Cost-Effective Pipe Cleaning for Improved Water Quality

David Abbaspour, James Kinard, Matthew Wilson, John Parks, Richard Voakes, Matt Grewe, Edward Talton Jr., and Weston Haggen

The City of St. Petersburg (City), like most chloramine disinfectant water systems in Florida, faces the challenge of controlling nitrification in its distribution system during warmer months. To optimize delivered water quality to its potable water customers and reduce flushing water volumes in the south portion of its service area, the City implemented cutting-edge nitrification mitigation strategies as recommended by its strategic autoflusher program. Higher water distribution age or stagnation, coupled with utilization of chloramine disinfectant and elevated summer temperatures, typically result in nitrification. The flusher program was prepared in 2010, with assistance from Reiss Engineering, to help address high water age concerns in the southern extremities of the system in three phases:

- Phase 1 – Develop Action Plan
- Phase 2 – Design/Implement Recommended Improvements
- Phase 3 – Track Program Progress and Adjust as Needed

Phase 1 of the program confirmed that nitrification was occurring in the southern portion of the City's distribution system, especially during summer months. The City is two years into implementation of Phase 2, including converting park irrigation, deploying autoflushers, pilot testing unidirectional flushing (UDF), and tracking the program's progress. Available research indicated that nitrifying bacteria can take refuge in distribution pipe sediment (*Fundamentals and Control of Nitrification in Chloraminated Drinking Water Distribution Systems*; AWWA, 2006); therefore, UDF was considered a potential nitrification mitigation tool. This article focuses on the use of UDF to support maintenance of water quality improvement.

Background

The City had concerns about oversized pipes and mains being the cause for water quality issues, which in turn was the need for excessive distribution system flushing. The majority of the City was not experiencing nitrification and, over a decade of chloramine disinfection, had maintained a stable distribution system. Excessive flushing requirements had been confined to the southern extremity of the service area. Water mains are typically sized for peak demand and proper fire flows without regard for water quality. These low-flow mains can cause sediment buildup in the bottom of the mains and the high water age in the southern part of the City's water distribution system was causing nitrification during warmer months, creating biofilm. The City actively implemented recommendations from the flusher program to clean transmission and distribution mains and reduce water age to mitigate nitrification.

David Abbaspour, P.E., is senior professional engineer, James Kinard is water distribution system coordinator, Matthew Wilson is civil engineer II, John Parks, P.E., is technical support manager, and Richard Voakes is water treatment and distribution manager with City of St. Petersburg. Matt Grewe is UDF design engineer, Edward Talton Jr., P.E., is project manager, and Weston Haggen, P.E., is project engineer with Reiss Engineering in Winter Springs.

Methodology

The City has implemented a portion of the recommend action plan, including: conversion of four City parks, ranging from 4-in. to 8-in. meters from reclaimed water to potable water irrigation; installation of an additional 17 new autoflushers throughout the south service area (as shown in Figure 1); and piloting a method to clean sediment and biofilm out of the transmis-

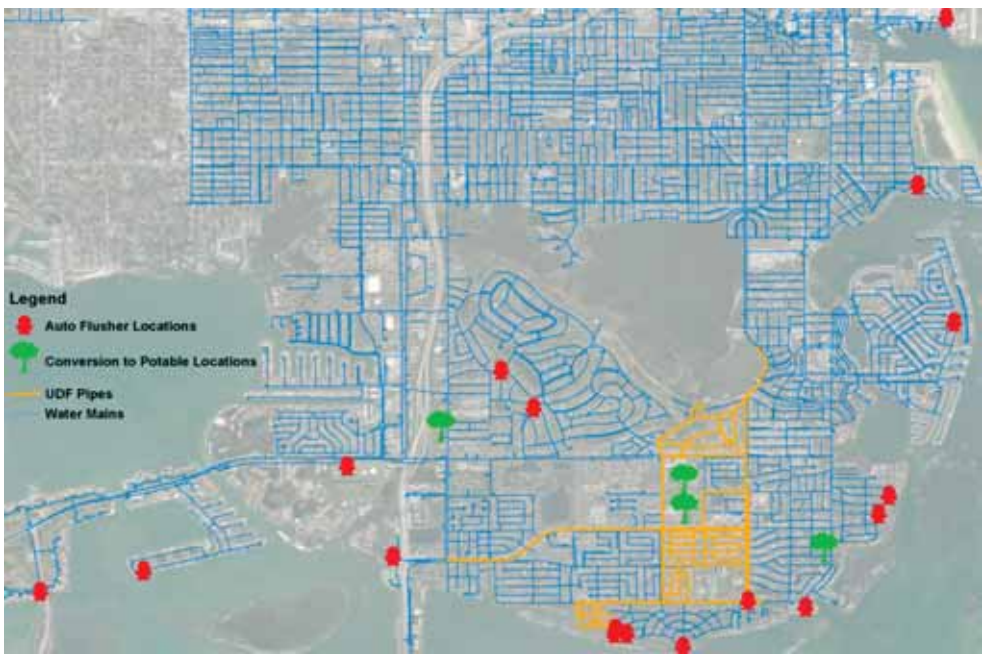

Figure 1. Conversion to Potable Locations, New Autoflushing Locations, and Pilot Unidirectional Flushing

sion and distribution mains. Based on a review of, and experience with, various pipe cleaning technologies, the City selected UDF for the pilot; the UDF has significantly lower costs than other available technologies and the City has had a successful experience with UDF in the past.

South Unidirectional Flushing Pilot Program

The UDF pilot was approved by the City as it provided the information it needed to make the decision to proceed with a future full-scale UDF implementation in the south area. The pilot program was planned for a portion of the City's distribution system where historical low chloramine residuals had been identified. This pilot area is circumferentially supplied by 20-in. transmission mains, of which a section was included in the UDF program. The 20-in. mains were sized years ago to serve commercial fire flows and demands that have been significantly reduced due to water conservation, reclaimed water, and lower density development, and are now oversized. The pipelines flushed during the UDF program are shown in Figure 1.

The pilot UDF program was designed by Reiss Engineering using the City's existing hydraulic model for all mains up to 20 in. in the pilot UDF. The pilot had eight zones, shown in Figure 2, including 51 flushing sequences in zone 1, which was a custom UDF design for the section of 20-in. transmission main. Approximately 3 mil gal (MG) of water were used to complete the pilot area UDF program. The custom 20-in. UDF included a 7,800-ft sequence that flushed over a half MG of water for two hours and 10 minutes.

The UDF pilot program was executed by City staff, which involved delivery of public notices, assessment of 122 system valves, 53 hydrants, and four blowoff valve assemblies (blowoffs). The assessment of the valves, hydrants, and blowoffs showed that the City had kept its system in excellent condition with all assessed valves, hydrants, and blowoffs located and operational. This was a major advantage as UDF redesign is required when valves, hydrants, and blowoffs are in disrepair or cannot be located.

Figure 2. Eight Zones in the Pilot UDF

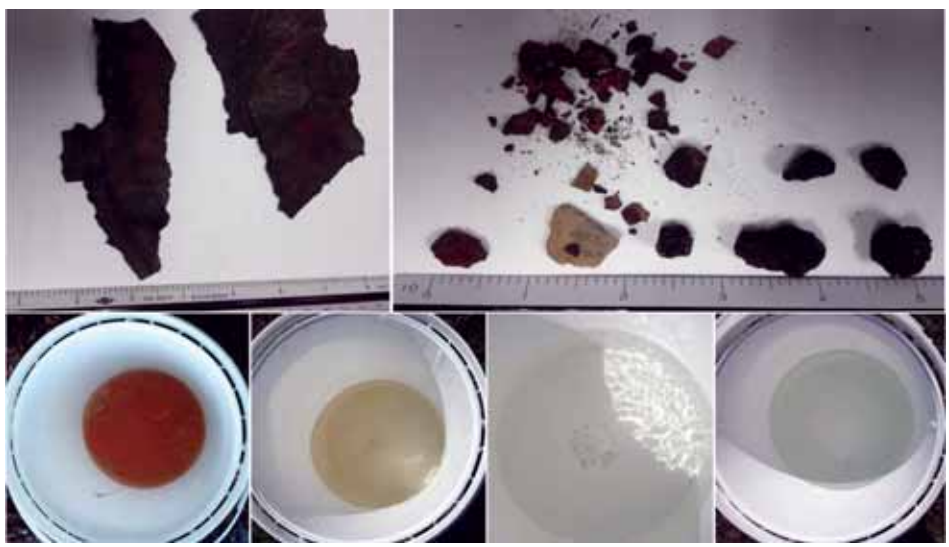

Figure 3. Examples of Sediment, Debris, and Iron Removal

The UDF pilot required the City crews to turn over a 100 valves to execute the program, with some sequences requiring up to 29 valve closures prior to implementing flushing activities. The City's policy is to hand-operate all valves to minimize damage. The large amount of valve closures was the direct result of successfully completing the pilot UDF program in the middle of an extensively interconnected distribution system. The UDF was designed to use the 16-in. and 20-in. transmission mains as source water for the smaller mains and valving off all other interconnected mains. This was done to maintain clean source water for the UDF, while maintaining minimum system pressure. Additionally, the City had to coordinate around ongoing stormwater projects to prevent flooding of neighborhood streets, residential yards, and driveways.

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Results

Due to the hard work and coordination of the City's crews, the pilot UDF program was successful in removing a significant amount of sediment and debris, including polyvinyl chloride (PVC) service taps, large sections of pipe lining, and pieces of metal, as shown in Figure 3. The flushing also removed a large amount of iron (shown in the white buckets), as the water that was flushed turned from reddish in color to clear.

To evaluate the effectiveness of the pilot UDF program, water quality parameters were collected by the City before and two weeks after the flushing occurred at eight strategically selected sampling points to encompass the overall effect from each UDF zone. The water quality parameters concluded that the pilot UDF program significantly reduced iron and turbidity levels. Iron had an average reduction of 88 percent, with a preflushing average of 313µg/L, to a postflushing average of 39 µg/L, as shown in Figure 4. Turbidity had an average reduction of 79 percent, with a preflushing average of 1.54 nephelometric turbidity units (NTUs), to a postflushing average of 0.33 NTUs, as shown in Figure 5.

Nitrite, nitrate, and chloramine levels were also tested two weeks after the flush. However, it was realized that upon review of the hydraulic flow paths into the pilot area, the nitrified water was flowing in from areas that had not been unidirectionally flushed; the nitrite, nitrate, and chloramine results confirmed this conclusion.

For fire flow and reliability reasons, the City could not keep the pilot area isolated, and hydraulic modeling indicated that most of the water flows into the pilot area from neighboring distribution areas and not from the cleaned transmission mains. Therefore, to get meaningful results for the effectiveness of UDF on nitrification mitigation, either a more isolated area should be tested or the entire south distribution area and major feeder transmission mains should be cleaned.

Turbidity readings were also performed during flushing activities showing a turbidity profile and how reduction took place. The turbidity profiles were very helpful to field crews to track flushing effectiveness and complete the flushing in an efficient manner. An example of this profile is shown in Figure 6 and an overall summary of all zones turbidity reduction is shown in Figure 7.

Conclusions

Since implementation of the strategic autoflusher program in spring 2011, the City has consistently reduced the potable water quantities flushed, resulting in lower labor and potable water costs. The flusher program has

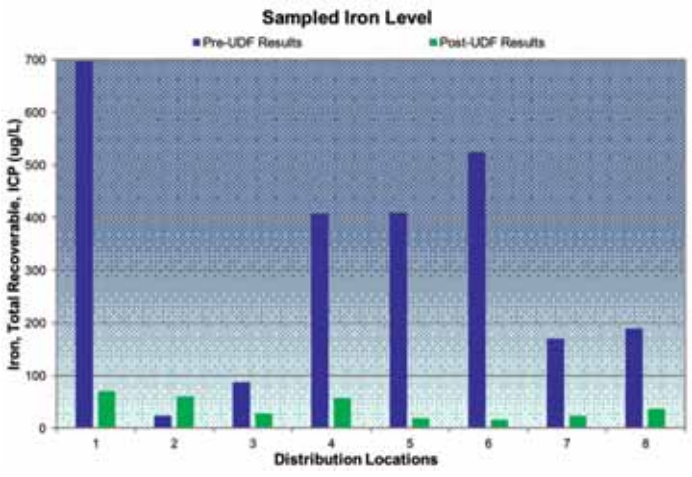

Figure 4. Iron Results Data for Pre-UDF and Post-UDF Sampling Events

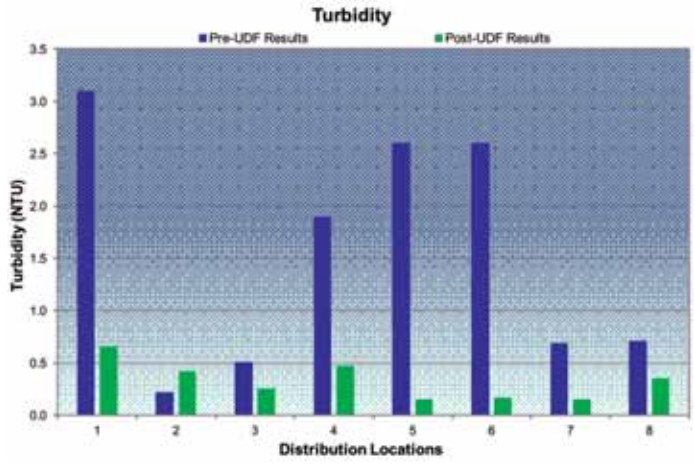

Figure 5. Turbidity Results Data for Pre-UDF and Post-UDF Sampling Events

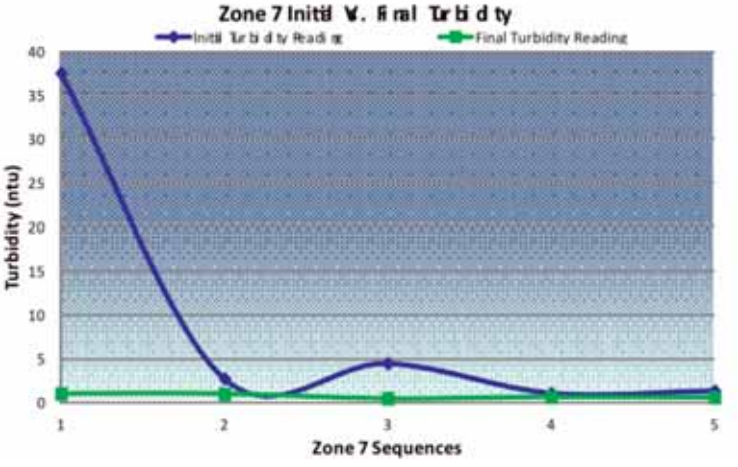

Figure 6. Zone 7 Initial Versus Final Turbidity During UDF

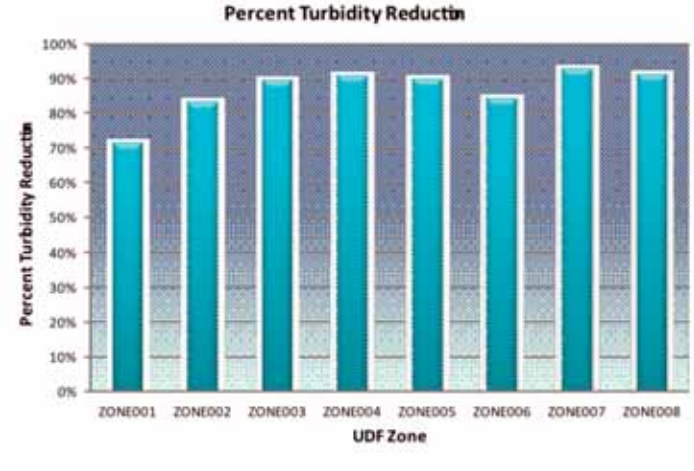

Figure 7. Turbidity Results Data Summary: Percent Turbidity Reduction During UDF

saved the City approximately $80,000 per year in flushing costs over the first two years of the program.

The UDF pilot program was successfully and efficiently completed due to the hard work of the City's staff, which was very effective at locating valves and executing the UDF flushing sequences. The City's diligent valve and hydrant maintenance program allowed UDF to be fully executed with minimal delay for repairs and UDF redesign. Staff knowledge of the system and familiarity with adopted procedures eliminated broken valve issues and saved the City considerable cost. The City's policy of hand-operating all valves resulted in no damaged valves during the UDF effort. Also, due to the high number of valves operated for each sequence, the City's flushing team resourcefully devised a protocol for tracking and checking valve openings and closures.

Water quality testing during the pilot program indicated that there was a significant amount of sedimentary particles in the pilot distribution area, especially in the larger diameter 20-in. transmission main. The pilot demonstrated that UDF was effective in cleaning the pipes, including the 20-in. transmission main, and flowing turbidities were reduced from over 100 NTUs in some cases to less than 3 NTUs. Preflush turbidities were reduced from up to 3 NTUs to less than 0.5 in almost all locations. Turbidity profiles devised during this project were vital in assessing the flushing effectiveness and flush durations. While UDF's effectiveness to mitigate nitrification could not be evaluated due to the influence from adjacent distribution areas that were not unidirectionally flushed, and research has identified that significant nitrification biomass exists in distribution sediment, it is surmised that a larger scale effort could significantly reduce nitrification rates.

A very complex pilot UDF was conducted, and a future full-scale UDF of the south system would significantly reduce the valve closing complexities. The pilot UDF demonstrated outstanding removal of turbidity and iron, which was sustained for at least two weeks after the flushing. The pilot UDF also demonstrated the effectiveness in cleaning 20-in. transmission mains, heretofore considered too large for UDF application. Overall, the pilot program demonstrated that the City could utilize UDF as an effective tool to help clean and maintain water distribution and transmission mains, providing City customers continued high-quality potable water delivered to the tap.