Prioritizing Well Rehabilitation With a Well Condition Survey

Douglas P. Dufresne and Valerie C. Davis

Case Study

Due to changes in the conditions of production wells over time within the potable water system, Toho Water Authority (Toho) requested a preliminary evaluation of the well conditions of all active production wells in its water supply system. This evaluation included the gathering of existing information on the wells and analysis of the data gathered in order to aid Toho in the prioritization of well rehabilitation or replacement efforts in the future.

Information requested from Toho included all pertinent well data, which may be obtained from well completion reports, well construction summary reports, maintenance records, water use permit information, historic pumpage rates and water quality records, and other technical well reports. The data collected were summarized on well data logs and included a thorough list of well and pump information.

Table 1 presents the data sought in the well condition survey. The wells in this well condition survey were all open borehole, Floridan aquifer wells. Additional information would be collected on screened wells, which may include screen diameter, screen slot size, screen material, gravel pack thickness, gravel pack size distribution, and gravel pack setting interval.

Permitted Wells

The water use permit issued from the South Florida Water Management District (SFWMD) to the Tohopekaliga Water Authority on Dec. 6, 2013, has 64 listed existing water supply wells. Currently, 35 active potable water supply wells are in the Toho water system, on which the well condition survey is focused. The 29 remaining permitted water supply wells are either to be abandoned (20 wells), already abandoned (seven wells), or are irrigation wells (two wells).

Several wells listed within the water use permit had different characteristics than those identified in the sanitary surveys performed regularly for the Florida Department of Environmental Protection (FDEP). When there was a conflict in names or well characteristics, in general, the information provided in the sanitary survey0 and the driller's well completion report took precedent over the information in the SFWMD table. Construction information found within an engineering report detailing well construction also took precedent over information found in a driller's well completion report.

Well Data Logs

The information and data gathered on the 35 active potable water supply wells were tabulated in the well data logs. Additional calculated values are also included on the well data logs, such as original specific capacity, current specific capacity, and well efficiency. The logs each show an aerial photograph location of the well, in addition to the state plane coordinates of the well in North American Datum 1983 (NAD83).

Well Age

The ages of the active wells were reviewed to determine the distribution of well age through the system. Figure 1 shows the well age versus the number of wells in each age category for the active wells in the Toho water system.

Douglas P. Dufresne, PG, is senior hydrogeologist/project director, and Valerie C. Davis, PG, is project hydrogeologist with Ardaman & Associates Inc., a Tetra Tech Company, in Orlando.

There is one well in the Toho system that is less than 10 years old, 16 wells were between 11 and 20 years old, and six wells were between 21 and 30 years old. The total number of active Toho water supply wells less than 30 years old is 23 wells, which accounts for 65.7 percent of the total number. The useful life of a water well is often considered to be 30 years, although many wells last longer than that without significant problems.

The total number of active Toho wells that are 31 years old or greater equals 12 wells, which is 34.3 percent of the total number. Those older wells include four wells between 31 and 40 years old, seven wells between 41 and 50 years old, and one well significantly greater than 50 years old at 91 years. The average age of the active Toho wells is 26.7 years, and without including the oldest well, the average age is 24.8 years. The geometric mean of well ages is equal to 23 years for the active Toho wells.

The remaining Toho wells, which include abandoned wells and wells to be abandoned, range between 13 and 56 years in age and average 33.7 years in age; many of these wells did not have recorded construction dates. The geometric mean of well ages for the remaining Toho wells is equal to 31.6 years. The average age of the remaining Toho wells is 7 years older than the active Toho wells. The geometric mean age of the remaining Toho wells is 8.6 years older than the active Toho wells.

Pumped Volume

The annual pumped volume and maximum monthly pumped volume for the active Toho wells for calendar year 2014 were used in the analysis. The total annual 2014 pumped volume for the 35 wells equaled 11,567 mil gal (MG). The wellfield annual pumped volume was

Table 1. Well Condition Survey Data

Well identification	Original static water level	Maximum monthly pumped volume
Location	Original pumping water level	
Well status	Current static water level	Water production problem
Completion report on file	Current pumping water level	Sand concentration problem
Geophysical logs on file	Test pump rate	Bacteriological problem
Year constructed	Design pump rate	Water quality problem
Casing type	Current pump rate	Pump type
Casing diameter	Original specific capacity	Pump manufacturer/model
Casing depth	Current specific capacity	Pump setting depth
Total well depth	Well efficiency	Pump installation date
Length of open hole	Annual pumped volume	Last pump repair date

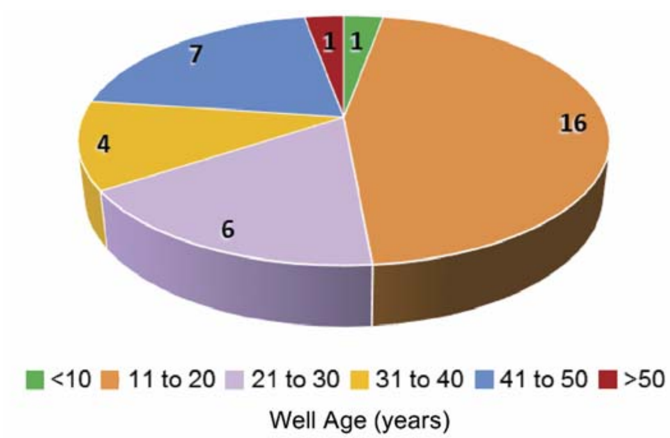

Figure 1. Well Age Versus Number of Wells

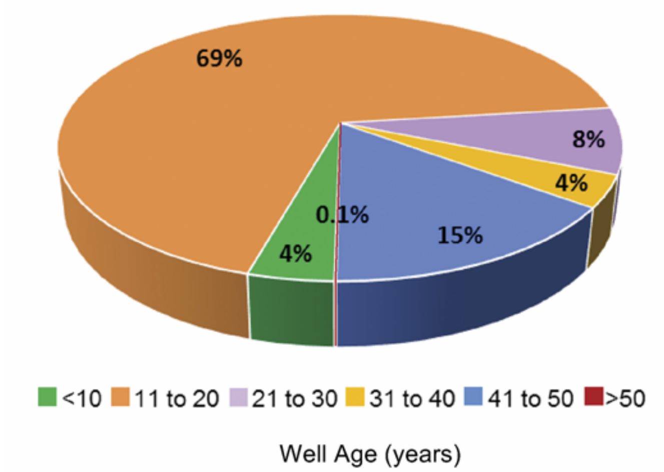

Figure 2. Well Age Versus Percentage Flow

calculated, along with the distribution of wellfield pumpage in percentage of the total annual pumped volume. The three wellfields with the largest annual volumes and percentages are North Bermuda with 4,821 MG and 41.7 percent, Southwest with 1,460 MG and 12.6 percent, and Parkway with 1,170 MG and 10.1 percent.

The pumped volumes of water from active potable wells for Toho were sorted by well age. Wells less than 10 years old account for about 4 percent of the annual pumped volume, whereas wells between 11 and 20 years old and between 21 and 30 years old account for about 69 percent and 8 percent, respectively. The wells 30 years old or less account for a total of 80.9 percent of the total annual volume. The active wells between 31 and 40 years old account for about 4 percent of the total annual volume pumped, and wells between 41 and 50 years old account for about 15 percent. Wells greater than 30 years old account for a total of 19.2 percent of the total annual volume pumped in 2014.

The annual volumes of water pumped in 2014 for the various well age groups were:

- Less than 10 years old - 477 MG
- Between 11 and 20 years old - 7,945 MG
- Between 21 and 30 years old - 931 MG
- Between 31 and 40 years old - 449 MG
- Between 41 and 50 years old - 1,753 MG
- Greater than 50 years old - 11 MG

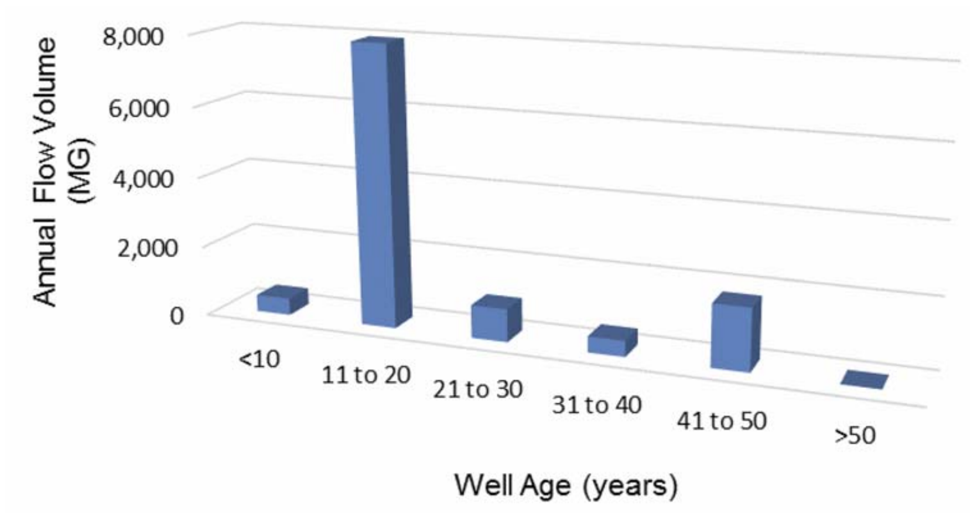

Figure 3. Well Age Versus Annual Flow Volume

Figure 3 shows the distribution of the total annual volume pumped in 2014 for the various well age groups.

The wells 30 years old or less had a total annual volume pumped of 9,353 MG in 2014; wells greater than 30 years old had a total annual volume pumped of 2,213 MG in 2014. Although the majority of pumpage comes from the newer wells, there is still a significant amount of water that comes from the older wells. As these older wells develop more problems as they continue to age, they need to be considered for rehabilitation to extend their useful life. If it is determined that these older wells cannot be effectively rehabilitated, they should be considered for replacement.

Static Water Level

The static water levels recorded at the original construction date were found for 24 of the 35 active potable wells. The original static water levels ranged between 0.61 and 45.19 ft below measuring point (bmp). These static water levels can vary due to the differences in the potentiometric surface elevation of the Floridan aquifer system, drawdown from pumping wells in the surrounding area, land surface elevation, and the time period the well pump has been off.

The current static water levels were recorded between June and September 2014 for 19 of the 35 active potable wells. There were 16 wells within the system that do not have appropriate access to measure the static or pumping water levels, predominantly due to the size of the pump within the final well casing not allowing a water level indicator to freely move to the water level for measurement. The current static water levels ranged between 4.48 and 50.52 feet bmp.

The changes in the static water levels (current minus original levels) could be determined for 12 active potable wells; these changes in the static water levels ranged from -1.52 to 12.79 ft bmp, and averaged 6.24 ft bmp. The current static water levels reflect the change in the potentiometric surface for the Floridan aquifer over the last couple of decades, with the increased use of the Floridan aquifer for potable water supply due to growth in the region.

Pumping Water Level

The pumping water levels recorded at the original construction date were found for 24 of

Continued on page 10

Continued from page 9
the 35 active potable wells. The original pumping water levels ranged between 5.08 and 70 ft bmp. These pumping water levels can vary due to the differences in the potentiometric surface elevation of the Floridan aquifer system, drawdown from pumping wells in the surrounding area, land surface elevation, and the time period the well pump has been pumping. It is critical to have the original water level data for the well when it was installed in order to properly track changes over time for determining the need for rehabilitation and to monitor the water supply sustainability.

The current pumping water levels were recorded between June and September 2014 for 19 of the 35 active potable wells. The current pumping water levels ranged between 10.69 and 77.22 ft bmp. The changes in the pumping water levels (current minus original levels) could be determined for 12 active potable wells; these changes in the pumping water levels ranged from 13.49 to 19.77 ft bmp, and averaged 5.62 ft bmp. The current pumping water levels reflect the change in the potentiometric surface for the Floridan aquifer over the last couple of decades, with the increased use of the Floridan aquifer for potable water supply due to growth in the region. These current pumping water levels can also be different from the original pumping water levels, if the pump rates are different.

Pump Rate

The design pump rate for the installed pumps in the active potable wells ranged between 75 and 3,500 gal per minute (gpm), and averaged 1,640 gpm; the current pump rate for the same wells ranged between 84 and 4,043 gpm, and averaged 1,757 gpm. The current pump rate data came from the most recent flow meter calibration reports. The change in pump rate (current minus design pump rate) ranges between -806 and 1,830 gpm, and averages 50 gpm. Figure 4 shows the change in pump rate versus the well age.

The majority of the active potable wells that are less than 20 years old have current pump rates that exceed the design pump rate for the existing pumps. The majority of wells that are greater than 20 years old have current pump rates that are less than the design pump rate for the existing pumps; the older wells likely have static and pumping water levels that are lower today than when the pumps were installed. With the change in head conditions, the pump rate can drop below the design rate, and the pump rate can also drop below the design rate due to pump wear. The wells can also experience a change in productivity with the clogging of the formation within a close proximity of the open borehole leading to greater drawdown within the well, thereby changing the head conditions. Clogging of the formation should be noted with a change in the specific capacity over time.

Specific Capacity

The specific capacity of a well is equal to the well discharge per unit of drawdown (Driscoll, 1986) expressed in gpm/ft or cubic meters per day per meter (m3/day/m); this value is used as a measure of a well's productivity. The original specific capacities were calculated for 20 of the 35 active potable wells. These original specific capacities ranged from 32 to 869 gpm/ft. The current specific capacities were calculated for 18 of the active potable wells; they range from 41 to 1,029 gpm/ft.

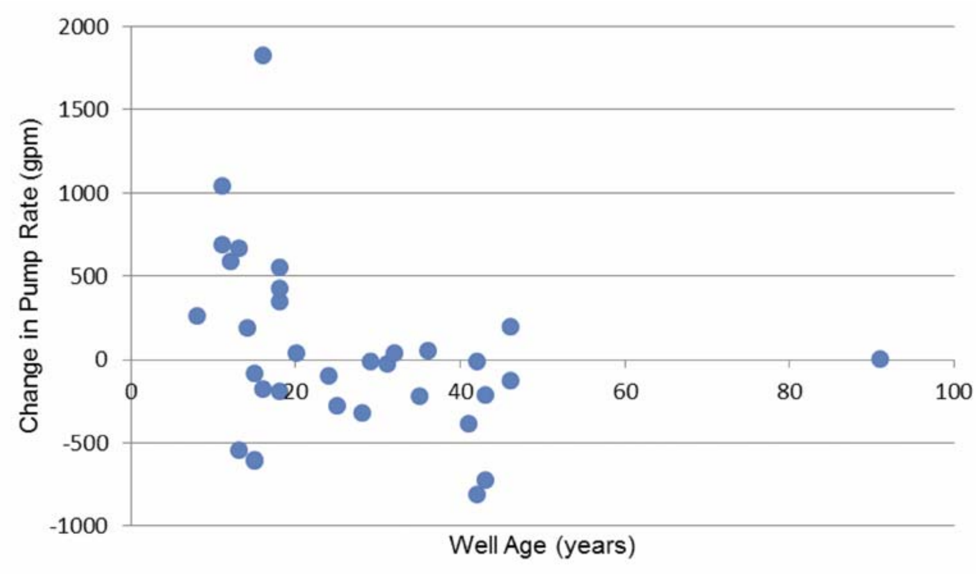

Figure 4. Change in Pump Rate Versus Well Age

The change in specific capacity (current minus original specific capacity) was calculated for the 12 active wells that had both original and current specific capacity values. Change in specific capacity ranged between -370 and 428 gpm/ft, and averaged 56 gpm/ft. There were four wells that had a decrease in specific capacity and eight wells that had an increase in specific capacity. The change is specific capacity could be influenced by the difference in the test rate between the original and current measurements. The higher the pump rate while testing, the more the specific capacity generally decreases due to the increase in turbulent flow within the well. A change in specific capacity, therefore, does not necessarily mean that there has been an actual change in the productivity of the well when the test rates are different.

Well Efficiency

Data from step-drawdown tests performed at the time of well construction were available for nine active wells. The step-drawdown test is generally run with four steps of increasing pump rates run for one hour of pumping for each step; the specific capacity and well efficiency is then calculated for each step of the test. For these wells, the design-rate well efficiency ranged between 29 percent and 69 percent, and averaged 47 percent. Well efficiency is equal to the ratio of theoretical drawdown in the aquifer to observed drawdown in the well (Driscoll, 1986). An efficiency of 70 to 80 percent is the target efficiency when constructing a well with good design, construction, and development practices (Driscoll, 1986). Due to high flow volumes in Floridan aquifer wells with fractured flow and cavities, turbulent flow in the borehole often leads to a well efficiency that is considerably less than 70 percent. If the discharge rate is high for a well and there is little drawdown, an inefficient well can be considered acceptable.

Well Problems

The well problems surveyed for the active potable wells for Toho included water production, sand concentration, bacteriological, and water quality. A water production problem was reported in 12 of the 35 wells. A sand concentration problem, where the well is pumping too much sand, was reported in one well. In 10 wells, a bacteriological problem was noted, and in 13 wells, a water quality problem was reported. Many of the wells with a water quality problem had the problem at the time of construction.

Figure 5 shows the number of wells with a water production problem distributed by well age. Water production problems were noted in four wells between 11 and 20 years old, three wells between 21 and 30 years old, one well between 31 and 40 years old, and four wells between 41 and 50 years old. Twelve active potable wells have a reduction in pump rate from the design rate greater than 15 percent, which defines them in this study as having a water production problem. These wells ranged in a reduction of pumpage from 16 percent to 67 percent.

A sand concentration problem was only noted in one well, and it was between 11 and 20 years old. After some investigation, it was determined that this well had sand entering the open borehole about 135 ft below the bottom of the casing, and that it was also pumping rust scale from a corroded casing. The well was rehabilitated by brushing the casing, disinfecting, and redeveloping through overpumping, and the well was placed back into service.

Figure 6 shows the number of wells with a bacteriological problem distributed by well age. Bacteriological problems were noted in one well between 11 and 20 years old (6 percent of the age group), one well between 21 and 30 years old (17 percent of the age group), two wells between 31 and 40 years old (50 percent of the age group), five wells between 41 and 50 years old (71 percent of the age group), and one well greater than 50 years old (100 percent of the age group).

It appears that the older the wells are, the greater the likelihood that they experienced a bacteriological problem. With aging comes the corrosion of the casing and fittings that may expose the well to bacteriological contaminants within the surficial aquifer. The wells could have been rehabilitated over the years by scrubbing the casing, disinfecting the casing and borehole with strong chlorine solution or other disinfectant, and redeveloping the well. This method is effective for several years or longer, but it all depends upon whether the root cause of the bacteriological contamination has been addressed or not; otherwise, the problem can reoccur.

Toho has addressed some of the concerns with bacteriological contamination by demonstrating a four-log inactivation at some of its water treatment plants. The water treatment plants that have had demonstrated four-log inactivation include Buenaventura Lakes, Camelot West, Northwest Kissimmee, and Parkway.

Figure 7 shows the number of wells with a water quality problem, most of which are due to the background water quality within an area. With the exception of two wells, all of the wells with water quality problems are located east of Lake Tohopekaliga, so it appears that the water quality problem for Toho is a regional problem and not necessarily individual wells. These water quality problems include disinfection byproduct precursors, hydrogen sulfide, and ammonia.

Continued on page 12

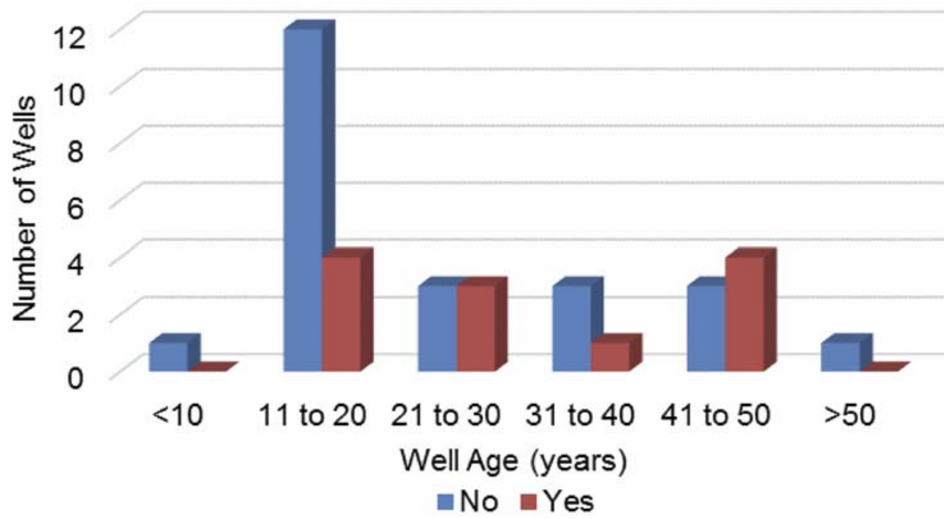

Figure 5. Well Age Versus Water Production Problem

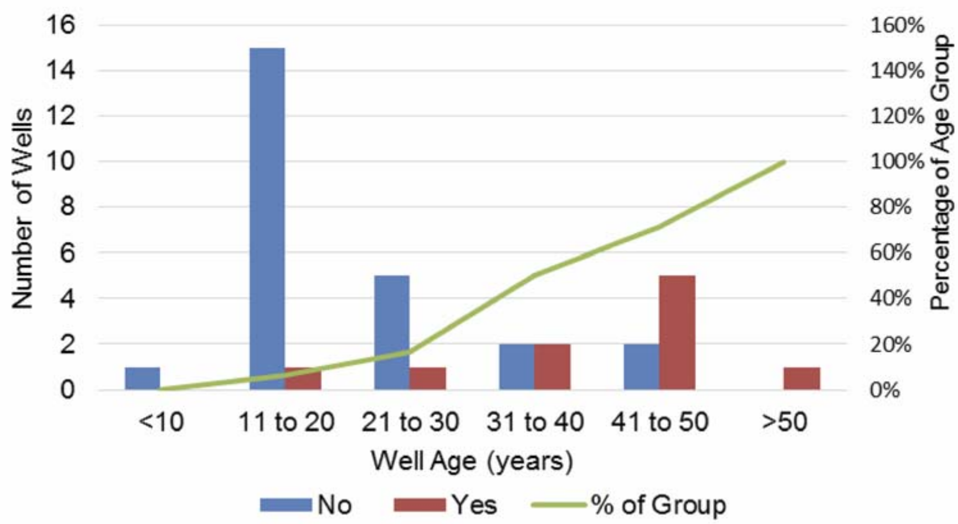

Figure 6. Well Age Versus Bacteriological Problem

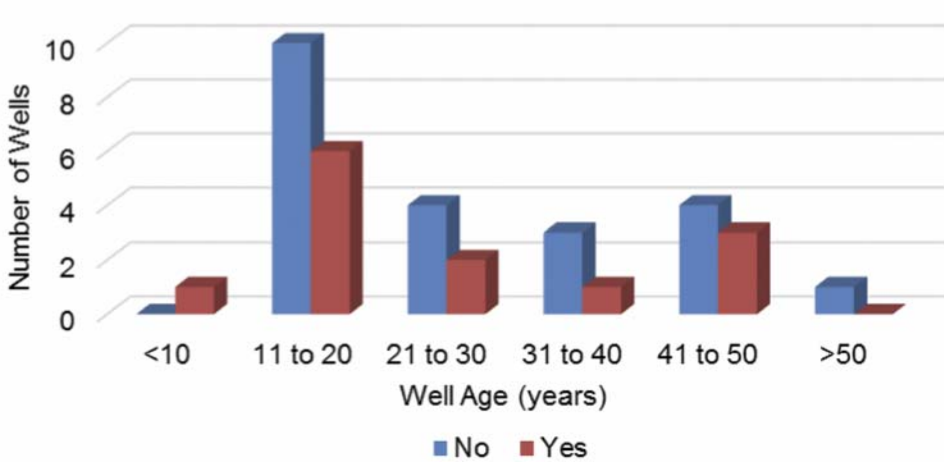

Figure 7. Well Age Versus Water Quality Problem

Continued from page 11

Water quality problems were noted in one well less than 10 years old, six wells between 11 and 20 years old, two wells between 21 and 30 years old, one well between 31 and 40 years old, and three wells between 41 and 50 years old.

Conclusions

The average age of active potable water supply wells for Toho is 26.7 years; the useful life of a water well is often considered to be 30 years, although, many wells last longer than that without significant problems. Active water supply wells less than 30 years old account for 65.7 percent of the total number of wells for Toho and have a total of 81 percent of the total annual pumped volume in 2014. The static water levels recorded at the original construction date were available for 24 of the 35 active potable wells. The current static water levels recorded between June and September 2014 were available for only 19 of the active potable wells. There are 16 wells within the system that do not have appropriate access to measure the static or pumping water levels.

It is critical to have the original water level data for the well when it was installed in order to properly track changes over time for determining the need for rehabilitation and to monitor the water supply sustainability. It is also necessary to have the ability to measure the current static and pumping water levels to monitor the performance of the well over time. The changes in the static water levels (current minus original levels) could be determined for 12 active potable wells, and they averaged 6.24 ft bmp. The changes in the pumping water levels could be determined for 12 active potable wells, and they averaged 5.62 ft bmp. The current static and pumping water levels reflect the change in the potentiometric surface elevation for the Floridan aquifer over the last couple of decades, perhaps due to the increased use of the Floridan aquifer for potable water supply in the region.

The change in pump rate (current minus design pump rate) averages 50 gpm. The majority of the active potable wells less than 20 years old have current pump rates that exceed the design pump rate for the existing pumps. The majority of wells greater than 20 years old have current pump rates that are less than the design pump rate for the existing pumps. Change in specific capacity averaged 56 gpm/ft for the 12 wells that had both original and current capacities to compare. There were four wells that had a decrease in specific capacity and eight wells that had an increase in specific capacity. The design-rate well efficiency ranged between 29 and 69 percent, and averaged 47 percent for nine of the active wells that had step-drawdown test data available.

There are twelve active potable wells that have a reduction in pump rate from the design rate that is greater than 15 percent, defined as having a water production problem. A sand concentration problem was reported in one well, which is 16 years old; in 10 wells, a bacteriological problem was noted. It is clear that the older wells have a greater likelihood that they will experience a bacteriological problem. A water quality problem was reported in 13 wells, but it appears to be a regional problem.

The results of the well condition survey allowed for a rehabilitation prioritization table to be prepared based on the number of well problems and the potential for affecting water supply reliability in certain areas.

Recommendations

It is generally recommended that additional information be gathered on the active potable wells in order to more fully evaluate the well conditions for all the wells. There are some wells identified in the well condition survey recommended for rehabilitation, and Toho could proceed with implementation in the near future. The other wells could be addressed as needed over the next several years in a maintenance program.

For ease of assigning recommendations, and to identify the order of rehabilitation, the wells were first prioritized. A table was created showing the wells with identified well problems as revealed in the well condition survey, including water production, sand concentration, bacteriological, water quality, and water-level measurement access. The 27 wells on the table were sorted by reduction in pump rate and then by the total number of problems. The wells with a reduction in pump rate and additional problems were assigned a higher priority for testing and rehabilitation.

Wells with some evaluation that were ready for additional testing and rehabilitation were prioritized, and wells with bacteriological problems would be next in line for testing and rehabilitation. Wells on the list with the lowest priority for rehabilitation included those requiring access for water level monitoring or for water quality issues that could be evaluated, but likely would not be easily remedied due to the existing background water quality in these areas.

Recommendations for any utility include:

- The next time pumps are pulled in wells without water-level measurement access, the utility should install a metal or plastic air line with a pressure gauge during reinstallation of the pump that can be used to monitor static and pumping water levels (USGS, 2001).
- Wells identified with decreased production need to be tested and analyzed to determine whether the change in production is a result of change of the potentiometric surface elevation for the Floridan aquifer, a change in specific capacity, pump wearing, or a combination of reasons.
- Wells with a sand concentration problem should be investigated. If the investigation shows that the well can be restored, the well should be rehabilitated and tested. If the investigation shows that the well cannot be rehabilitated, and the well is older than 30 years, consideration should be given to replacing the well.
- Wells identified with bacteriological problems need to be tested and analyzed to determine the source of the contamination and whether the well can be properly rehabilitated. The wells can often be remediated by scrubbing the casing, disinfecting the casing and borehole with strong chlorine solution or other disinfectant, and redeveloping the well. If there are perforations in portions of the casing, a liner can be installed to seal the casing from the aquifer only when the casing diameter is large enough to accommodate the liner. If the bacteriological problem is persistent and reoccurring, and the well is older than 30 years, consideration should be given to replacing the well.
- Wells identified with water quality problems need to be investigated to determine the source of the water quality issues and whether the well can be properly rehabilitated. If the source of the water quality problems is not ambient water quality, the wells can often be remediated. If the water quality issues are persistent and reoccurring, and the well is older than 30 years, consideration should be given to replacing the well.

References

- Ardaman & Associates Inc., March 2015. "Toho Water Authority Well Condition Survey, Osceola County, Florida." File No. 15-10-0401, Orlando, Fla.
- Driscoll, Fletcher, 1986. "Groundwater and Wells, Johnson Screens." St. Paul, Minn.
- U.S. Geological Survey, 2011. "Groundwater Technical Procedures of the U.S. Geological Survey Techniques and Methods." 1-A1, Reston, Va., pp. 111-116.