The Thornydale Reclaimed Booster Station was designed to deliver 1.25 mgd to five golf course lakes. This was arranged through a user agreement contract between Tuscon Water and a developer. Total delivery of 6.25 mgd, or 4,340 gpm, is transmitted through a class 150, 24 in.-concrete cylinder pipe (CCP) and an assortment of smaller mains as each lake receives its allotment. One 500 gpm and three 1,400 gpm vertical turbine pumps provide 343 ft of head, lifting reclaimed water through many deep washes and over a small mountain, for a total distance of 43,400 ft; not counting the parallel mains.

INVESTIGATION REVEALS CRITICAL OMISSIONS

When Tuscon Water joined this project the four boosters were only producing 2,300 gpm at 167 psi, or 385 ft of head. Three of the golf courses existed, but two more were in the works. Tuscon Water needed to meet its contractual obligation, and time was running out. The limit of the class 150 pipe was being exceeded by 17 psi and, on occasion, 180 psi was recorded at start-up. A hydraulic model of the project was assembled. Additionally, data loggers were placed on a stretch of parallel 12-in. mains. After reviewing data from the model and the data loggers a plan was devised to add a parallel 16-in. main to reduce head losses in this area. However, by adding the main the city only gained 500 gpm and reduced the pressure by seven pounds, which was not enough. The pipeline projects leading from the booster to each delivery point were then reviewed revealing an astonishing omission. In 12 critical locations where reclaimed main ‘drop’ sections crossed washes or dove under potable mains, air release valves (ARVs) or combination ARVs were neither designed nor installed. A plan to have a contractor excavate and place ARVs in the existing pipeline in Dove Mountain Boulevard and to have city crews repair or replace several existing ARVs that were buried met with some resistance. In the mean time, the fourth and fifth lakes were being built and Tuscon Water’s director determined the assistance of a consultant was needed to find a solution. The projected cost to have the consultant evaluate the system and provide solutions was $80,000.

MANAGEMENT AGREES TO DELAY HIRING CONSULTANT

By repeatedly presenting the gradual results of placing ARVs in the system and by graphing real time data, Tuscon Water’s management team was convinced to delay the consultant’s review and allow the author to continue the investigation. The placement of valves was slow, but each month additional ARVs were added resulting in positive test results, increased flows, and decreased pressure. With six additional ARVs placed the city was now recording flows of 3,000 gpm at 154 psi.
ADDITIONAL PROBLEM DISCOVERED

As part of the investigation a Tucson city planner was consulted. This led to the discovery of another issue plaguing the system. A lateral 16-in. main connects the Dove Mountain storage tank to pumps and, when full, this control tank turns boosters off. The Dove Mountain Tank sits 70 ft. above the high point of this delivery main (Figures 1 and 2). Again, the flow system dynamics were tested, and with the valve closed on the lateral pipe to the Dove Mountain Tank, Tucson Water experienced flows above 4,000 gpm at 143 psi. The city now opens lake-filling valves downstream of the high point in the main before boosters are started. This start up method empties the tank and the lateral main, draws down the head condition on the pumps, and continuously keeps booster pressures lower throughout the lake-filling process. The remaining five air release valves provided another gain; Tuscon Water is currently flowing 4,200 gpm at 139 psi—11 psi below the limit of the class of pipe at the booster station. Tuscon Water is now only 140 gpm shy of the contractual demand of 4,340 gpm.

CAREFUL RESEARCH REVEALS SOLUTIONS

By carefully researching all aspects of the booster delivery system and its mains, the problems were identified and the solutions slowly improved this system. For example, by calculating net positive suction head available, conducting surge pressure analysis, calculating anticipated head losses, and tracking down odd pressure readings at selected main locations, Tuscon Water was able to narrow the field and pinpoint trouble. During pump tests volts, amps, and flow were recorded eliminating pump problems. However, during a check of the boosters’ suction a major delivery problem was discovered. The 24-in. main could suddenly only deliver one third of its capacity indicating a possible buried ARV or a pinched valve. This issue had to be addressed before testing of the discharge portion of the Thornydale booster system could be finished. A total of 26 data loggers were placed on a 26-mile stretch of pipe from the Roger Road treatment plant to an inline variable frequency drive booster station, which assisted in lifting water to the Thornydale boosters. This inline booster concept was suggested so Tucson Water wouldn’t have to build six miles of 30-in main to overcome the head losses in the 24-in main. This resulted in a savings of approximately $2.5 million for Tuscon Water. However, more important was the time savings.

Data loggers were placed every 4 miles. The problem area was found, and four data loggers were placed in that single 1-mile stretch. It was discovered that a 24-in. valve was 75% closed on a main trying to move 6 mgd. This pinched valve reduced flow to 2 mgd. The problem was resolved and Tuscon Water now had enough flow to finish its testing.

FINAL SOLUTIONS GET THE JOB DONE

Additional ways to increase flow were investigated. This resulted in raising the lift on a small pump by nineteen feet—from 324 to 343 ft of head—with an impeller replacement. Initially there has not been much gain but future improvements to the system will make the new head condition on the pump beneficial.

A 12-in. parallel main provided the final solution to the problem. Research revealed that the a 12-in. main was to be paralleled downstream of the second delivery point. A user agreement stated that the additional 12-in. main must be installed by the developer before all five lakes were to be in service. Calculating the head loss of 5 mgd through 1,000 ft of 12-in. pipe versus the same flow through two 12-in. mains revealed 21 ft of head loss that would be eliminated. This improvement will move the pumps to the right on their curve and it is hoped that Tusco Water will be able to deliver 4,500 gpm at 134 psi. The new main should be constructed within a year.

LESSONS LEARNED

To find problems of low flow or pressure utilities should assemble all plans for boosters and related piping. Study AWWA Manual M51: Air-Release, Air/Vacuum, and Combination Air Valves and do the calculations according to your system. It is imperative to model the system and create a hydraulic grade line or pipe profile. Test each pump and then perform a composite pump test. Plan to spend many days in the field checking valves and installing ARVs at high points, at their proper location. You may have to pot-hole the main to find these proper high points. Place data loggers or pressure recorders on the ARVs, then test, study, and retest.

—Dan Denman is project manager for the City of Tucson Water Department where he has worked for the past 20 years designing reservoirs, wells, and booster pumping stations and their construction. Denman also teaches classes in hydraulic design to determine the proper lift for multiple pump booster stations. He can be contacted at Dan.Denman@tucsonaz.gov.
**FIGURE 1** Pipeline profile*

*Not to scale

HW—high water measured in feet above sea level

Each lake takes 1.25 mgd

**FIGURE 2** Pipeline velocities and flows