model was used to assess available flows, ensure pressure constraints were met, and develop detailed field UDF mapping and logs. The UDF Plan developed identifies the sequences of pipes to be flushed, the specific sequence of valve operations, hydrants to be operated, available and required hydrant flows and estimated flushing times.

Concept of Unidirectional Flushing

A variety of water quality problems that occur in a distribution system can be, at least partially, addressed by distribution system flushing. Watermain maintenance should include flushing distribution mains for many reasons, including: sediments, deposits, biofilm build-up, pits (water corrosity). These generate as a result: poor taste and odor, high turbidity, chlorine degradation, increased pipe roughness, increased O&M costs, and a reduction of hydraulic capacity.

Conventional Flushing vs. Unidirectional Flushing

Conventional flushing procedures involve flushing mains in areas where water quality complaints have occurred - a reactionary approach. Conventional flushing procedures can also be system-wide, but no effort is made to assure that clean water is entering the pipe being flushed or that adequate velocities are being reached to scour the pipes. Conventional flushing typically does not result in sufficiently high flow velocity to remove biofilm or to remove all sediment from the pipes. Improvements in distribution system water quality may be marginal and short-lived.

Unidirectional flushing consists of isolating particular pipe sections or pipe loops, typically through closing appropriate valves and opening hydrants in an organized, sequential manner. Unlike conventional flushing, unidirectional flushing targets individual pipe segments to maximize flushing effectiveness. By isolating individual pipe segments, it is possible to
consistently achieve higher scouring velocities e.g., approximately 5 ft/s or more, that can effectively remove sediments and biofilm. **Figure 1** illustrates the difference between conventional and UDF methods. In addition, a UDF plan is organized such that each target pipe segment is flushed from a “clean” source. Complete unidirectional flushing of a water system ensures that every pipe segment is effectively cleaned. Other benefit of UDF is that problematic valves and hydrants are often discovered during UDF process. These can be replaced or fixed as part of the UDF program.

![Figure 1 - Example of Conventional vs UDF Flushing Configurations](Source: Paul F. Boulos, *WaterWorld Magazine*, 23(9), Sept 2007)

**UDF Program in Sault Ste. Marie (SSM)**

**Water System**

The SSM water system is serviced through five treatment sources; four wells sites and a single treatment plant (connected to Lake Superior). A pipe network of approximately 470 km with diameters ranging from 2 - 48 inches connects the two pressure zones, one booster station, and two reservoirs to the customers and approximately 2,450 hydrants.

**Existing Water Quality Issues in the City of Sault Ste. Marie**

In 2011 PUC modified the City’s water treatment process, switching from Chloramine to Chlorine. The City eliminated 10 tons of ammonia added to the water each year. Water from the different treatment sources with a wide pH variation when mixed with chlorine provided issues with tastes and odors in some areas of the City, especially to the east.

Selecting the Free Chlorine method allowed PUC to potentially satisfy the new provincial regulations without incurring substantial increased costs. This on the other hand triggered water quality issues that need to be addressed.

**Addressing the Problem**

As a short term improvement strategy Sault Ste. Marie implemented the Unidirectional Flushing Program. The main goals defined were: improve water quality due to aging
infrastructure and change in disinfectant, reduce customer complaints, improve hydrants and valves conditions.

**Hydraulic Modelling for UDF**

*Hydraulic Model and Selection of Software*

The UDF Plan was developed using an up-to-date and calibrated hydraulic model of the Sault Ste. Marie water distribution system. GIS information of water assets was also utilized.

As the existing hydraulic model was developed in Innovyze’s InfoWater Suite, the InfoWater UDF add-on was considered for this project. Due to a variety of factors including cost, analysis preferences and specific mapping requirements, it was decided that the InfoWater UDF add-on would not be used for this project.

A UDF scenario was created with specific control and demand sets that satisfied real hydraulic conditions at the time of doing the flushing of each area. The hydraulic analysis was done under Steady-State Simulation.

*Division of Areas*

UDF program took place so far within Pressure Zone 1 (PZ1). PZ 1 was divided into 15 sub areas, as shown in Figure 2, based on proximity to water sources and logical zonal breaks in the distribution network. During this program, only pipes with diameters less than or equal to 400 mm were flushed. Larger diameter along the transmission lines were considered sources of clean water and were not scheduled for flushing.

Each zone was further divided into flushing sequences. Sequence start from a water entry point and progress outward to the periphery of the distribution system.

![Figure 2 - Sault Ste. Marie Water System with Pressure Zone 1 Subareas](image)

Some general considerations when developing flushing sequences include:

- Flush from clean source to periphery of system
- Flush from larger mains to smaller mains (maximize capacity and minimize chances for debris to be collected at high velocities and then stagnate within larger pipes with reduced velocities on route to flushing hydrant)
- Maximum flushing sequence length of 500 m (1640 ft)
- Flushing areas generally included 40 to 100 sequences

**Adjusting Water Demands**

To provide an accurate estimate of the system conditions, unique demand scenarios were developed based on plant flow records. Analysis for each flushing area was based on the month when flushing would be completed (refer to Figure 3).

![Figure 3 - Typical Monthly Water Demand in Sault Ste. Marie](image)

**Hydraulic analysis for each sequence**

Prior to commencing the hydraulic analysis for an area, a paper copy of the network is marked up with a draft sequencing approach. This process allows for a more efficient analysis as the hydraulic analyst is able to plan several sequences ahead when deciding on valve closures, improving the efficiency of valve operations, and the use of hydrants for flushing.

The following procedure reflects the typical analysis of a UDF sequence:

- **Model Set-up**
  - Select system demand for month of hydrant flushing
  - Ensure system operation was reset after previous flushing analysis was completed
- **Sequence Set-up**
  - Manage valve closures to ensure isolation of target watermains – analysis is completed in the order of the sequence flushing and valve operation is tracked
    - Open valves that were closed in the previous sequence but are no longer required
    - Keep closed any valves still required
    - Close any additional valves required for the next sequence
o Run the fire flow analysis to determine available flow at the flushing hydrant
o Run steady-state analysis with required demand assigned to the hydrant and review system velocities (> 5 ft/sec for target pipe) and pressures (> 20 psi)
o Record valve and hydrant ids, results and comments in tracking spreadsheet to be used for mapping and field logs
o Repeat for all sequences in a flushing area

Logs and Maps
Field maps were developed for each sequence showing valve operations, target watermains and previously flushed pipes (see Figure 4). These maps allow operators to track what valves are closed, find alternative valves in the event of inaccessible or inoperable valves and locate hydrants.

Field logs accompanied the mapping for each flushing sequence (see Figure 5). These field logs were used by PUC operators to carry out the UDF program and track available flows, turbidity results, flush times and additional notes.

Figure 4 – UDF Field Map
Field Testing (UDF) Procedure

PUC crews used maps and logs generated for flushing sequences in each area. Prior to the flushing of each sequence PUC crews ensured that required valves were operational. In the event that the valves were inoperable or could not be located, sequences were revised to accommodate.

The general procedures for the completion of each flushing sequence were as follows:

2. After reviewing UDF maps and logs, identify valves to be closed/open as well as hydrant to be flushed.
3. Specific flow and residual pressure hydrants must be selected for each test that are accessible, in good working order and can be safely flowed without damage or disruption. Proper traffic control measures should be applied.
4. 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.
5. Install pressure gauges on residual hydrants
6. With the hydrant gate valve closed, slowly open the hydrant fully. Control water flow with hydrant gate valve.
7. During the hydrant testing program, regular hydrant flushing activities within the same zone should be curtailed, if possible.
8. Measure flow-rate from Hose Monster® to determine flushing velocity. Use flow charts. Ensure minimum flushing time and turbidity target levels are achieved.
9. 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.

10. Move to next location and repeat procedure.

As part of the field testing procedure, PUC crews recorded pressures, turbidity (at start and end of test), start/end time and flow.

**PUC's Communication Plan**

One of the key objectives for the UDF program was the ability to provide updated information to the customers. For achieving this, the following actions were taken:

- 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 built signs indicating that flushing is ongoing in the area. The signs are installed daily on the road(s) leading into the area being flushed.

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**IMPORTANT NOTICE**

**WATERMAIN CLEANING & FLUSHING IN YOUR AREA**

PUC crews will be flushing the watermains 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 watermains?*

- Flushing the watermains improves water quality by removing sediment that slowly builds up at the bottom of the watermains over time. This sediment comes from internal corrosion of the watermains 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 stations) 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 watermains 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 the PUC has flushed the watermains?*

- Water is sometimes discoloured after watermain cleaning, but this should not last long. You should avoid wearing clothing or intexte dishes, and using hot water for a short time while flushing is taking place.

*How much does it cost me for the water I use to flush my taps?*

- The typical kitchen faucet draws about 6 to 7 litres per minute when opened up to flush household plumbing. Therefore, the typical cost of flushing a typical household is 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 watermains on each street?*

- It takes about 30 minutes to 60 minutes to flush the watermains on each street.
UDF Field Testing Results

To show the effectiveness of the UDF program, a sample area (3A) has been assessed. Figure 7 and Figure 8 show customer complaints within 10 months pre and post flushing activities in the summer of 2012. There were a total of 86 complaints filed within the 10 months prior to the flushing and only 19 complaints in the 10 months following flushing.

Customer Complaints are filed in a database and linked to GIS however, not all complaints are recorded in the database (e.g., voicemails after hours). Typical issues include discolorations, odors, bad tastes and particulates.

Lessons Learned

A UDF program maintains distribution system water quality. It does a more effective job of removing debris, biofilm and dirty water than conventional flushing.

Utilizing the City’s hydraulic model allowed for unnecessary low pressures to be minimized and ensured that valve operations effectively controlled the system for flushing.
The existing UDF program in SSM is working with some areas requiring flushing every 6 months due to source water quality.

Preliminary analysis shows a reduction in water quality complaints after the implementation of the UDF program. Additional analysis based on the zone wide results will provide further insight into the effectiveness of the program and the frequency requirements for future iterations.

The UDF Maps and Logs developed are valid for a number of years with minor adjustments required based on pipe upgrades and valve operational statuses.

Public notification is crucial - as described before, the PUC Services has been implementing a communication plan which has helped the community to be informed about the UDF program.

Unidirectional flushing model is a tool to enhance O&M.

In summary, the City of Sault Ste. Marie’s UDF program has been implemented with success and provides a framework for the successful implementation of Uni-Directional Flushing programs for other municipalities.

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