Successful Completion of a Uni-Directional Flushing Program

C. Robert Reiss, Harold Nantz, and Paul Schumi

When the annual number of customer complaints doubled at the city of Melbourne because of water-quality issues, the city decided it needed to change direction on routine maintenance procedures and embark on an aggressive water-quality enhancement effort.

Prior to 2004, Melbourne was accustomed to receiving approximately 500 customer complaints per year, but during the years of 2004, 2005, and 2006, customer complaints more than doubled, as shown in Figure 1.

In response to the significant increase in 2006, the city engaged Reiss Engineering Inc. (REI) to perform a preliminary investigation into the potential causes of the elevated customer complaints. This preliminary investigation was completed in July 2006 and included an evaluation of geographically located customer complaint events versus potential distribution system water-quality factors, including dead ends, remote areas (water age), and distribution pipe materials. The July 2006 study initially indicated that the complaints were distributed evenly throughout the system, with no clear association to the system layout or pipe materials.

A cursory review of available finished water-quality data (2002 to 2006), however, suggested a correlation between the concentrations of Total Dissolved Solids (TDS) and chlorides in the city's finished water quality and the number of customer complaints, as shown in Figure 2.

Figure 1: Annual Customer Complaints

For the purposes of this study, Figure 2 was updated to include the data from August 2006 to February 2007, which continued to exhibit the same correlation as observed in past data.

Further investigation into these changes in finished water TDS and chlorides identified the cause as a change in the blending ratio from the two independent water treatment processes at the city's water treatment plant. Specifically, Melbourne operates a ferric coagulation conventional surface water treatment process and a separate reverse osmosis (RO) groundwater treatment system for production of potable water. While each system independently produces drinking-quality finished water, the city blends the two streams prior to transmission into the distribution system.

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It was found that the ratio of surface water to RO-treated groundwater, which changes seasonally based on the quality of the surface water and the overall potable demands,

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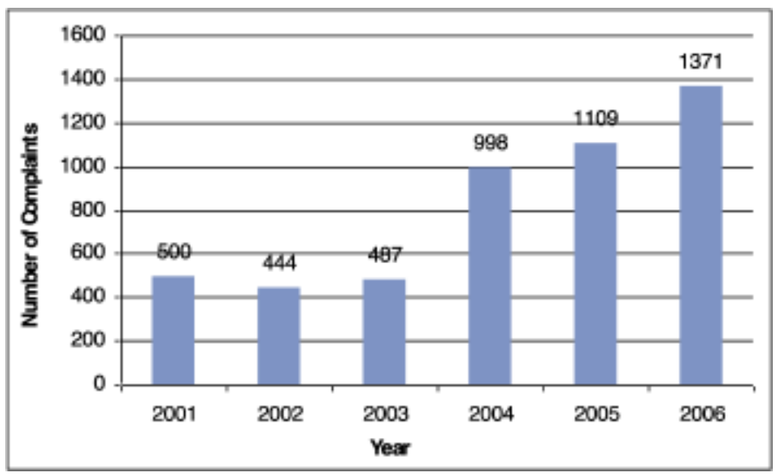

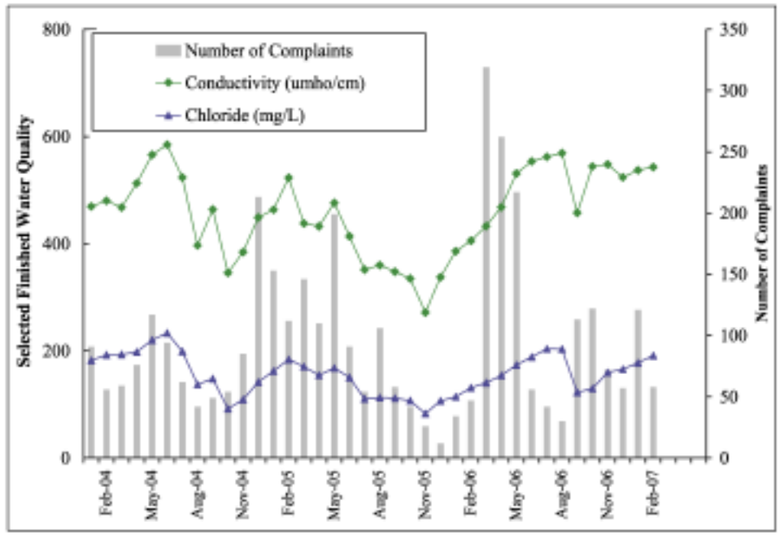

Figure 2: Total Monthly Complaints versus Selected Finished Water Quality

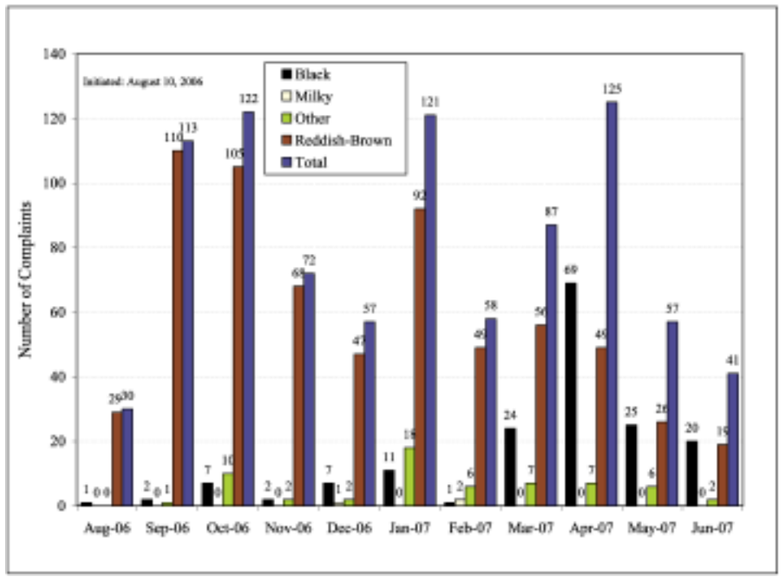

Figure 3: Customer Water-Quality Complaints

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directly affected the resulting TDS and chloride levels in the finished water. The results, therefore, suggest that although both the surface-water facility and the RO facility are both producing a high quality of potable water, the seasonal change in blend ratio or raw surface water quality may be causing instability in the distribution system, leading to an increase in water-quality complaints.

A recommendation implemented as part of the REI 2006 study included enhancing the city's customer complaint database to better define the type of water-quality complaints. In August 2006, the city and REI revised the customer complaint database to incorporate various water-quality characteristics and establish the types of quality issues being experienced by users in the distribution system. The water-quality questionnaire reserved for "dirty water" callers included determining the water color, the appearance of particles in the water, low-pressure occurrences, and other questions specific to the caller's location.

Updated Customer Complaint Analysis

Since the implementation of the enhanced customer complaint database in August 2006, the city has been recording customer complaints, including characterizing the type of water-quality complaints (red versus black and white color). REI assessed this new data to determine the specifics of the complaints.

Analysis of 11 months of data (August 2006 to June 2007) indicated that 74 percent of the city's water-quality customer complaints are associated with a reddish-brown water color (red water), as summarized in Figure 3. Also, black-water complaints have been rising since March 2007. In addition, the locations of the red-water complaints show that the red-water problem is occurring consistently throughout the distribution system.

As a final check, it was considered appropriate to establish that the number of complaints received likely denotes a true water-quality issue, not merely a typical level of customer contact for such concerns. In order to determine whether the number of complaints observed by the city is typical, the recorded number of complaints was compared to the standard "number requiring immediate attention level" developed in a study by the American Water Works Research Foundation (AwwaRF, 2001). The study indicated that when the number of customer complaints exceeds 2 percent of the total number of accounts on an annual basis, immediate attention should be strongly considered.

Figure 4 shows that the city experienced a threefold increase in the annual number of customer complaints between 2002 and 2006. In addition, the city shifted from a complaint level in 2002 of 0.8 percent of total accounts, well below the AwwaRF 'immediate attention' level of 2 percent, to approximately 2.5 percent in 2006. It was concluded, therefore, that the increase in the number of complaints is likely associated with a real and substantial change in water quality within the city's system.

Initiation of the Uni-Directional Flushing Program

For many years, Melbourne's maintenance operations have been successful at providing high-quality services to the utility's customers with a relatively low occurrence of localized or widespread customer complaints regarding water quality. The city administered a pipe replacement program to meet water-quality criteria and upgrade aging infrastructure. Also, the city routinely flushed its system through standard operating procedures by dispatching its maintenance crews to spot-flush distribution mains in the complaint areas, but the high number of complaints continued. This situation resulted in an increase in reactionary flushing, increasing staff overtime and overall customer dissatisfaction.

As a result, a comprehensive program to correct the distribution system water-quality issues was implemented by the city. As part of this multifaceted enhancement effort, the city directed Reiss Engineering to develop and manage a uni-directional flushing (UDF) program.

Uni-directional flushing is a relatively new method of flushing that consists of flushing the system's water mains in segments at high velocities, in such a way that the entire distribution system is flushed in one direction from a clean source. The standard flushing program previously administered by the city consisted of opening hydrants in complaint areas so that water flowed at approximately one foot per second from various directions.

Through the UDF program, only one hydrant is opened and specifically selected valves are closed to isolate and flush a specific segment of pipe at a target velocity of five feet per second. Flushing at a high velocity scours the inner pipe walls and removes corrosion-related debris and sediment. Also, by flushing in one direction from a clean source outward through the distribution system, the possibility of reintroducing debris into a previously flushed pipe is eliminated.

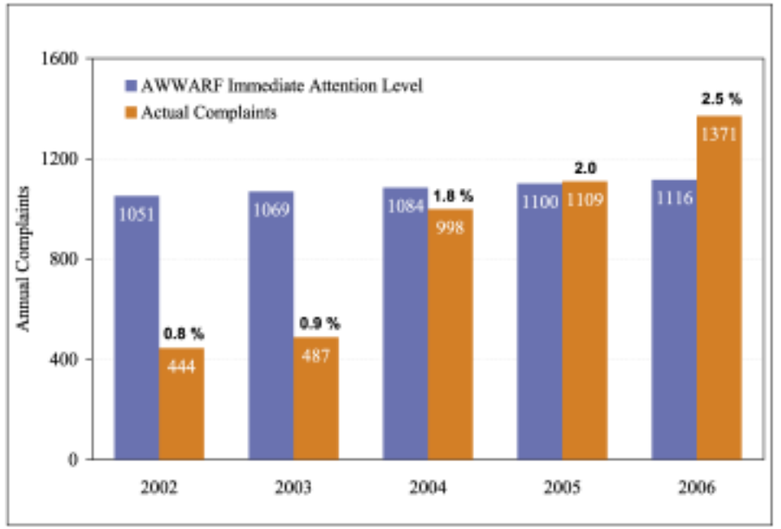

Figure 4: Annual Customer Complaints Performance Measures

UDF Program Approach

The UDF program consists of the following major tasks:

- Prioritizing Critical Areas
- Modeling and Preparing UDF Valve and Hydrant Maps
- Locating, Inspecting, and Testing Specific Valves and Hydrants
- Preparing UDF Flushing Map Books
- Public Notification
- Uni-Directional Flushing of the System

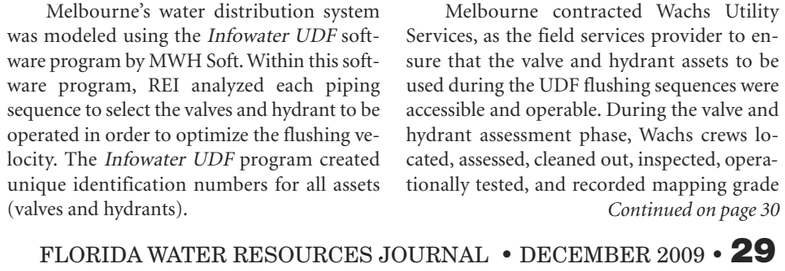

Figure 5: Example of a Typical Valve & Hydrant Map

Prioritizing Critical Areas

To initiate the UDF program, the entire water distribution system was divided into 340 zones, based on grouping the various distribution main branches coming off transmission mains. For this program, it was collectively assumed that transmission mains would be considered a source of clean water.

Each zone was then further divided into sequences, each of which consisted of an individual pipe segment within the zone and the corresponding flushing hydrant and valves to be isolated.

Each zone was cross referenced through the city's customer complain database to establish the water-quality complaints reported for each zone. Zones with the highest number of complaints received the highest priority rankings. It would be in this order that the flushing of the water distribution system would be implemented.

Modeling & Preparing UDF Valve & Hydrant Maps

Melbourne's water distribution system was modeled using the *Infowater UDF* software program by MWH Soft. Within this software program, REI analyzed each piping sequence to select the valves and hydrant to be operated in order to optimize the flushing velocity. The *Infowater UDF* program created unique identification numbers for all assets (valves and hydrants).

After the UDF model was completed, UDF valve and hydrant maps were prepared for each sequence of zone. An example of the valve and hydrant maps is shown in Figure 5.

Locating, Inspecting, & Testing Specific UDF Valves & Hydrants

Melbourne contracted Wachs Utility Services, as the field services provider to ensure that the valve and hydrant assets to be used during the UDF flushing sequences were accessible and operable. During the valve and hydrant assessment phase, Wachs crews located, assessed, cleaned out, inspected, operationally tested, and recorded mapping grade

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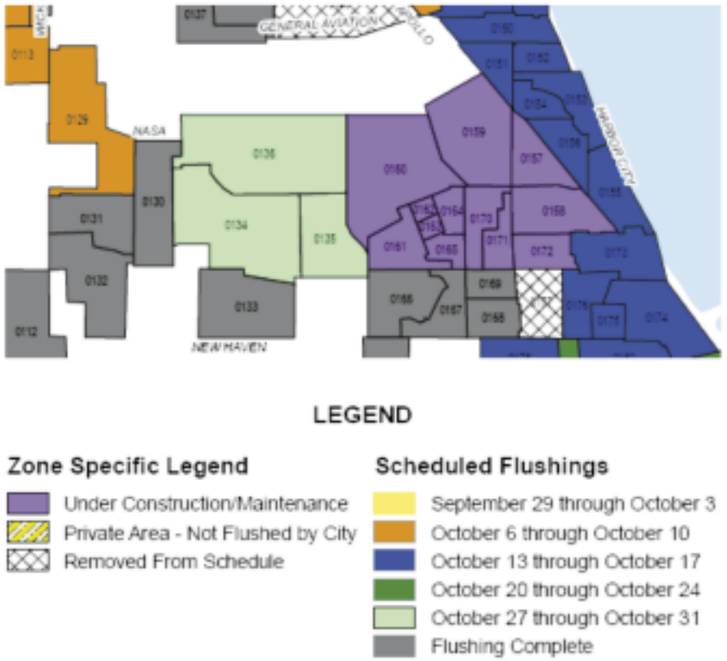
Figure 6: Portion of a Typical UDF Schedule Map



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GPS data for over 2,500 target valves and over 1,700 target fire hydrants.

Data gathered from each asset was stored in a geo-database. As a method of quality control, REI plotted the coordinate points from the geo-database to verify that the correct valves and hydrants were being marked in the field.

During the data collection process, a number of valves were identified as "inoperable" and logged in the geo-database. This information was provided on a daily basis to the city's operations department to aid in maintenance work orders.

Preparing UDF Flushing Map Books

When all the UDF valves and hydrants for a particular zone had been located and verified, REI prepared flushing maps for Wachs to use as a guide during flushing operations. Each flushing map book contained a separate map specifically created for each sequence.

The sequence map listed the valves to be closed for that particular sequence and the hydrant to be used during the flush. Also, the recommended length of time for flushing the sequence was identified.

Public Notification

The ability to provide continuous and updated information to the public regarding future assessment and flushing schedules, current location of flushing activities, and a method for residents to obtain instant answers to questions were major objectives for the UDF program. To obtain these objectives, the following sub-programs were established:

- Color-coded assessment and flushing schedule maps updated weekly on the city Web site
- Initial notifications via U.S. mail
- Notification street signs set up in neighborhoods prior to flushing
- Customer telephone hotline

Within Melbourne's public Web site, a UDF Web page was established containing a schedule map of the city that informed residents of assessment and flushing activities presently occurring and scheduled for the following four weeks. By color coding each UDF zone, residents could refer to the color legend at the bottom of the map to see when their corresponding zone would either be assessed or flushed, as shown in Figure 6.

The schedule map was updated weekly by coloring in new zones as they were added to the schedule and graying out zones that had been completed. Based on the average flushing productivity rate of 11 sequences flushed per 10-hour work day per crew, new zones were added to the schedule at approximately six zones per week.

Based on the schedule map, as the flushing date approached for a specific scheduled zone, initial notification postcards were created and mailed to the customers in the specific zones two weeks prior to their flushing week. The two-week time frame was carefully selected to give customers ample time to ask questions and plan personal events, while not providing so much lead time that they would tend to forget. The postcards included the following information:

- The purpose of the UDF program.
- A notice that street signs would be posted in their neighborhood the day prior to flushing.
- An explanation that during flushing, lower-than-normal pressure and/or discolored water may occur.
- A recommendation that during flushing, residents should avoid using water to avoid the possibility of sediment being drawn into their service.
- An explanation that if cloudiness or chlorine smell occurs after flushing, the resident should run cold-water faucets for five to 10 minutes.
- A customer hotline for questions.
- The city's Web site address for additional information.

On the day before flushing operations were conducted, notification street signs were placed at the entrances of neighborhoods to alert residents. An example of the street signs used on this project is shown in Figure 7.

Uni-Directional Flushing of the System

Using the UDF flushing maps provided by REI, Wachs crews systematically closed predetermined valves, opened specific hydrants, and flushed the system working from a clean water source. As part of the flushing process, Wachs recorded flushing times, calculated water usage, and returned all valves and hydrants to their standard operational position. As a result of the uni-directional flushing activities, there was a dramatic improvement in water quality and a reduction in customer complaints.

Water-Quality Improvements

As a method to measure the impact of the UDF effort, water samples from each zone were obtained two weeks before and two weeks after flushing. A comparison of the pre- and post-flushing samples showed the following results:

- Iron concentration dropped by 77 percent.
- Chlorine residual increased by 15 percent.
- Turbidity dropped by 57 percent.

As a result of the various improvements administered by the city of Melbourne, the number of water-quality complaints dropped. A total of 756 such complaints were logged from January through December 2007. After the initiation of uni-directional flushing in January 2008, the total registered water-quality complaints dropped to 161 in 2008—a reduction of 78 percent from the previous year.

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Lessons Learned

The uni-directional flushing program executed by the city of Melbourne, Reiss Engineering, and Wachs Utility Services represents the first UDF program completed in Florida where an entire distribution system was modeled and flushed uni-directionally. A literature review was performed early in the project and limited information on successful UDF programs was found, so challenges were expected. For the benefit of other utilities that are interested in completing a UDF program, the following factors impacted the Melbourne program:

- Quality of maps/ability to locate assets
- Condition of valves
- Public notification

Implementing a UDF program successfully requires knowledge of where valves and hydrants are located. As with many utilities, the city of Melbourne is gradually gathering GPS information on its distribution system to facilitate the development of a complete GIS-based asset management system; however, current information includes paper Atlas maps, electronic as-builts submitted by developers, GIS data for a portion of the system, and institutional knowledge of the city field staff.

The initial efforts to locate valves and confirm their operability was hampered by the quality of the historical maps available to locator crews. Those crews were forced to devote more effort than had been anticipated to either locate the necessary valve or select an alternate valve that would serve the same isolation function required to achieve the high water velocities associated with UDF flushing.

Figure 7: Example of a Notification Street Sign

It is critical that a utility allocate significant resources and time to ensure that valves and hydrants can be located and exercised before embarking on the actual UDF flushing itself. Because of the time-sensitive nature of the Melbourne project, one valve and hydrant assessment crew was deployed ahead of the flushing crew to focus solely on getting areas of the city operational and ready for flushing.

In some instances, valves could not be located, in which case Reiss Engineering was tasked with re-modeling the hydraulics of the system using different valves to isolate flow. For the Melbourne UDF program, approximately 25 percent of the city's total valves were utilized to isolate and direct flow to achieve velocity targets.

Once a target valve is located, the valve must be functional for use in the flushing program. Nonfunctional valves cannot be utilized in UDF sequences, and without a plan and resources to repair or replace these assets, they can impact the viability of a UDF program.

For the city of Melbourne, approximately 264 valves were found inoperable. While this represents a small percentage of the total valves employed in the program, it resulted in considerable effort by REI to remodel the hydraulics of the UDF plan to flush each zone successfully.

Finally, public notification is critical. As described previously, the Melbourne Public Works and Utilities Department went to great lengths to communicate the purpose of the program and its impact to its customers. Nevertheless, many notification cards were returned in the mail as undeliverable, and some residents were uncertain about the impact of the flushing program on their water quality. Ultimately, one of the most effective (and least costly) methods of communicating with residents was the signs posted outside of neighborhoods several days in advance of and during flushing events.

In summary, the city of Melbourne's UDF program was a tremendous success and can serve as a model for successful implementation of uni-directional flushing programs for other utilities in the state.

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