UDF ANALYSIS USING HYDRAULIC MODELING

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Abstract

Flushing is one of the most effective tools available to maintain and improve water quality in a water distribution system. Almost all water utilities use some form of flushing program in a regular maintenance schedule. However, these flushing programs are not typically sequential and often do not use valve isolation techniques. Adopting a Uni-directional flushing (UDF) program will result in significant system improvements and cost savings. Uni-directional flushing consists of isolating particular pipe sections or loops by closing the appropriate valves and opening hydrants in an organized sequential manner. Earth Tech Canada has developed a new computer-based UDF approach aiming at a systematic cleaning of the pipes of the City of Penticton (BC, Canada) water distribution system. Hydraulic and fire flow simulations were performed to identify the flushing sequences as well as the expected flushing velocities for each pipe. By spatially joining different Geographical Information System (GIS) database layers and the hydraulic model, the valves to close were identified for each flushing sequence as well as the hydrant to open. Finally, this new computer-based UDF approach is easy to implement and results in immediate and long-term solutions to water quality concerns by determining the optimal flushing sequences.

Keywords
Uni-directional flushing, hydraulic network modeling, water distribution system, fire flow, valves, and hydrants.

1. INTRODUCTION

Water system inspection and flushing are crucial elements of any piping maintenance program. UDF consists of isolating particular pipe sections or loops by closing the appropriate gate valves and opening hydrants in an organized sequential manner. In general flushing proceeds from flushed to unflushed pipes, and from larger to smaller water mains, moving from the source out to the ends of the system.

This technique removes more mineral and biological deposits in water distribution lines than traditional flushing methods. The UDF system cleans piping more efficiently than conventional flushing methods because it uses higher water velocity with less water through systematically opening and closing valves. A minimum velocity of 1.5 m/s is recommended to ensure effective removal of sediment and biological deposits. For this reason, water mains greater than 300 mm diameter are not normally included as the required velocity would need the opening of more than one hydrant.

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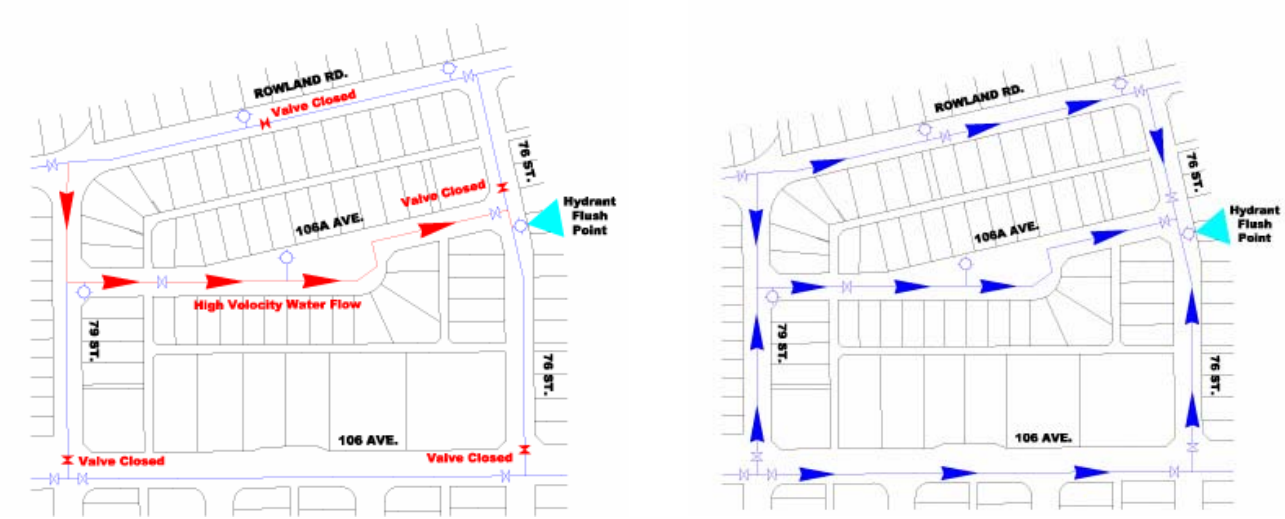
2. ADVANTAGES OF UDF

Adopting a UDF program will result in significant system improvements and cost savings such as:

- Increased water velocity, which promotes better pipeline scouring;
- Improved mineral and biological deposit removal;
- Taste and odour control;
- Reduction of turbidity;
- Elimination of waterline re-fouling;
- Reduced frequency of mainline flushing;
- Reduced water usage;
- The opportunity for infrastructure preventative maintenance (valve and hydrant exercising); and
- Cost savings over traditional flushing.

Figure 1 below compares traditional flushing (no valves to close) with UDF. With uni-directional flushing, water is channelled by systematically opening and closing valves, resulting in better cleaning with less water. With traditional flushing, water flows from all directions, resulting in lower water velocity and less scouring of the pipes. [4]

Fig. 1. UDF Flushing (Left) and Traditional Flushing (Right).



3. OPERATIONAL GUIDELINES

The following operational guidelines should be followed to maximize the benefits of the flushing plan and reduce potential problems. The City Operations Staff should be aware of and follow these guidelines at all times while performing the UDF flushing program:

- Flushing should originate at the source and progress outward towards the periphery pipes. This will allow water used to flush a main to originate from a segment that has already been flushed and eliminates flow reversals.
- A larger water main should generally not be flushed from a smaller water main. The velocity reduction in the larger water main will decrease the effectiveness of the scour. This may necessitate redirecting the flow by closing and reopening gate valves.
- During flushing, care must be taken to avoid reducing water distribution system pressures below 20 psi (about 14 m).
- Before beginning each sequence, adequate source water for flushing should be verified as either adequate storage volume or pumps in operation to provide the required flow rate and duration.
- The flushing times shown on the field logs are estimated times based upon hydraulic modeling. The actual time required to flush each hydrant may be more or less, as each hydrant should be flushed until the water clears.

- Where valve closures isolate pumping facilities or where the operation of pumps would contribute flow opposite of the desired direction of water flow, pumps should be turned off.
- Before beginning each day the Fire Department should be notified so they are aware of the general locations where flushing will be performed and that system valves will be closed which could reduce the available fire flows in the system.
- At the end of each day closed valves should be opened to provide maximum fire flow protection in the case of an emergency and then closed again the following day as required.

4. UDF METHODOLOGY

Earth Tech has developed a computer-based UDF program aiming at a systematic cleaning of the pipes in the water distribution network by draining the water through a fire hydrant. The flushing operations will be launched sequentially, in a preset order, so that the water used in the flush sequences remains clean. Our approach included the use of an operational water model to streamline the UDF process. The assignment included the following tasks:

4.1 Model Conversion and Selection of Flushing Locations

The existing EPANET (US EPA, OH, USA) model was first converted to H_2ONET Version 3.x (MWH Soft, Inc., CA, USA) [1] [2]. All valves (gate valves, etc.), hydrants, and other water supplies were also provided in GIS shapefile format and were reviewed by Earth Tech.

4.2 UDF Model Simulation and Analysis

A standard hydraulic model simulation was first completed (steady-state condition) to determine the nodal pressures and pipe flow rates. Using H_2ONET Flow Stepper tool [2], the order of the flushing sequences was determined. A fire flow simulation was then completed to determine the available fire flow under 20 psi. Using the available fire flow, the pipe velocity was determined as well as the turnover time for each section of the water main. Flow velocities were checked to make sure that they reach at least 1.5 m/s. By spatially merging GIS database layers showing the locations of the gate valves and the hydrants and the hydraulic model using ArcView (ESRI, CA, USA), each gate valve was assigned to the closest pipe while each hydrant was assigned to the closest junction [3]. Finally, a MS Excel Macro was developed to determine the valves to close for each flushing sequence by applying the following rules for each pipe to be flushed:

- Rule 1: Close all the pipes that are connected to the downstream node of the pipe to be flushed.
- Rule 2: Close all the pipes that have the same upstream node of the pipe to be flushed.

4.3 Graphing and Reporting the UDF Sequences

The UDF program starts from the water source and then moves in a downstream direction. Valves were closed to ensure flow is from a clean source on a one-way path. Earth Tech produced a comprehensive report following completion of the flushing program. For ease of use in the field, the City system has been divided into 60 dissemination areas. Graphical plots (11x17) were created for each area to present the flushing program. Finally, tables listing those valves to be closed and hydrants to be opened for each flushing sequence were also created.

5 FLUSHING SEQUENCES

The UDF flushing sequences were designed by dividing the Penticton water distribution system into two primary groups: dead end pipe sections, and non-dead end pipe sections. Boundary conditions for each flushing sequence were then determined, based on the location of the supply points in the distribution system. This information was then entered into the model, which was used to determine:

- The pipes required to be flushed.
- The direction in which to flush the pipes.
- The order in which to flush the pipes, based on each pipe's designated level (i.e. all "Level 1" pipes must be flushed before any "Level 2" pipes are flushed).
- The hydrant to open to flush the selected pipe.
- The pipes to close in order to flush the selected pipe, (including which valves are required to close to shut these pipes).

- The maximum available flow at the hydrant to flush the selected pipe (not allowing the residual pressure to fall below 20 psi).
- The corresponding velocity to flush the selected pipe (the velocity must be greater than 1.5 m/s).
- The required time to flush the selected pipe to have three turn over volumes (TO). It is strongly recommended that these predicted times are used as an estimate only, and that flushing be continued until the water flows clear.

The location of each supply source was located and the pipe network was divided based on the location of these supply sources, to flush the non dead end pipe sections. Once the non dead end pipe section flushing sequences were finished the remaining pipe network was reviewed. Dead end pipe sections were defined as having no looped networks and resemble one main branch having single pipes stemming off of it. One dead end section may have many pipes, however none of which form a loop.

6 CONCLUSION

The purpose of a flushing plan is to assist in the improvement of water quality and operation of the water system. A flushing plan should be developed for any water system in order to maintain the cleanliness and efficiency of the piping network by allowing for scouring of the pipes and operation of valves/hydrants. The general objective of flushing is to assist in preserving and improving water quality and service.

References

[1] EPANET Users Manual, EPA-600/R-94/057, Environmental Protection Agency Risk Reduction Engineering Laboratory, Cincinnati, Ohio, 1994.

[2] H_2ONET Users Guide. MWH Soft, Inc. 300 Lake Avenue, Suite 1200, Pasadena, CA 91101 USA, 2000.

[3] de Schaetzen, W. and Boulos, P.: "Locating Monitoring Stations in Water Distribution Systems Using GIS." Proceedings of the 2002 Annual ESRI International User Conference, July 7-13, San Diego, CA.

[4] http://www.epcor.ca/Municipalities/Water+Services/Water+and+Sewer+Field+Services/UDF.htm