Who Needs Pretreatment? Not Orange County Utilities' Operational Aquifer Storage and Recovery

Mary Fickert Thomas, Kim Kunihiro, Kathy Traexler, and Mark Johnston

Arsenic is an element found naturally in the limestone aquifers that underlie Florida. The introduction, or recharge, of a water containing a higher dissolved oxygen (DO) concentration than the native groundwater causes a chemical reaction that results in the release of soluble arsenic into the groundwater. In 2001, with the passage of the Chemical Contaminants Rule, the U.S. Environmental Protection Agency (EPA) lowered the arsenic maximum contaminant level (MCL) from 50 parts per billion (ppb) to 10 ppb, and aquifer storage and recovery (ASR) permits were slowed to a near halt. With a historic MCL of 50 ppb, a number of operational permits were issued for ASR systems that could successfully reduce concentrations below this limit; however, the significantly lower MCL of 10 ppb meant that far fewer ASR well systems could comply, so many who wished to utilize ASR as a water storage option sought out pretreatment options to lower the DO concentrations, thereby reducing the potential for arsenic mobilization. Though some pretreatment systems proved successful, many remained riddled with challenging maintenance issues and significant cost.

Orange County Utilities (OCU) pursued an alternative to DO pretreatment with its potable water ASR well system. By injecting a "buffer" water volume, far in excess of its storage volume, OCU created a physical barrier between the stored water and the arsenic-containing limestone aquifer. Through a number of successive cycle tests, OCU conditioned the aquifer with the introduction of oxygen-rich water. Using several operational techniques, OCU was able to steadily reduce arsenic concentrations in the recovered water until the concentrations were consistently below the 10 ppb MCL for two consecutive cycle tests.

Technique One: Extensive Aquifer Conditioning

During the course of OCU's cycle testing program, a number of cycle test patterns were attempted. Initial cycle tests were large in volume and long in duration. This was done to maximize the storage zone and the buffer between the native limestone aquifer and non-native recharge water. It was thought that by pushing the storage zone to the higher end of its capacity, the interaction between the arsenic-containing formation and the oxygen-rich water would occur at a farther distance from the ASR well, and therefore have a lesser impact on the water quality sampled from the ASR well. While that concept did not occur quite the way it was intended, there was another consequence that would later be realized as beneficial: the aquifer was being conditioned.

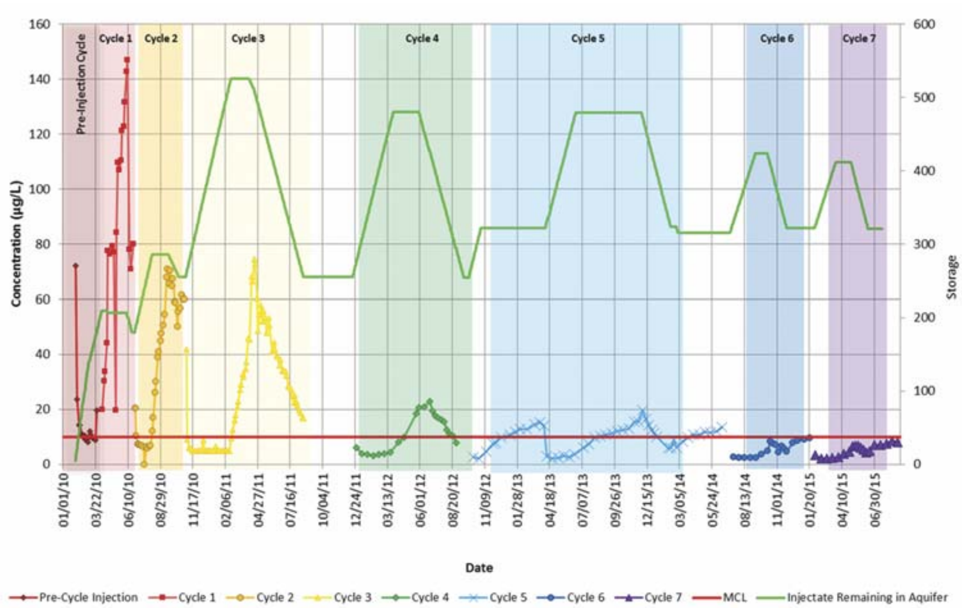

Figure 1. Arsenic Concentration in the Nearby Monitor Well

Mary Fickert Thomas, P.E., is supervising engineer and Mark Johnson is senior environmental engineer with WSP | Parsons Brinckerhoff in Orlando. Kim Kunihiro is water quality and water production manager and Kathy Traexler, P.E., is senior engineer with Orlando County Utilities.

Initial cycle tests at the onset of the cycle testing program caused a significant imbalance in aquifer water chemistry. A precycle test buffer of approximately 180 mil gal (MG) was injected to act as a barrier between the formation and the ASR storage zone, but this volume was never recovered. The first cycle test involved the injection of approximately 30 MG, for a total injected volume of 210 MG.

Treated potable water contains a relatively high level of DO (on the order of 5 to 6 mg/L). The introduction of this water to the native aquifer with nearly no DO resulted in the release of a significant amount of arsenic from the aquifer formation, and an arsenic concentration of over 140 ppb (Figure 1). This recharge water was subsequently recovered and never reinjected, removing the leached arsenic from the system.

The second cycle test, which resulted in a slightly larger storage zone of approximately 285 MG, continued to expand the storage zone and resulted in additional leaching of arsenic from the limestone aquifer; however, with only a slight increase in the storage zone of approximately 93 ft, or 16 percent of the first cycle test radius, the arsenic concentration was not nearly as high, with concentrations at less than half of that seen in the first cycle test.

Upon reviewing the water quality data, the third cycle test appeared to have had the most perceptible impact on the aquifer conditioning. By pushing approximately 525 MG of potable water to a storage zone radius of 893 ft, the greatest amount of the formation that would ever be exposed to oxygen-rich water was exposed and "scrubbed" of leachable arsenic. Once again, all of the water from this cycle test was removed and never reinjected, leaving the aquifer free of the newly introduced arsenic.

All subsequent cycle tests were smaller than the third. By remaining within that maximum radius, oxygen-rich water was never exposed to portions of the formation, which had not already been "scrubbed" of the leachable arsenic. While some arsenic remained in the aquifer, cycle tests four and five exhibited significantly reduced arsenic, with cycle tests six and seven meeting the MCL for arsenic in drinking water.

Technique Two: Mimic Seasonal Conditions

The functionality of a fully operational ASR system is similar to that of any other storage facility: the storage zone is recharged, or "filled," during periods of excess rainfall when the additional water is available and then recovered when water demands increase during drier periods. This approach of recharge and recovery attempts to mimic naturally occurring seasonal weather patterns. In central Florida, the wet season is generally late May to mid-October (Figure 2), which means that, at some point following the beginning of the wet season, an ASR well is filled, or recharged, over the course of a number of months. After a period of time, or some desired well volume, the well is placed into a storage phase until there is a demand for the stored water, and it is then withdrawn.

The goal of the cycle testing program was to demonstrate that all water quality requirements could be met under practical operating conditions. Since precipitation in the state varies, it was important to test a variety of cycle-testing scenarios. Initial cycle tests involved the injection of water at somewhat higher flow rates and relatively short storage periods, on the order of 40 to 60 days. Because the aquifer was still being conditioned and the aquifer chemistry was unstable, there was a significant increase in arsenic concentrations in the native water, even when storage periods were somewhat short. With time, storage periods were extended, with the longest occurring during the fifth test cycle. With storage ultimately lasting nearly one year due to mechanical issues at the well, chemical reactions were allowed to occur for a longer duration, resulting in a gradual increase in the arsenic concentration. Though still at the lowest peak levels observed for a cycle test to date, it can be seen in

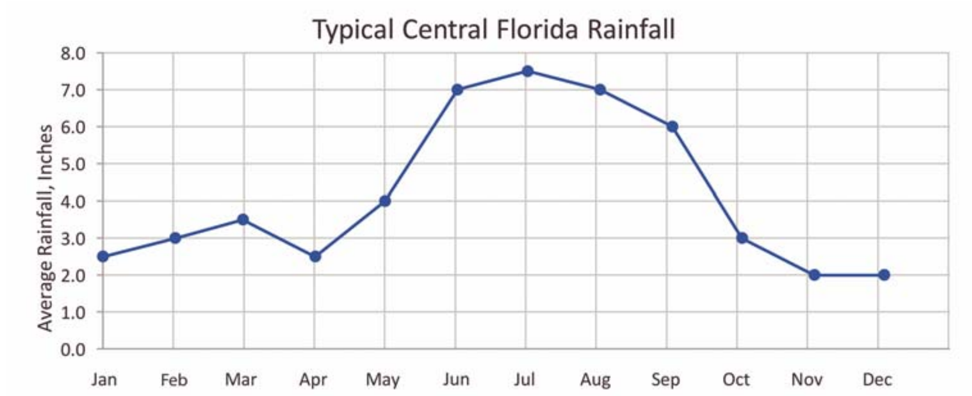

Figure 2. Typical Monthly Central Florida Rainfall

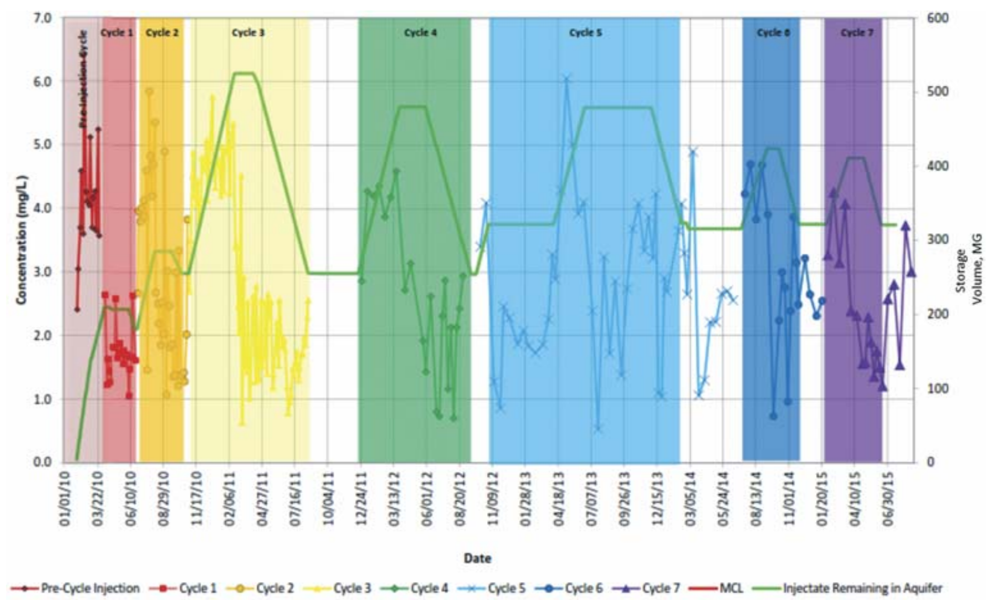

Figure 3. Dissolved Oxygen Concentrations in the Nearby Monitor Well

Figure 1 that as the storage period advanced, so did the arsenic concentration. Cycle tests six and seven were both shorter in duration, and this is thought to have been another factor in the lower levels of arsenic observed in the sampling wells.

Technique Three: Minimize Agitation With Injection Rate Management

The pump used to recharge the ASR well was sized at approximately 3 mil gal per day (mgd), but averaged an injection rate of approximately 2.5 mgd in early 2010. Cycle tests one through five were all operated at a rate of between 2 and 2.5 mgd. During these cycle tests, DO levels were extremely varied, with a range of 1 to 6.4 mg/L during the injection of the buffer volume and 0.5 to 6 mg/L during the fifth cycle test (Figure 3).

With the goal of reducing agitation in the aquifer from the injection of the higher DO water, the injection rate was lowered to approximately 1.7 mgd for cycle tests six and seven. It was hypothesized that by reducing agitation in the well, mixing in the aquifer would be reduced, as would the potential for high-DO water to reach portions of the formation where arsenic could be released (Figure 3); this resulted in some success. While the DO sampled from the nearby monitor well was not reduced significantly, the variation in maximum and minimum concentrations were narrowed in cycle tests six and seven, as compared with previous cycle tests.

Technique Four: Extensive Water Quality Monitoring

One of the greatest tools in determining what impact the treated potable water had on the native aquifer system is an extensive water quality monitoring program. While not all parameters analyzed showed much value in the determination of aquifer performance, and while testing samples for a long list of parameters for a long period of time—in this case, over 6 years—is quite costly, much of the data proved to be

Continued on page 36

Continued from page 35

valuable in determining what operational changes might improve ASR water quality.

For OCU's ASR well, water quality sampling results were utilized to develop a better understanding of the extent of the ASR storage zone. In order to achieve this, an analyte that exists in the potable water supply, but not in the native aquifer, needed to be observed in the aquifer. For OCU's ASR well, fluoride was used as the tracer analyte and is added to OCU's potable water supply to a concentration of approximately 0.6-0.7 mg/L, as it does not exist naturally in the groundwater. Fluoride is also stable in the environment and does not degrade or convert to another analyte. As Figure 4 shows, fluoride concentrations in the far well reached concentrations of 0.6 mg/L and above in the third cycle test, indicating that the storage zone edge had indeed reached the far monitor well, 510 ft away from the ASR injection well; however, at no point during any cycle test did arsenic in the far well reach the 10-ppb MCL, as shown in Figure 5. In addition, fluoride concentrations in the well increased and decreased consistently with ASR recharge and recovery, indicating that the storage zone remained somewhat well-defined during cycle testing. Information of this type is invaluable to understanding the performance of the ASR well and would not be possible without extensive water quality monitoring.

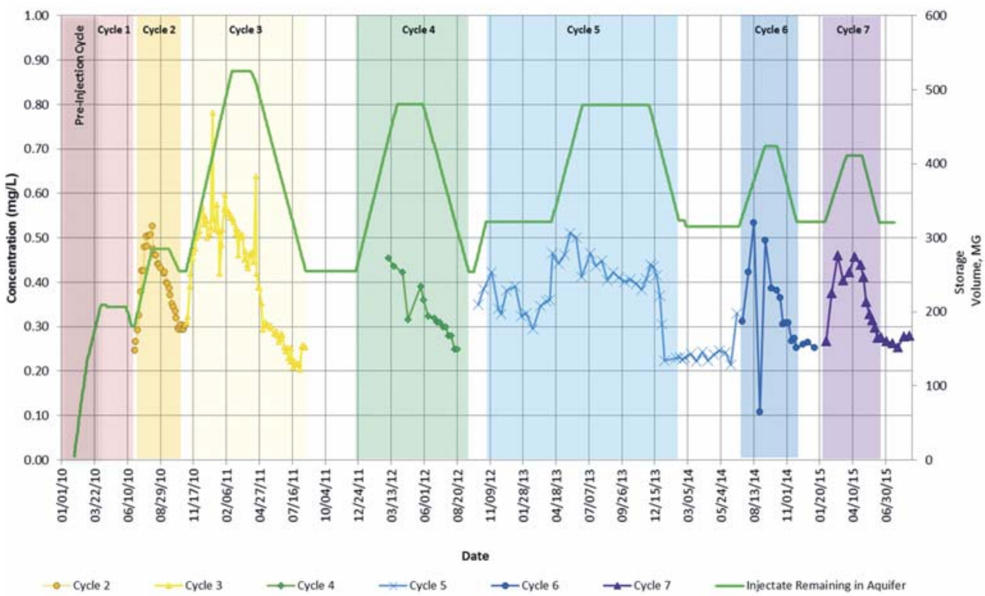

Figure 4. Fluoride Concentrations in the Far Monitor Well

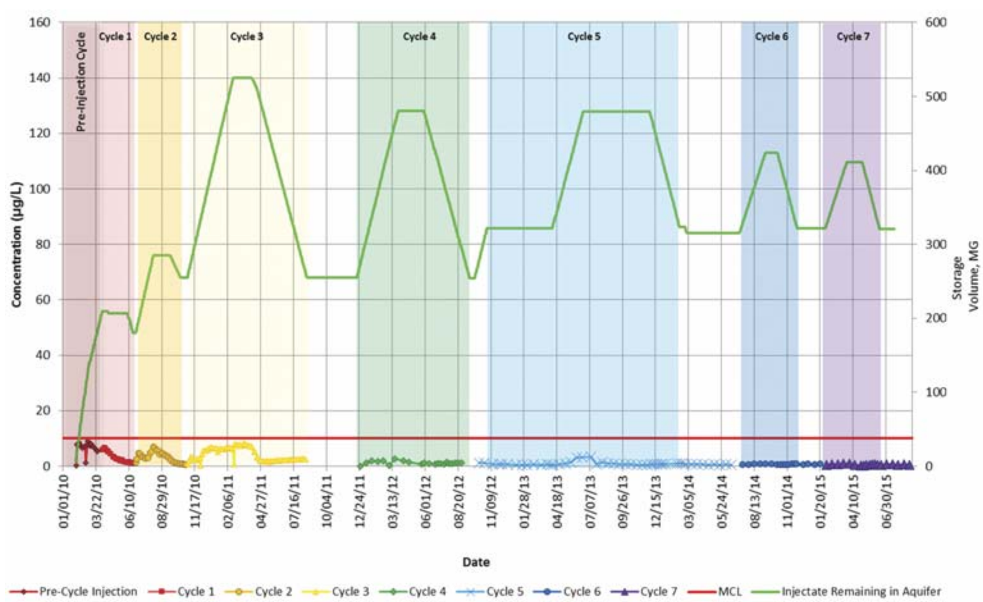

Figure 5. Arsenic Concentrations in the Far Monitor Well

Summary and Conclusions

The passage of the Chemical Contaminants Rule by EPA resulted in a decrease in the arsenic MCL from 50 ppb to 10 ppb and made it far more difficult for those applying for an ASR operational permit to obtain one. Pretreatment systems are implemented by many applicants hoping to minimize the occurrence of arsenic exceedances by removing the DO from the injectate that causes the arsenic leaching in the first place; however, these pretreatment systems can be expensive and are often riddled with ongoing and cumbersome maintenance issues. The OCU pursued an alternative to DO pretreatment with its potable ASR well system and ultimately obtained an operational permit by utilizing the following techniques:

- *Technique One: Extensive Aquifer Conditioning* - The native limestone aquifer was exposed with DO-rich potable water during early cycle test phases. The stored water, with high levels of arsenic, was removed from the aquifer. By implementing this conditioning approach during early cycle tests, subsequent, smaller cycle tests revealed significantly lowered arsenic levels.
- *Technique Two: Mimic Seasonal Conditions* - By keeping storage periods relatively short to demonstrate variability in precipitation, OCU reduced the potential for additional migration of the storage zone and, therefore, the potential for additional arsenic leaching chemical reactions.
- *Technique Three: Minimize Agitation with Injection Rate Management* - It is possible that lowering the injection rate resulted in less agitation in the aquifer, thereby lowering the potential for mixing and chemical reactions between high-DO recharge water and the native aquifer.
- *Technique Four: Extensive Water Quality Monitoring* - Tracking certain water quality parameters frequently and over extended periods can give meaningful insight into aquifer behavior.

While these techniques require extensive monitoring and evaluation, they can result in a more cost-effective ASR well operation.

References

• Orange County Utilities, "Operational Permit Application and Supporting Documentation, OCU Eastern Potable ASR Project." December, 2015.